The Review Committee

for the subject area

"Condensed Matter Physics including Surface Physics and Nanoscience"

Members:

1. Prof. S.K. Joshi (Chairman), National Physical Laboratory
2. Prof. Peter Pershan, Harvard University
3. Prof. Michel Pepper, London University
4. Prof. T.V. Ramakrishnan, Benaras Hindu University
5. Prof. Peter Littlewood, Cambridge University
6. Prof. Samuel Bader, Argonne National Laboratory
7. Prof. Ajay Sood, Indian Institute of Science
8. Prof. Mustansir Barma, Tata Institute of Fundamental Research
9. Prof. E.V. Sampathkumaran, Tata Institute of Fundamental Research

31 August – 2 September, 2010

SAHA INSTITUTE OF NUCLEAR PHYSICS
1/AF, Bidhannagar, Kolkata 700064
Experimental Condensed Matter Physics (ECMP):

Permanent members of the Division:

<table>
<thead>
<tr>
<th>Scientific</th>
<th>Technical</th>
<th>Adm/Auxiliary</th>
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<tbody>
<tr>
<td>A. Ghoshray</td>
<td>Sr. Prof.</td>
<td>T.K. Sarkar</td>
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<td>A.K. Bhattacharya</td>
<td>SO</td>
<td>Superintendent</td>
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<tr>
<td>R. Ranganathan</td>
<td>Sr. Prof.</td>
<td>P.P. Ranjit</td>
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<tr>
<td>T.K. Pyne</td>
<td>SO</td>
<td>Helper</td>
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<tr>
<td>A.I. Jaman</td>
<td>Sr. Prof.</td>
<td>S. Chakrabory</td>
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<tr>
<td>K.K. Bardhan</td>
<td>Sr. Prof.</td>
<td>A. Chakrabarti</td>
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<td>K. Ghoshray</td>
<td>Prof.</td>
<td>P. Mandal</td>
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<td>C.D. Mukherjee</td>
<td>Prof.</td>
<td>D.J. Seth</td>
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<td>S.N. Das</td>
<td>Prof.</td>
<td>A.K. Paul</td>
</tr>
<tr>
<td>I. Das</td>
<td>Prof.</td>
<td>A. Karmahapatra</td>
</tr>
<tr>
<td>P. Mandal</td>
<td>Prof.</td>
<td>S. Hembrom</td>
</tr>
<tr>
<td>B. Pal</td>
<td>Prof.</td>
<td>P. Das</td>
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<tr>
<td>A. Poddar</td>
<td>Prof.</td>
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<tr>
<td>B. Bandyopadhyay</td>
<td>Prof.</td>
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<tr>
<td>C. Mazumdar</td>
<td>Prof.</td>
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Ph. D. Students (2007 – onwards)
R. Sarkar, A. Biswas, S. Mukhopadhyay, B. Pahari, S. Maji, P.R. Varadwaj, T. Samanta,
M. Ghosh, A. Pandey, N. Choubey, P. Sarkar, D. Talukdar, D.K. Bhoi, N. Khan, A. Midya,
M. Majumder, S. Duttagupta, K. Das

Post doc.
N. Duttagupta, K. Chakrabarti, Papri Dasgupta, Joydip Sengupta

Equipments and Resources in the Division:
1. Liquid nitrogen plant (20 L/hr) and Liquid helium plant (20 L/hr without LN\textsubscript{2} pre-cooling)
2. Room temperature x-ray powder diffraction
3. Pulsed Laser Deposition for thin films
4. Travelling Float Zone Furnace; for preparation of single crystals
5. Argon arc furnace
6. High temperature box and tube furnaces
7. SQUID magnetometer
8. physical properties measurement systems; temperature range 2-300 K
9. AC Susceptibility measurements system at low temperature
10. 14 tesla superconducting magnet
11. 7 tesla superconducting NMR magnet (Temperature range 3.8 - 300 K)
12. 100 MHz NMR spectrometer (Bruker), 400 MHz customized NMR spectrometer
13. Mossbauer spectrometer with low temperature facility
14. Home-built Stark/source modulated microwave spectrometer 10-100 GHz
15. Home-built acoustic spectrometer
16. Home built DC magnetometer
17. AFM equipment

Research Activities:
The objective is to carry out research in experimental condensed matter physics with special emphasis in (i) the design and development of advanced experimental systems suitable for measurements using high pressure, low temperature and high magnetic field, and (ii) to process new materials and study their macroscopic and microscopic properties.
Research in experimental condensed matter physics was conducted in the general areas of conducting nano-composites, rare-earth based intermetallics, perovskites, double perovskites, quasi low-dimensional system, quantum spin chains, strongly correlated systems and nano-crystalline materials.

**Important Results:**

i) Magnetism/Transport of magnetic and Superconducting oxide materials:
Magnetic, transport, thermolectric power, and NMR measurements are being made in the newly discovered Fe-base superconductor RFeAsO (R = La, Ce, Pr, Nd, Sm, and Gd). Evidence of strong electron-phonon coupling was observed from normal and super conducting state transport properties of PrFeAsOF superconductor. The resistivity and $^{75}\text{As}$ NMR results of superconducting CeFeAsO$_{0.8}F_{0.16}$ and its parent compound CeFeAsO reveal formation of vortex lattice in the superconducting state. Spin-fluctuation dominated ferromagnetically ordered state was revealed in Co based LaCoPO. Large low field magnetoresistance ([(R(H)-R(0))/R(0) ~ 100%]) due to charge order melting was observed in nanocrystalline Pr$_{0.65}$(Ca$_{0.6}$Sr$_{0.4}$)$_{0.35}$MnO$_3$ sample. This is in contrast to the general belief that charge order melting is a high field phenomenon. Magnetic phase transition in Sm$_{0.52}$Sr$_{0.48}$MnO$_3$, critical behavior and electronic properties of Sm-Nd-Sr and La$_2$Sr$_{1.3}$CoO under pressure and field have been investigated. Glassy magnetic behaviour in La$_0.5$Sr$_0.5$CoO$_3$ nanoparticles, orbital ordering in LaMnO$_3$ spin polarised transport, charge ordering and related phenomena in magnetic nanostructures are some of the important findings in manganite/cobaltite system. Large magnetocaloric effect in Sr$_2$FeMoO$_6$ systems were also reported. Large Energy gap (230 K) in the excitation of Cu$^{2+}$ electron spin in BaCu$_2$V$_2$O$_8$ confirms alternating chain model. A small band gap of 25 K at the low energy excitation in SrNi$_2$V$_2$O$_8$, ($S=1$ quasi-one-dimensional antiferromagnet) suggests its ground state as a disordered "spin liquid" Haldane state. A Core-shell model for AFM small particles have been proposed to discuss the increase of magnetization below AFM ordering ~ 20K for both in bulk and nano particles and unconventional relaxation of spinel oxide CoRh$_2$O$_4$.

ii) Magnetism and transport of intermetallic alloys
Transverse vibrations driven negative thermal expansion behaviour in GdPd$_3$B$_{0.25}$C$_{0.75}$, an AFM anti-perovskite material, magnetism of ordered metallic compound GdPd$_3$B$_{1.3}$, and the possibility of negative temperature coefficient of resistivity (NCTR) in the absence of chemical/structural disorder have been studied. Valence fluctuation behaviour in filled/ vacant anti-perovskite compounds, intermediate valency of Eu stimulated by the valence instability of dopant Ce in cubic Ce$_{0.3}$Eu$_{0.3}$Pd$_3$ and Ce$_{0.3}$Eu$_{0.3}$Pd$_3$B$_4$ have been reported. Magneto-resistance changes sign upon boron doping in TbPd$_3$ and shows highest GMR ~30% in the series of RPD$_3$ compounds. Novel method of generating magnetic phase diagram using magneto-caloric effect has been proposed. Evidence of Largest Magnetic Cooling Power was obtained from the Magnetocaloric Effect in Ho$_3$Pd$_2$. The evaluated value of relative cooling power (RCP) is 6.32 J/cm$^3$ for a magnetic field change of 5 T. Interplay of RKKY, Kondo and crystal field interactions governs the fascinating ground state in RNi$_2$Al$_3$ (La, Ce and Pr). In the heavy fermion compound CePt$_3$B$_2$C, a suppression of the effect of magnetic correlation, due to the dominance of the Kondo effect over the RKKY interaction was observed. Microstructure, magnetic and Mossbauer studies on spark-plasma sintered (SPS) nano composite comprising Sm-Co-Fe (hard magnet) intermetallic phases and Fe(Co) (soft phase) suggest magnetically single phase behaviour of the SPS magnets. Structural and Magnetic studies on SPS SmCo$_5$/Fe bulk nanocomposite magnet
shows stronger exchange coupling between the hard and soft magnetic phases in SmCo$_5$ with 5 wt % Fe than 10 wt % Fe containing sample.

**iii) Microwave spectroscopy:**
Conventional microwave spectroscopic studies of organic molecules like phenol and benzonitrile compounds in the gas phase reveals the ground state molecular constants and molecular structures. An indigenously built millimeterwave spectrometer was used to study the rotational spectra of DC discharge produced species like halogen cyanides (XCN, X= Cl, Br, I) and analysis leads to the assignment of many new transitions and determination of accurate rotational parameters and geometry of the molecules.

**iv) Non-linear transport in disordered system:**
In case of field-dependent conduction in disordered systems, a sample with localised states is found to possess a field-scale. This observation leads to a phenomenological scaling, and to a nonlinearity exponent. The exponents in various systems are found to be integer multiples of a number ~0.08. 1/f-noise measurements reveal that bias exponents as well as noise levels may be good indicators of any changes in conduction mechanisms. The suggested model seamlessly fit the resistance minima data in composites. The higher temperature data are described by the Weibull distribution. An ultra low-noise current source has been developed.

**v) Ultrasonic related activity:**
Study on the propagation characteristics of ultrasound through material medium has been done and a computational Fourier transform method for the characterization of materials has been proposed. Variations of ultrasound propagation parameters near structural phase transition in β-brass and simulation studies of some model systems have been reported.

**List of publications (2007-date)**
(Please see next page)
List of publications (2007-date)

2010


4. Rotational spectrum of propyne observed in a DC glow discharge and DFT calculation. A.I. Jaman, P. Hemant Kumar and P. R. Bangal, Asian J. Spectroscopy (accepted).

5. Millimeter-wave spectrum of Chlorocyanoacetylene (CICCCN) generated by DC glow discharge technique, P. R. Varadwaj and A. I. Jaman, Asian J. Spectroscopy (accepted).


13. Spin glass-like behaviour in Fe-rich phases of SrₓFe₁₋ₓMnₓMoO₆ (0.1 < x < 0.4): Asok Poddar and Chandan Mazumdar, J. Alloys Comp. 502 (2010) 15.


16. Effect of hydrostatic pressure on magnetic phase transition and magnetocaloric properties of (Sm$_{0.8}$Nd$_{0.2}$)$_{0.52}$Sr$_{0.48}$MnO$_3$: S. Arumugam, P. Sarkar, P. Mandal, A. Murugeswari, K. Matsubayashi, C. Ganguli, and Y. Uwatoko, J. Appl. Phys. 107, 113904 (2010).

2009


21. $^{75}$As NMR study of oriented CeFeAsO and CeFeAsO$_{0.84}$F$_{0.16}$: A. Ghoshray, B. Pahari, M. Majumder, M. Ghosh, K. Ghoshray, B. Bandyopadhyay, P. Dasgupta, A. Poddar, and C. Mazumdar, Phy. Rev. B79, 144512 (2009).


24. Negative pressure driven valence instability of Eu in cubic Eu$_{0.4}$La$_{0.6}$Pd$_3$; Abhishek Pandey, Chandan Mazumdar, R. Ranganathan, J. Phys. Condens. Matter 21, 216002 (2009).


32. Effect of uniaxial pressure on metal-insulator transition in (Sm$_{1-x}$Nd$_x$)$_{0.52}$Sr$_{0.48}$MnO$_3$ single crystals: A. Murugeswari, P. Sarkar, S. Arumugam, N. Manivannan, P. Mandal, T. Ishida, and S. Noguchi, Appl. Phys. Lett. 94, 252506 (2009)


37. 90 MeV O-16 heavy-ion irradiation effects on La$_{0.9}$Pb$_{0.1}$MnO$_3$ single crystals: M. R. Babu, X. F. Han, P. Mandal, et al. Materials Chemistry and Physics 117, 113 (2009).


43. Thermoelectric power of RFeAsO (R = Ce, Pr, Nd, Sm, and Gd), Asok Poddar, Sanjoy Mukherjee, Tamnay Samanta, Rajat S. Saha, Rajarshi Mukherjee, Papri Dasgupta, Chandan Mazumdar, and R. Ranganathan, Physica C469 (2009) 789.


2008


51. Modification of the spin state in Sm$_{0.5}$Sr$_{0.48}$MnO$_3$ by external magnetic field, P. Sarkar and P. Mandal, Appl. Phys. Lett. 92, 052501 (2008).

52. Large magnetocaloric effect in Sm$_{0.52}$Sr$_{0.48}$MnO$_3$ in low magnetic field, P. Sarkar, P. Mandal, and P. Choudhury Appl. Phys. Lett. 92, 182506 (2008)

53. Hydrostatic pressure effect on archetypal Sm$_{0.52}$Sr$_{0.48}$MnO$_3$ single crystal K. Mydeen, P. Sarkar, P. Mandal, A. Murugeswari, C. Q. Jin, and S. Arumugam Appl. Phys. Lett. 92, 182510 (2008).

54. Size-induced metal insulator transition and glassy magnetic behaviour in La$_{0.5}$Sr$_{0.5}$CoO$_3$ nanoparticles: B. Roy and S. Das, Applied Physics Letters 92, 233101 (2008).

56. NMR study of the impurity induced ordered state in the doped Haldane chain compound SrNi$_{1.93}$Mg$_{0.07}$V$_2$O$_8$: B. Pahari, K. Ghoshray, R. Sarkar, and A. Ghoshray; Phys. Rev. B77, 224429 (2008).


63. Magnetocaloric properties of nanocrystalline Pr$_{0.65}$(Ca$_{0.6}$Sr$_{0.4}$)$_{0.35}$MnO$_3$: Anis Biswas, Tapas Samanta, S. Banerjee and I. Das; J. Appl. Phys. 103, 013912 (2008).

64. Observation of large low field magnetoresistance and large magneto caloric effects in polycrystalline Pr$_{0.65}$(Ca$_{0.7}$Sr$_{0.3}$)$_{0.35}$MnO$_3$: Anis Biswas, Tapas Samanta, S. Banerjee and I. Das; Appl. Phys. Lett. 92, 012502 (2008).

65. Influence of charge ordering on magnetocaloric properties of nanocrystalline Pr$_{0.65}$(Ca$_{0.7}$Sr$_{0.3}$)$_{0.35}$MnO$_3$: Anis Biswas, Tapas Samanta, S. Banerjee and I. Das, Appl. Phys. Lett. 92, 212502 (2008).

66. Colossal enhancement of magnetoresistance in La$_{0.67}$Sr$_{0.33}$MnO$_3$/Pr$_{0.67}$Ca$_{0.33}$MnO$_3$ multilayers: reproducing the phase-separation scenario: Soumik Mukhopadhyay and I.Das; Europhys. Lett. 83, 27003 (2008).


73. Intermediate valence behavior in Ce$_{0.5}$Eu$_{0.5}$Pd$_3$, Abhishek Pandey, C.Majumdar, R. Ranganathan, AIP conf. Proc. 1003, 216 (2008)


77. Re-entrant Spin-Glass Phenomenon in Ca$_2$Fe$_{1-x}$Co$_x$MoO$_6$ (0.1≤x≤0.4), Asok Poddar and Chandan Mazumdar, AIP Conf. Proc. 1003, 292 (2008).


2007


84. Correlation between structural, transport, and magnetic properties in Sm$\text{1-}x\text{A}_x\text{MnO}_3$

85. Dielectric anomaly at TN in LaMnO$_3$ as a signature of coupling between spin and orbital
degrees of freedom: P. Mondal, D. Bhattacharya, P. Choudhury, and P. Mandal, Phys. Rev. B76,
172403 (2007).

86. Magnetization and $^{65}$Cu NMR studies on granular FeCu alloys: B. Bandyopadhyay, B. Pahari,

87. $^{27}$Al NMR in grain aligned PrNi$_2$Al$_5$: A. Ghoshray, R. Sarkar, B. Pahari, K. Ghoshray and B.

88. Crystal field calculation of Pr$^{3+}$ in orthorhombic PrNi$_2$Al$_5$ from $^{27}$Al NMR Knight shift: R.

89. Impurity induced antiferromagnetic order in Haldane gap compound SrNi$_2$Mg$_2$O$_6$: B. Pahari,

90. $^{31}$P NMR of trimer cluster compound Sr$_3$Cu$_3$(PO$_4$)$_4$: M. Ghosh, K. Ghoshray, B. Pahari,

91. A Comparative Study of the Magnetic Properties and Phase Separation Behavior of the Rare
Earth Cobaltates, Ln$_{0.5}$Sr$_{0.5}$CoO$_3$ (Ln=Rare Earth): Asish Kundu, R. Sarkar, B. Pahari, A.

92. Giant magnetocaloric effect in antiferromagnetic ErRu$_2$Si$_2$ compound: Tapas Samanta, I. Das

93. Magnetocaloric effect in Ho$_2$Pd$_3$: Evidence of large cooling power: Tapas Samanta, I. Das

94. Magnetotransport properties of nanocrystalline Pr$_{0.65}$(Ca$_{1-x}$Sr$_x$)$_{0.35}$MnO$_3$ (y = 0.4, 0.3):

95. Magnetic and transport properties of nanocrystalline Nd$_{0.5}$Sr$_{0.5}$MnO$_3$: Anis Biswas and I. Das;

96. Unified description of spin dependent transport in granular ferromagnetic manganites:

97. Low temperature magnetotransport properties in granular ferromagnetic manganites: Soumik

98. Smooth crossover from variable range hopping with Coulomb gap to nearest neighbour inter-
chain hopping in con-ducting polymer: Sanjib Maji, Soumik Mukhopadhyay, R. Gangopadhyay

99. Silica Encapsulated Ni Nanoparticles: Variation of Optical and Magnetic Properties with
Particle Size, Soumen Das, Subhendu K. Panda, Prithiwish Nandi, Subhadra Chaudhuri,


Prof. Amtabha Ghoshray  
ECMP Division 

1. Ph.D: Physics, 1982, Calcutta University 
2. Position held & date of joining SINP (in permanent position): Lecturer, August 10, 1984 
3. Academic assignments (Post Doctoral/ Teaching) prior to joining SINP in permanent position 

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Position held</th>
<th>Univ./ Inst.</th>
<th>Period</th>
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<tr>
<td>1.</td>
<td>Research Associate</td>
<td>SINP</td>
<td>1982</td>
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4. Present position: Sr. Professor (H) 
5. Honor: Invited to be a member International Advisory Committee for 19th International Conference on Magnetism (ICM2012) be held in Busan, Korea from July 8th to 13th, 2012. 
6. Essential strength of research/development output:  
   (a) Hydrogen location, mobility and its effect on the electronic properties of the rare earth intermetallics were explored. Ordered arrangement of proton pairs, with H-H separation ∼ 1.5 Å was reported for the first time in CeNiInHₓ and PrNiInHₓ (confirmed later by other groups from neutron scattering and by theoretical models).  
   (b) Occurrence of Co³⁺ and Na⁺ charge ordering was reported, for the first time, in metallic NaCo₂O₄ (termed as Curie-Weiss metal). This has an important role in the discovery of superconductivity that occurs on intercalation with water. Cited several times in international journals including Nature, Nature Materials, 
   (c) Electronic phase separation was first time observed in Nd¹ₓSrₓCoO₃. Later, a comparative study of the magnetic properties of a few members of the Ln(0.5)Sr(0.5)CoO(3) family with different radii of the A-site cations, < r(A) >, in the range 1.19-1.40 Å has been made. The variation of the FM/PM ratio with < rA > and size-disorder suggest that electronic phase separation is an inherent feature of this type of cobaltates, with the nature of the different magnetic species in the phase-separated system varying with < r(A) > and size disorder. 
   (d) Large Energy gap (230 K) in the excitation of Cu²⁺ electron spin in BaCu₂V₂O₈ confirms alternating chain model. A small band gap of 25 K at the low energy excitation in SrNi₂V₂O₈, a S=1 quasi-one-dimensional antiferromagnet suggests its ground state as a disordered "spin liquid" Haldane state. 
   (e) Interplay of RKKY, Kondo and Crystal field interaction governs the fascinating ground state in RNi₂Al₃ (La, Ce and Pr). In the heavy fermion compound CePt₃B₂C, a suppression of the effect of magnetic correlation, due to the dominance of the Kondo effect over the RKKY interaction was observed. 
   (f) The resistivity and As-75 NMR results of superconducting CeFeAsO₀.₈₄F₀.₁₆ and its parent compound CeFeAsO reveal important information for this newly discovered Fe-base superconductor. In contrast, on Co based LaCoPO, a spin-fluctuation dominated ferromagnetically ordered state was revealed. 
   (g) Liquid Helium plant was lying unused for couple of years. I have personally trained the technical staffs of the division to run and maintain liquid helium. 
7. List of recent important publications:  
7. R. Sarkar, A. Ghoshray and K. Ghoshray, Crystal field calculation of Pr$^{3+}$ in orthorhombic PrNi$_2$Al$_5$, from $^{27}$Al NMR Knight shift, J. Phys. Condens. Matter 19, 086202 (2007).

8. Ph.D. students: (completed):
1. Co-guide of Dr. B. Bandyopadhyay:

9 Any other information (academic)
iv) Acted as a referee on behalf of the Organising Committee ICM 2003, held in Rome, Italy; Satellite- ICM 2006 (QuBS 2006), held in Tokai, Japan.
v) Member: Monitoring Committee for the project proposal “Magnetic Materials for High-Permeability GHz-Frequency Indutors” IIT, Delhi: Dept. of information Technology, Govt. of India, New Delhi.
1. Name and present position: R. Ranganathan - Senior Professor.

Education: M.Sc., University of Madras (1977) - First class; Ph.D - Indian Institute of Technology (IIT) - Madras (1983)

2. Awards and fellowship:
   - French govt scholar at CRTBT-CNRS Grenoble (1983-84)
   - RA at University Hamburg (1985-86)
   - UGC visiting associate fellow at CGC- Anna university (1992-93)
   - Invited as Honorary visiting faculty S.N.Bose Institute - Calcutta (2005)
   - SINP foundation day award (2010): Highest citation category from SINP

3. Research/development output: summary - work done at SINP

   “Physics of magnetism – role of ordered moments in the absence of true long range order”
   materials and instrumentation.

   We have undertaken a systematic experimental investigation of disordered magnetic materials to
   investigate the nature of magnetism in the absence of true long range order. This includes, as a part of
   the programme, materials synthesis and related instrumentation work. We have carefully identified new
   systems, covering both alloys and oxides, prepared through structural, quenched, chemical process. We
   have proposed a new experimental techniques “Enhancement of AC susceptibility” by applying second
   ac field with different frequency on ac susceptibility measured by the conventional method. This is
   some what similar to method used in tape recorder where a high frequency signal is mixed with audio
   signal to ensure greater “fluidity” in magnetic media. This technique is useful to study ferromagnetic
   materials, domain nucleation, and domain wall motion. We have also developed DC magnetometer
   using Tchebycheff quadrature method of numerical integration over Fast Fourier Transform (FFT)
   method. (Rev. of Sci. Instrum. 67 789 (1996), ibid 68 2834 (1997). We summarize some of the reported
   new experimental results as: (i) Magnetic glassy behavior coexistence with FM state in disordered
   magnetic materials have been investigated through a new approach namely, the field-cooled coercivity
   to observe the progressive freezing of clusters below Curie temperature due to thermal activation and
   also to estimate the volume fraction of super paramagnetic clusters. (Physical Review B 54 9267 (1996)
   – citation: 146).(ii) It has been found, in general, that most of the work on magnetic oxide materials are
   focused on perovskite, pyrochlores materials. On the other hand, the author’s approach is to focus on
   spinel oxides as the interest in the spinel oxides stems from the fact that spinel ferrite (nano) particle is
   an ideal small particle magnetic system whose crystal chemistry can be controlled where as for pure
   metal particles the crystal chemistry is basically fixed. We have reported (Solid State Communication
   ferrimagnets (Fe₂Mo₁₋ₓTiₓO₄), where not only the spin compensation temperature due to two sub- lattice
   contributions for magnetizations are different under zero field-cooled condition and field cooled
   process, but also the magnetization with temperature maintains symmetry with reference to the
   direction of the applied magnetic field. Further, we have reported the increase of magnetization below
   AFM ordering, unconventional relaxation in AFM nano particle and enhancement of surface
   magnetization in CoRh₂O₄, lattice expansion and magnetism in MnCr₂O₄. The Core-shell model
   suggested by us (Phys. Rev.B 69 054430 (2004) for the AFM spinel oxide has been extended by
   others to understand the magnetism of nano particle in perovskite materials.(X.G. Li etal Phy RevB 76
   174415 (2007). (iii) Further we have also shown the possibility of negative temperature coefficient of
   resistivity (NTCR) in the absence of chemical / structural disorder, negative thermal expansion (NTE)
   in AFM pervoskite materials GdPd₃BₓC₁₋ₓ. The importance of NTE arises due to the fact that unlike
   positive thermal expansion, NTE has different origin in different materials and there is no single unique
   mechanism to explain the phenomenon of NTE. This work also establishes some synergy between
isotropic NTE and NTCR in these magnetic intermetallic compounds. (Applied Phy. Letter 92 261913
2008, Euro Phy. Letters 84 47007 (2008). We have also observed negative giant magnetoresistance
(GMR) in cubic TbPd3(-30%), which is the highest among the RPd3 series(Applied Phys. Letter 94
172509 (2009). The NTE and nano composite work have been cited recently by A.Bojan etal Chem.
Matter 21 2886 (2009) and in the recent review articles by I. Betan court and H.A.Davies -Materials
Science and technology 26 5-19 ( 2010). In our opinion, the above results can be considered as original
contributions.
This programme is in collaboration with Dr Arani Chakravarty, Dr Sanjoy Mukherjee, Dr Anindita
Ray, Dr. R.N.Bhowmik, Ms Anulekha Datta, Mr Abhishek Pandey as a part of their thesis work. Also
in collaboration with Prof C. Mazumdar for intermetallic alloys and DMRL for composite magnets

4. Future research and development plan:
   a) Anti perovskite magnetic materials focusing on low Z elements with out oxygen.
   b) Magnetism in small particle including bio magnetic materials- role of core-shell spin structure-
      Core with different magnetic structure.
   c) High Curie temperature intermetallic materials- ZT factor for high TEP materials.
   d) Nano composite magnets for high energy product, (BH)max, material.
   e) Setting up of sensitive magnetization experiments using high magnetic field facilities ~20T at
      very low temperature.

5. Recent Publication list for the period 2003-2009 (in collaboration with A. Pandey, R.N. Bhowmik,
Anulekha Dutta)

<table>
<thead>
<tr>
<th>No.</th>
<th>Journal</th>
<th>year</th>
<th>Publications</th>
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<tr>
<td>3</td>
<td>Euro Physics Letter</td>
<td>2008</td>
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<td>6</td>
<td>J. alloys and compounds</td>
<td>2009,2004</td>
<td>3</td>
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<td>8</td>
<td>J. Nano Science and Technology</td>
<td>2007</td>
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<td>J. Phys. Condensed Matter</td>
<td>2009</td>
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<td>10</td>
<td>Solid State communication</td>
<td>2007</td>
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<td>11</td>
<td>Physica C- superconductivity</td>
<td>2009</td>
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Recent important publications for the period 2003-09 focusing on:

a) Intermetallic anti pervoskite materials:
(2008)

b) Small particle magnetism

Mater. 312 252 (2007):

d) Some of the earlier work: i) focusing on instrumentation: S. Mukherjee etal Review of Scientific
on cluster glass S. Mukherjee etal Physical Review B 54,9267 (1996).( citation 146)
KAMAL KUMAR BARDHAN

Date of Birth: January 25, 1952.

Educational Qualification:
Ph.D. (1980, Carnegie-Mellon University, USA)

Present position: Sr. Professor (2008-)

Date of joining SINP: May 5, 1987 (Reader)

Academic assignments prior to joining SINP:
2. Pool Officer (CSIR), SINP (1986-87).

Awards: Received $25000 grant from STICHTUNG fund (Schlumberger, USA) for research purpose.

Area(s) of research:
Soft Condensed Matter; Electrical transport properties, including noise, of the disordered systems in general, and composites in particular, with emphasis on non-Ohmic regimes.

Research highlights:

Our work has revealed many new transport properties of the hitherto little explored nonlinear regimes in composites and other disordered systems through application of scaling concepts. We have proposed a three-variable scaling to take into account the applied field (PRL, 1992). Measurement of noise in non-ohmic regimes indicates a very interesting prospect of differentiating transport mechanisms even when usual resistance appears to behave in a similar manner (AIP Conf. Proc. 2005). We have also extended measurements up to electrical breakdown in Composites. It was found that under certain conditions it was actually possible to predict an imminent breakdown - which is of course the goal of any study on breakdown (PRL 1999).

Presently, our efforts are concentrated around a possible scaling formulation of non-Ohmic conduction in disordered systems. The motivation stems from the observation of existence of a field-scale in a disordered sample. Simultaneously, noise measurements are carried out to see its utility in probing various characteristics of electronic processes in disordered systems.

Future research:
We intend to continue efforts as mentioned above.
List of important publications:

Books:

Selected Papers:


Name:- Sailendranath Das  
Affiliation:- Experimental Condensed Matter Physics       Designation:- Professor  
M. Sc. : Calcutta University       Post M. Sc. Associateship Course: Saha Institute of Nuclear Physics.       PhD: 1990 (Calcutta University),  
Joined in Saha Institute as Faculty Member in 1990.  
1. Received Foundation Day Award for my work.  

Besides my own laboratory I am in-charge of three other laboratories.  
1. Travelling Solvent Floating Zone Image Furnace  
2. Mossbauer Spectroscopy Laboratory.  
3. PPMS (Physical Property Measurement Systems) laboratory.

Research interest  
Mott-Hubbard insulator, Strongly Correlated Electron systems, Transition metal oxides in general. Insulator to metal transition. Superconductivity. Spin, charge and orbital ordering phenomena in low- and three-dimensional transitional metal oxides and their unusual physical properties due to the interplay between these degrees of freedom, colossal magnetoresistance phenomenon, electronic and thermal transport, magnetic, and thermal study at ambient as well as at nonambient conditions (external pressure, magnetic field, electric field, etc). Growth and structural studies of single crystals. Electrical and magnetic properties of of transition metal oxides with nano-scale particle or cluster size. Study of coexisting long-range orders, Magnetocaloric Effect (MCE) in transition metal oxides (manganites, cobaltates, ferrites, etc.)

Research Works  
In the present plan period our project involves studies of transport, magnetic as well as thermodynamic properties of novel correlated electron systems exhibiting exotic properties. We have investigated several d-electron systems such as perovskite manganites, cobaltates and ferrates in the form of polycrystals, single crystal, nanoparticles to understand various aspects of their transport and magnetic properties as a function of temperature, field, pressure and doping. We have studied the charge and spin dynamics and role of core-shell spin structure in Nd_{0.5}A_{0.5}MnO_{3} (A = Sr, Ba) nanoparticles and La_{0.5}A_{0.5}CoO_{3} (A = Sr, Ca and Ba) nanoparticles. The results reveal the size-induced metal-insulator transition, the decrease of magnetization in nano particles below FM ordering temperature, decrease of Tc in comparison with bulk samples, spin glass or cluster glass-like behavior due to frustration but no remarkable signature of glassy behaviour on magnetoresistance. Magnetocaloric effect was studied in multiferroic manganites RMnO_{3} (R = Y, Ho, Tb, Dy, Yb) crystals grown by traveling solvent floating zone method. The results suggest that multiferroic manganites exhibits metamagnetic transitions due to the long
range order of $R^{3+}$ ions. The large values of magnetic entropy, relative cooling power, adiabatic temperature change, together with small hysteresis, suggest $R MnO_3$ could be a potential materials for magnetic refrigeration in the low temperature range. The polaron hopping was studied in the charge ordered $R_{1/2}Sr_{2/3}FeO_3$ ($R$ = La, Pr, Nd) and also for $R$ = Sm and Gd) by AC and DC conductivity and thermopower. From dc conductivity measurement we found that the adiabatic small polaron hopping mechanism is valid for $R$ = La, Pr and Nd and non-adiabatic small polaron hopping mechanism is active for $R$ = Sm and Gd but the power law exponent s obtained from ac conductivity measurement indicates overlapping large polaron hopping. Magnetic, electric transport and calorimetric study has been performed on the as-grown, deformed and oxygen annealed samples of icosahedral $Al_{70.4}Pd_{20.8}Mn_{38.8}$ quasicrystals.

In analogy with electron doped superconductor $Nd_{2-x}Ce_xCuO_6$ where the Ce ions attain the tetravalent state we have prepared Ce-doped $RMnO_3$ ($R$ = La, Pr and Nd). In Ce-doped manganite the Mn valency is expected to be $Mn^{3+}/Mn^{2+}$ and this makes a sharp contrast with the case of divalent ion doped manganites. The works received world wide attention as an electron doped manganite. Publications on this subject are well cited. We have studied the metal-insulator transition in $R_{1-x}A_xTiO_3$ ($R$ = Y, Nd; $A$ = Ca, Sr and Ba) and showed that M-I transition occurs due to the mass enhancement. We have also studied electrical transport properties of conducting polymer and polymer nanocomposites.

**On going research programme**

1) We are studying the effect of Ce-doping in $SrCoO_3$, $BaCoO_3$, cell-doubling in $CeBaCo_2O_5+\delta$, $YbBaCo_2O_5+\delta$ & $GdBaCo_2O_5+\delta$ and also the effect of Cr- and Al- doping in $La_{0.8}Sr_{0.2}CoO_3$.

2) To understand the evolution of transport properties with doping and to determine the role of several scattering mechanisms we are investigating the structural transition, electrical transport and magnetic properties of $Ca_{1-x}Sr_xMnO_3$ ($0 \leq x \leq 1$) & $Ca_{1-x}Ce_xMnO_3$ as a function of doping and temperature. (single crystals)

3) Study of multiferroic properties of $RMnO_3$ ($R$ = Y, Ho, Tb, Er, Yb) crystals.

4(a) Development of an automated thermal expansion and magnetostriction measurement system operating in the temperature range 4-300 K under 8 T magnetic field.

4(b) Development of dielectric measurement and electric polarization measurement system with Sawer-Tower process.

**List of important publications**


**Future research/development plan**

We want to carry out the following programmes in future

1. Study of magnetoelectric effect in multiferroic manganites/chromates.
3. Study of pressure-and field-dependent quantum critical phenomena in strongly correlated systems.
4. Study of magnetocaloric effect and magnetic scaling behaviour of novel magnetic material.
5. Setting up a four- mirror TSFZ furnace and developing other methods of growing single crystals. Cutting single crystals.
Prof. Kajal Ghoshray: ECMP division

Educational background: Ph. D in Physics Calcutta University, 1986

Academic profile: Research Associate at SINP during June, 1986 – February, 1989
Lecturer in the Condensed Matter Physics Division of SINP in March, 1989
Present position: Professor ‘G’ (from February, 2007)

Awards: Invited as a Guest Scientist at International Institute of Theoretical and Applied Physics (IITAP), Iowa State University, USA during September 1999 – November 1999

Collaborations: Indo-Ukraine Programme of cooperation in science and technology (Project No. DST/INT/UKR/P-2/04): Indian Project Coordinator: Prof. K. Ghoshray
Ukrainian Project Coordinator: Prof V. Eremenko, Director, Institute of Low Temperature Physics and Engineering, Kharkov, Ukraine

Essential strength of research/development: Experimental investigations using nuclear magnetic resonance (NMR) and magnetization measurements
(1) Investigation of magnetic properties of the low-dimensional systems: extended to the quantum spin chains exhibiting various types of ground states depending on the extent of electron correlation. We have established from $^{51}$V NMR in alternating spin chain compound, BaCu$_2$V$_2$O$_8$, the existence of large energy gap (230 K) in the low energy excitation of Cu$^{2+}$ electron spins and a temperature dependent spin gap in Haldane spin chain compound SrNi$_2$V$_2$O$_8$.
(2) Effect of geometrical (topological) frustration on the magnetic property in low dimensional quantum spin systems.
(3)Study of the electronic property of the rare earth actinide based intermetallic compounds exhibiting unusual low temperature state, e.g. (a) Unusual pairing states in heavy fermion superconductors, (b) existence of “Hidden Order” etc. due to the competition between the Kondo and the RKKY type exchange interaction.
(4) Electronic and magnetic property ReTmPn (Re= rare-earths, Tm= transition metals and Pn=As, P) based high Tc superconductors. We have shown from NMR, the presence of dominant 2D spin fluctuations in the normal state of LaFePO and in the paramagnetic state of LaCoPO. To explore the role of spin fluctuations on the pairing mechanism, experiments in different members are in progress.

Ph.D. students (completed + ongoing):
1. Co-guide of the thesis of Dr. Mita Sen (1998); Topic: NMR investigations in hydrides of rare-earth based ternary intermetallocs
2. Guided the thesis work of Dr. Sourav Giri (1997); Topic: Experimental investigation on some layered compounds with non-collinear magnetic structure
4. Guiding the thesis work of Manasi Ghosh (Joined in 2005); Topic: NMR study of quantum antiferromagnets
5. Guiding the thesis work of Mayukh Majumder (Joined in 2008); Topic: Fe-As based high Tc superconductors.

Teaching experience (Post M. Sc):

Guiding the review work of Post M. Sc students:
1. Magnetic phase transitions in low dimensional systems: Mita Sen (1990)
2. Solid state NMR techniques for the study of surface phenomena: Sourav Giri (1992)
5. Experimental studies of low dimensional quantum spin systems: Manasi Ghosh (2005)

**Future research/development plan:**
Strongly correlated systems: e.g. Investigation of the electronic and the magnetic property of (a) Fe-As based high Tc superconductors, (b) Magnetic properties of low dimensional compounds with transition metal clusters, (c) Transition metal oxides exhibiting GMR

**List of important publications starting with recent publications:**
6. A. Ghoshray, B. Pahari, M. Ghoshray, M. Mazumdar, K. Ghoshray, B. Bandyopadhyay, P. Dasgupta, A. Poddar and C. Mazumdar $^{75}$As NMR study of oriented CeFeAsO and CeFeAsO$_{0.83}$F$_{0.17}$. Phys. Rev. B79 144512 (2009)
8. B. Pahari, K. Ghoshray, R. Sarkar and A. Ghoshray, NMR study of the impurity induced ordered state in the doped Haldane chain compound SrNi$_{1.93}$Mg$_{0.07}$V$_2$O$_8$, Phys. Rev. B77 224429 (2008)
15. I. Manna$^1$, P. Nandi$^1$, B. Bandyopadhyay, K. Ghoshray and A. Ghoshray, Microstructural and nuclear magnetic resonance studies of solid state amorphization in Al-Ti-Si composites, Acta Materialia 52 (2004) 4133. $^1$Department of Metallurgy, IIT Kharagpur

**Other Important academic activity:** Act as a referee for PRL and PRB and other Elsevier published journals on a regular basis.
Name: **ABU ISMAIL JAMAN**

**Education:**

M.Sc. (Physics) (University of Burdwan, 1975) (Session 1971-73)
Post M.Sc. (Saha Institute of Nuclear Physics, 1976-77)
Ph.D (Sc.) (University of Calcutta, 1983)

**Academic Profile (at SINP):**

7. Professor ‘H’ - August, 2009 –

**Special awards, honours or distinctions:**

1. Acted as reviewer of paper for Journal of Molecular Structure, Elsevier.
2. Acting as reviewer of papers of Indian Journal of Physics.
5. Acted as an external expert in a committee formed to recruit new people at IISER, Kolkata.

**Overseas visits/deputations:**

5. Visiting Scientist, Universidad de Valladolid, Spain, Oct.-Nov., 2010 (Invitation received)

**Essential strength of research/development output:**

**Conventional microwave and millimeter wave spectroscopy of stable and transient molecules**

1. Microwave (MW) spectroscopic studies of gas phase rotational spectra of stable molecules leading to the determination of their molecular parameters, structures, conformations, barrier to internal rotations, quadrupole hyperfine structures etc. using conventional MW as well as RF-MW and MW-MW double resonance techniques.
2. Production and characterization of stable and transient molecules of chemical and astrophysical interest using an indigenously built millimeter-wave spectrometer coupled with DC glow discharge facility. This facility was developed and tested successfully in the Xth. plan period.
Measurement of broadband microwave absorption and dielectric properties of materials

Studies on broadband microwave absorption and dielectric properties of low dimensional materials e.g., conducting polymers, nano composites and nano fibres etc. (A new project under the XI th plan programme) has been initiated. A new facility has been set up for the measurement of dielectric constant, dielectric loss, shielding effectiveness and different S-parameters of low dimensional materials in the frequency range 10 MHz-26.5 GHz using a VNA.

Future research/development plan:

1. In the coming years, we plan to extend the frequency range of investigation of the millimeter-wave spectrometer above 100 GHz by incorporating higher frequency Gunn diodes and frequency multipliers. Efforts would be made to produce transient species e.g., free radicals and molecular ions of astrophysical interest and analyze their rotational spectra. A liquid helium cooled bolometer detector is to be installed for this purpose. Spectral data in the higher frequency range help radio-astronomers identify unknown molecules in the interstellar space.

2. The microwave frequency range of the electromagnetic spectrum will be used to study different properties e.g., complex conductivity, dielectric constant, dielectric loss, shielding effectiveness, insertion loss etc. of low dimensional materials. Information regarding dielectric behaviour of various materials will be obtained through measurements of permittivity at microwave frequencies.

List of important publications starting with recent publications:


CHANDI DAS MUKHERJEE
(b. Feb. 18th, 1955)

Education:
M.Sc. in Physics, Calcutta University.
Premchand Roychand Studentship (Sc).
Ph.D., University of Calcutta.
Thesis on “Some Theoretical Studies on the Chain Ordering and Even-Odd Effect in Liquid Crystals”.

Academic Profile
Research Fellow Physics Department, Calcutta University 1979-84
Research Fellow SSMP division, S I N P 1985-87
Research Associate SSMP division, S I N P 1988-91
Permanent position Lecture - SC, S I N P, January 3, 1992
Present position Professor – SG

Essential Strength of Research development output:

Stating from my early research career, I have worked on two major projects, viz., i) Phase transition in Liquid Crystals which are partially disordered systems; and ii) Electrical transport properties in disordered systems with special emphasis on composite systems. Apart from these, I also worked on the field of Superconductivity. In order to study the transport properties, we had to do a little bit of developmental work like fabrication of heat chambers, high current constant current source and different types of sample holders etc., which were required for building up the experimental set up. We had to develop the facilities for the preparation of low dimensional systems by using Pulsed Laser deposition technique. For the preparation of carbon nanotubes, we had to fabricate the set up for the thermal chemical vapor deposition chamber. The works carried out in the different fields mentioned above led to the following interesting findings.

For different liquid crystalline phases
- The mean-field models put forward by us can predict correctly the nature of the experimental phase diagram as well as the thermo-dynamical behaviour of phase transition.
- Our results corroborate with the hypothesis of Gray and the order of transition predicted by McMillan, the ‘even - odd’ effect, the dependence of mesomorphous states on the biaxial parameter etc.
- The molecular mean-field model for a rectangular columnar to hexagonal columnar phase transition is cable to show that a gradual lowering of biaxial with the addition of flexible chain segments can lead to the full phase sequence observed in the case of the HAT series.
- The experimentally observed effect of the chain length on the phase sequence corroborates well with our theoretical prediction.

For electrical transport properties of disordered systems
- The sensitivity of 1/f noise to conduction mechanism and geometry as observed in our work succeeds in establishing ‘1/f ’ noise is a firm tool in probing transport properties in disordered systems.
- It is generally observed that when a composite sample is subjected to a high voltage the length of time it takes to relax back to its initial state after the bias is removed is found to depend on the initial voltage. Relaxation time in the composite system in the nonlinear regime found both sub-super- exponential behaviour.
• In the Joule regime, we have observed that the resistance up to breakdown point is described by a universal curve as a function of the applied electric field. Surprisingly the ratio of the breakdown resistance to the zero field resistance assumes a fixed value, which is independent of volume fraction of the conducting part (p), size and shape of the sample and the external conditions, but depends on the nature of the conductor.

• The thermal relaxation data in Joule region provides unique information concerning the breakdown transition and indicates that the classification of usual thermodynamic phase transition is inadequate for explaining this transition.

For Superconductivity
• One of our interesting results is of Superconductivity in low bismuth containing system, which has a new phase that sustains bulk superconductivity below 74K.

Future research/development plan:

The electrical response to an applied field ($F$) on the disordered systems is much more complicated than the traditional theories suggested. The interest in this area has increased considerably in recent years because these systems exhibit many exotic properties. Basically these systems are nonlinear because of the presence of localized states in their structure. The time-dependent information comes from the time traces of fluctuations, which are simply not available from the average quantities like resistance or noise power. So we plan to study in future the persistence phenomena from the time domain data for the single and multi component disordered system. We generally use the three-dimensional disordered system, which is not a clean system as there are no fixed directional properties. So we are planning to use low dimensional system like disordered metallic thin film or the composites with carbon nanotubes, which have the directional properties. Some advances have been made in this field, but more effort is needed to understand the underlying mechanism.

List of important publications starting with recent publications:


Profile

Name
Bilwadal Bandyopadhyay

Academic Profile
1983  M. Sc. (Physics), University of Calcutta, India
1984  Post M. Sc. Associateship Course, Saha Institute of Nuclear Physics, Calcutta
Sept. 1993  Awarded ph. D. Degree in Physics, University of Calcutta
   Title of Thesis: Nuclear Magnetic Resonance Studies on
   Hydrides of Some Intermetallic Compounds
   Supervisor:  Prof. Nikhilesh Chatterjee
   Saha Institute of Nuclear Physics, Calcutta
1993-94  Post-doctoral Research Associate in Solid State and
   Molecular Physics Division, Saha Institute of Nuclear Physics, Calcutta
1994-96  Post-doctoral Research Fellow in the Department of Physics,
   Ben-Gurion University of the Negev, Beer-Sheva, Israel
1997-99  Guest researcher in National Institute of Materials and Chemical Research,
   Tsukuba, Japan, on STA Fellowship awarded by JRDC
1999  Lecturer ‘C’ in Saha Institute of Nuclear Physics, Kolkata

Present Position
Professor ‘F’ in Saha Institute of Nuclear Physics, Kolkata

Highlights of Scientific Contribution
The pressure-composition isotherms, hydrogen mobilities and the hydrogen induced changes in electronic
properties were studied in hydrides of a number of ternary intermetallic compounds. In one of our
compounds, namely CeNiIn, NMR studies revealed that the absorbed hydrogen atoms were paired at a
separation of 1.48 Å, which was much closer than the then valid theoretical limit of 2.1 Å. This observation
was later confirmed through neutron diffraction studies by another lab, and a spurt of experimental and
theoretical activities followed.

Intrinsic magneto-electronic phase separation was revealed in perovskite compounds Nd$_{1-x}$Sr$_x$CoO$_3$
(0.0 < x < 0.5) through $^{59}$Co NMR studies. Depending on the level of doping, there may be a co-existence of
paramagnetic and ferromagnetic phases which may not be yielded separately even by x-ray studies. The
paramagnetic phase may also consist of more than one type of ionic co-ordinations.

The electronic and magnetic properties including heavy-fermionic and Kondo behavior of various
intermetallic compounds have been studied by magnetic and NMR measurements.

Microstructural evolution of ball-milled alloys of Al-Ti-Si and Al-Cu-Nb which are of importance in
automobile and aviation industries, have been studied by NMR using different probe nuclei. The results
show the formation and co-existence of amorphous and/or nanocrystalline phases at different intermediate
stages of milling.

Plan of Future Research
Preparation, characterization and study of electronic and magnetic properties of correlated electron systems
including oxides and intermetallic compounds in both bulk and nanocrystalline forms.
Selected Publications

1. Effect of Interfacial Hydrogen Bonding on the Freezing/Melting Behavior of Nanoconfined Liquids

2. Crossover of the dimensionality of 3d spin fluctuations in LaCoPO
   M. Majumder, K. Ghoshray, A. Ghoshray, B. Bandyopadhyay, B. Pahari, and S. Banerjee

3. \(^{11}\text{B}\) and \(^{195}\text{Pt}\) NMR study of heavy fermion compound CePt\(_2\)B\(_2\)C

4. Magnetization and \(^{63}\text{Cu}\) NMR studies on granular FeCu alloys
   B. Bandyopadhyay, B. Pahari, and K. Ghoshray

5. Microstructural and nuclear magnetic resonance studies of solid state amorphization in Al-Ti-Si composites
   I. Manna, P. Nandi, B. Bandyopadhyay, K. Ghoshray and A. Ghoshray

6. Phase separation in Nd\(_{1-x}\)Sr\(_x\)CoO\(_3\) using \(^{59}\text{Co}\) NMR

7. NMR study of the electronic state in the dense Kondo compound CeNiAl\(_4\)
   K. Ghoshray, B. Bandyopadhyay and A. Ghoshray

8. Sites and dynamics of hydrogen and deuterium in V-H-D alloys studied by \(^1\text{H}\) and \(^2\text{H}\) NMR
   B. Bandyopadhyay and S. Hayashi

9. Observation of 'Pake Doublet' in the \(^1\text{H}\) nuclear-magnetic-resonance spectrum of CeNiInH\(_x\)
   K. Ghoshray, B. Bandyopadhyay, Mita Sen, A. Ghoshray, and N. Chatterjee
Name: INDRANIL DAS

1. **Educational background:**

2. **Academic profile including earlier appointments, awards etc.**
   * Recipient of DAE SSPS best thesis award 1994 and
   * Indian National Science Academy (INSA) Young scientist award 1995.

3. **Essential strength of research/development output:**
   Research career started at TIFR Mumbai, India. During the Ph.D. work (1988 to1994), contributed significantly in the field of strongly correlated electron system (Kondo effect, Heavy-fermion behaviour, 4f-electric quadrupolar effect in rare earth compounds, high Tc superconductivity etc).

   About Twenty two years of research experience in experimental condensed matter physics as well as wide experience in low temperature instrumentation, computer automation, cryogen handling, sample preparation by various technique etc. Developed very efficient low temperature laboratory at IUC-DAEF (Indore) and at SINP (Kolkata), with various home made indigenous set-ups including efficient and sensitive 21-sample magneto-transport set-up, unique 4-sample heat capacity set-up, 1.5-300 K 0-8 Tesla etc.

   Taken leading role for research in India in the three frontline areas of condensed matter physics; (i) Magnetocaloric effect, (ii) Spin polarized transport in magnetic nano-structure, and (iii) charge order nanocrystalline materials, which have both fundamental and technological interest. Published around 90 research papers in internationally reputed journals. Most of the works not only carried out in India, but the majority of the published works was obtained by the home made set-ups on the samples prepared by the same group.

**Recent Major contributions in the field of:**

(a) **Magnetocaloric effect** (Tapas Samanta & I. Das)
   * Reported material with Largest Magnetic Cooling Power [APL 91, 082511 (2007)]
   * Reported Novel origin of Giant Magnetocaloric effect: Order-Order transition [APL 91, 152506 (2007)]
   * Novel method of generating magnetic Phase diagram using magnetocaloric effect [JAP 104, 123901(2008)]
   * The observation of Giant Inverse Magnetocaloric Effect in bulk manganite and Particle size induced destabilization of antiferromagnetic state [APL 94, 233109 (2009)]

   Besides large number of invited talk within India, in recognition of the contributions in the field of Magnetocaloric effect, received invitation and Presented Invited Talk: “Magnetocaloric effect: Powerful tool to understand various phenomena in magnetic materials” at “Moscow International Symposium on Magnetism” (MISM-2008, June 20-25, 2008, Moscow). Also Chaired the session on Magnetocaloric effect in the international symposium (MISM-2008, Moscow).

(b) **Spin Polarized transport in magnetic nano structure** (Soumik Mukhopadhyay & I. Das)

   In recognition of the contributions in the field of Spin Polarized transport, received invitation and Presented Invited Talk: Spin polarized transport & novel phenomena in manganite nanostructures, on 10th June 2008 at...
“Indo Japan workshop on Novel Magnetic Ordering in Nanostructured Materials (June 10 to June 11, 2008)” at University of Tokyo (Japan). Also delivered invited talk at Tohoku University Sendai, and at ISSP Tokyo (Japan).

(c) Charge order nano materials (Anis Biswas & I. Das)


4. Future research/development plan:

Nano structure fabrication and research on Spintronic nano-devices using interconnected UHV systems: Planning to develop internationally competitive, state-of-the-art laboratory for fabrication of low dimensional structures/ spintronic devices and studies of various spin dependent quantum phenomena. New generation spintronic nano devices will be fabricated in ultra clean UHV condition for research on Tunnel Magnetoresistance (TMR), Giant Magnetoresistance (GMR), Ballistic Magnetoresistance (BMR), etc. It will give a golden opportunity to combine basic scientific interest with an emerging applied research such as (a) Spin polarized transport in Magnetic tunnel junction, (b) Quantum-well oscillation, (c) Spin-dependent coulomb blockade effect, (d) Spin-dependent resonant tunneling, (e) Spin Hall effect, etc..

Research on * Magnetocaloric effect in novel materials, and * Studies on Magnetic Nano materials, Magnetic Thin film, Multilayer, Nano wire etc. also will be continued.

5. List of important publications (recent):

1. Magnetocaloric properties of nanocrystalline La0.125Ca0.875MnO3 [JAP 94, 233109 (2009)]
2. Colossal enhancement of magnetoresistance in La0.67Sr0.33MnO3 thin films: possible evidence of electronic phase separation [JPCM 21, 026017 (2009)]
3. Colossal enhancement of magnetoresistance in La0.67Sr0.33MnO3 / Pr0.67Ca0.33MnO3 multilayers: reproducing the phase-separation scenario [EPL 83, 27003 (2008)]
4. Influence of charge ordering on magnetocaloric properties of nanocrystalline Pr0.65(Ca0.7Sr0.3)0.35MnO3 [APL 92, 212502 (2008)]
5. Comparative studies of magnetocaloric effect and magneto transport behavior in GdRu2Si2 compound [JAP 104, 123901 (2008)]
6. Observation of large low field magnetoresistance and large magneto caloric effect in Pr0.65(Ca0.7Sr0.3)0.35MnO3 [APL 92, 012502 (2008)]
7. Magnetocaloric effect in Ho2Pd2: Evidence of large cooling power [APL 91, 082511 (2007)]
8. Giant magnetocaloric effect in antiferromagnetic EuRu2Si2 compound [APL 91, 152506 (2007)]
9. Magnetotransport properties of nanocrystalline Pr0.65(Ca1-y Sr2)0.35MnO3: Influence of phase co-existence [APL 91, 013107 (2007)]
10. Unified description of spin dependent transport in granular ferromagnetic manganites [PRB 76, 094424 (2007)]
11. Experimental observation of charge ordering in nanocrystalline Pr0.65Ca0.35MnO3 [PRB 74, 172405 (2006)]
12. Negligible Influence of Domain Wall on Magnetocaloric Effect in GdPt3 [PRB, 74, 132405 (2006)]
13. Giant enhancement of room temperature magnetoresistance in La0.67Sr0.33MnO3 / Nd0.67Sr0.33MnO3 multilayer” [APL 88, 032506 (2006)]
15. Anomalous Bias Dependence of Tunnel Magnetoresistance in a Magnetic Tunnel Junction [APL 86, 152108 (2005)]
Name: Prabhat Mandal  
Educational background: M. Sc (Physics), Ph. D  
Post-doctoral Experience:

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<th>SL#</th>
<th>Position held</th>
<th>Univ./Inst.</th>
<th>Period</th>
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<tr>
<td>1.</td>
<td>Research Associate</td>
<td>Saha Institute of Nuclear Physics</td>
<td>June 05, 1992– September, 1993</td>
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<td></td>
<td>(French Govt. fellowship)</td>
<td>(GHMFL), Grenoble, France</td>
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<td>(GHMFL), Grenoble, France</td>
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<td>4.</td>
<td>Alexander von Humboldt</td>
<td>University of Göttingen Germany, &amp;</td>
<td>November,</td>
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<td></td>
<td>Fellow</td>
<td>GHMFL-MPI, France</td>
<td>1994– June 25, 1996</td>
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Special awards, honors and other information relevant to research activity

1. Received research award from the Third World Academy of Sciences and the Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.
2. My current H-index is 19 and total citation is about 1300
3. Referee of more than 13 journals of International repute such as PRL, PRB, APL and JAP.

Research/development output

Last two decades we are studying doped Mott insulator where the electron-electron correlation driven unusual physical properties such as high-temperature superconductivity, non-Fermi liquid behavior, quantum phase transition, CMR, etc are observed. At present, we concentrate our research activity mainly on CMR oxides (where the interplay between spin, charge and orbital degree of freedom is crucial) and Fe-based pnictide superconductors. Our study on narrowband Sm$_{1-x}$Sr$_x$MnO$_3$ ($x=0.48$) single crystal revealed: (1) Due to the lattice mismatch (site-disorder) between Sm$^{3+}$ and Sr$^{2+}$ ions, the system exhibits a sharp first-order ferromagnetic-paramagnetic transition at around 110 K at ambient condition. (2) Application of external pressure, internal/chemical pressure and magnetic field weaken the first order nature of the transition and the transition becomes second order above a critical strength of these perturbations, i.e., there exists three critical points in the phase diagram. (3) We were able to demonstrate from the critical behavior analysis that the system becomes 3D Heisenberg FM in presence of high pressure.

The effect of high pressure (up to $\sim$21 GPa) on electronic properties of La$_{1-x}$Sr$_x$CoO$_3$ ($x=0.10$, 0.33) single crystals reveals interesting behavior related to pressure- and temperature-induced spin-state transition. In recent past, we have studied the role of orbital ordering on transport and structural properties in single crystals of LaMnO$_3$ and divalent-doped LaMnO$_3$. A sharp discontinuity in resistivity and volume collapse at 750 K due to the first-order orbital ordering is observed in LaMnO$_3$. The anomalously volume change (determined from the x-ray synchrotron data) in LaMnO$_3$ at the orbital order-disorder transition is quite similar to ice-water melting phenomenon.

Apart from CMR and related materials, we are also investigating transport and magnetic properties of pnictide superconductor PrFeAsO$_{1-x}$F$_y$. We have shown that this system shows resistivity saturation at high temperatures. Several important parameters in the normal and superconducting state (related to vortex dynamics) have been derived that helps to understand this mechanism of the transition. A phase diagram in the mixed-state has been constructed from the magnetization and resistivity data at high magnetic field.
Future research and development:

1. We would like to set-up a state-of-art single crystal growth facility (to grow high quality single crystals of different transition metal oxides/sulfides and of similar materials) along with different microscopic characterization facility. The techniques to be used for this purpose are Float zone, Chemical vapor transport, Czochralski, Bridgman.

2. As the systems we are studying are sensitive to external stimuli like pressure, magnetic and electric field, I have plans to set-up a high pressure facility (hydrostatic, quasi-hydrostatic and non-hydrostatic). We believe that the combination of high pressure and magnetic field will reveal interesting physics in strongly correlated systems.

List of some important publications:


2. Role of external and internal perturbations on the ferromagnetic phase transition in Sm$_{0.52}$Sr$_{0.48}$MnO$_3$ P. Sarkar, P. Mandal, K. Mydeen et al: *Phys. Rev. B* 79, 144431 (2009)


7. Large magnetocaloric effect in Sm$_{0.52}$Sr$_{0.48}$MnO$_3$ in low magnetic field P. Sarkar, P. Mandal, and P. Choudhury: *Appl. Phys. Lett.* 92, 182506 (2008)


12. Transport, magnetic and structural properties of La$_{1-x}$M$_x$MnO$_3$ (M=Ba, Sr, Ca) for 0≤x≤0.20 P. Mandal and B. Ghosh: *Phys. Rev. B* 68, 014422 (2003)


17. Thermoelectric power of Bi$_x$Sr$_2$Ca$_{1-x}$Y$_2$Cu$_3$O$_{8+y}$ (x=0-1.0) system J. B. Mandal, S. Keshri, P. Mandal, A. Poddar, A. N. Das, and B. Ghosh: *Phys. Rev. B* 46, 11840 (1992)


Name: Chandan Mazumdar

Present Position:
Professor-F,
Experimental Condensed Matter Physics Division
Saha Institute of Nuclear Physics, Kolkata 700 064

Educational background:
Ph.D (Physics), 1995, Indian Institute of Technology, Bombay, India

Awards:
i) Young Scientist (Physics), 1997, Indian National Science Academy
ii) Alexander von Humboldt Fellowship, 1997

Research/development output:

Three broad areas of condensed matter physics, viz., superconductivity, valence instability and magnetism are of my primary interest. My recent works includes (in collaboration with R. Ranganathan) the observation of negative thermal expansion (NTE) at low temperatures in GdPd$_3$B$_{0.25}$C$_{0.75}$ and discovery of negative temperature coefficient of resistivity (NTCR) in GdPd$_3$B, both of which have very unconventional origins. Through a well planed, non-routine experiment, we could show that fluctuation of valence of Eu-ions in EuPd$_3$ by introducing valence fluctuating Ce ions at the Eu site. Using inelastic neutron scattering experiments (in collaborations with scientists abroad), we had shown that low-lying crystal field levels is responsible for magnetic ordering in PrNi$_2$B$_2$C that have nonmagnetic, singlet ground state. In our laboratory, we have installed a high-homogeneity large-bore 14 Tesla magnet system to be used in connection with various measuring probes, viz., magnetoresistance, magnetostriction, heat capacity, etc. A special copper hearth has also been designed for arc furnace to draw long, thin rods.

The most notables among my earlier work are the important observation of superconductivity in YNi$_4$B (Citation 140) and discovery of superconductivity in Y-Ni-B-C system (Citation 579) (in collaboration with TIFR). This work is a milestone in the field of research in superconductivity and magnetism, resulting the creation of a new PACS index (74.70.Dd). Discoveries of another superconductor Lu$_2$Ni$_2$Si$_5$, valence fluctuating material Ce$_2$Ni$_2$Si$_5$, largest positive magnetoresistance in intermetallic polycrystalline material Tb$_2$Si$_3$Si$_5$, and monolayer-thin domain wall in ferromagnetic SmNi$_4$B are also noteworthy. While working in FU-Berlin, we have also performed the first direct measurement of magnetic structures in thin film form using magnetic x-ray diffraction techniques. We had shown that below the respective magnetic transition temperatures of rare-earths, splitting of valence bands scales linearly with $4f$ moments regardless the material is antiferromagnetic, that devoid any net magnetization, or ferromagnetic.

Future research/development plan:

The future research program include setting up laboratories for 20 Tesla dc field with an aim to further enhance the limit in near future using magnetic pulsed field. A dilution refrigerator and high pressure cells will also be employed to reach extreme corners of phase diagrams. Based on our experiences, emphasis will be given on studying various intermetallic compounds, particularly those of intermetallic perovskite and double perovskite compounds and compare the findings with those obtained in their oxide counterparts. Although voluminous work may be found on oxide perovskite systems due to their technological importance, hardly any work is reported for intermetallic perovskites. Beside these, we also would like to initiate research on finding new materials having large thermoelectric power (high ZT). Such materials are the key for the development of energy technologies with much reduced environmental impact.
List of important publications:


1. Name: **Barnana Pal**

Educational qualification: M.Sc. (CU), Post M.Sc. (SINP), Ph.D. (CU).

2. Academic profile:

   Associate Professor ‘E’: 01.02. 2003.
   Professor ‘F’: 01.08.2007.

3. Essential strength of research:

   **I. Propagation Characteristics of Ultrasound Through Material medium:**

   The responses observed in various ultrasonic experiments (e.g. continuous wave(cw), pulse echo, coherent pulse/cw, long pulse etc.) depend on various internal and external parameters. An extensive analysis based on a “propagating wave” model has been made to understand the nature of waveform deformation caused by these factors. The analysis explores the possibility of developing a computational Fourier transform method for the characterization of materials. The proposed method, being a general one, is applicable to different types of waves. As an application, the method has been employed to study the propagation behaviour of ion-acoustic waves in plasma. The propagation parameters and dispersion characteristics obtained from experimentally observed waveforms are found to be in good agreement with the theoretical prediction.

   **II. Ultrasonic Study of Structural Phase Transitions:**

   Structural phase transitions are associated with strong anomalies in the acoustic propagation parameters. We intend to study the nature of anomaly observed near structural transitions in different systems. Study on the variation of propagation parameters of 10MHz ultrasound as a function of temperature over a wide temperature region from 240°C to 490°C in β’-brass has been done. This system shows order-disorder transition at 468°C. Temperature variation of attenuation coefficient ($\alpha$) of longitudinal acoustic wave propagating along [100] and [110] directions shows a small peak around 300°C. Near the transition temperature, $\alpha$ rises sharply following a relation $\alpha \sim (T_\text{c}-T)^{0.24}$.

   To extend our study in liquids we consider aqueous electrolytes. In aqueous electrolytes the mobility of the ions depend on the molar concentration of the solution. Also water as a solvent plays significant role due to hydrogen bonding and network structure. These facts lead to interesting structural properties in aqueous electrolytes. The concentration dependence of velocity and attenuation in NaCl solution at 800KHz, 1MHz and 2MHz ultrasound frequency indicates the existence of structural changes at some specific solute concentrations. There is a possibility for the formation of large size ion-water clusters as indicated by other different experiments reported in the literature. An elaborate study in this regard is in progress.
III. Developmental work:

Growth of large size single crystals from solution:

Study of acoustic properties near structural transitions in different systems requires large size good quality single crystals. To meet our requirement we started developing the facility for growing such crystals. We choose KSCN that exhibit order-disorder transition. Such crystals can be grown from solution using acetone as the solvent. The solubility of KSCN in acetone decreases very slowly with temperature. This enables one to grow high quality crystals by evaporating the solvent. The growth process should be carried out in a closed vessel since the solution is extremely hygroscopic. A special type of growth vessel has been designed and crystals of size \(2.30 \times 2.36 \times 17.7 \, \text{mm}^3\) has been grown in ambient conditions. Work is in progress to grow larger crystals.

IV. Simulation studies on some model systems.

Monte-Carlo simulation on different model systems is done with a view to understand the observed physical phenomena from a microscopic point of view. Different systems like Diffusion Limited Aggregate (DLA), Langmuir monolayer, Strongly Correlated Liquids and Lennard-Jones (L-J) clusters have been studied.

In our recent study on the dynamical evolution of two-dimensional Lennard-Jones (L-J) clusters, realistic thermal motion of the particles have been introduced through a modification of the conventional Metropolis algorithm. The proposed algorithm leads to a quick equilibration from the nonequilibrium cluster configuration in a certain temperature regime, where the relaxation time \(\tau\), measured in terms of Monte Carlo Steps (MCS) per particle, vary inversely with the square root of system temperature \((\sqrt{T})\) and pressure \((P)\); \(\tau \sim (P\sqrt{T})^{-1}\). From this a realistic correlation between MCS and time has been predicted. In the low temperature regime the system shows the presence of two relaxation times when the particle concentration is greater than a critical concentration. With the sudden decrease in temperature it firstly attains an amorphous structure and then slowly approaches towards an ordered crystalline structure.

Another system of our concern is aqueous electrolytic solution. A realistic model to study the properties of an aqueous electrolyte surface consisting of interacting particles, ions and dipoles, has been developed. The possible interactions existing in the system are charge-charge, charge-dipole, charge-quadrupole and dipole-dipole. The concentration and temperature dependence of the ionic diffusion co-efficient indicates structural phase transition at some specific ionic concentration.

4. Future research/development plan:

A. Ultrasonic study of structural transitions in different solid and liquid systems.
B. Development of Computational Fourier Transform Ultrasound technique.
C. Simulation study on L-J clusters, aqueous electrolytes and other systems.

5. List of important publications:

**Name:** Asok Poddar

**Educational background:** Ph.D. (Phys), 1994 (Calcutta University)

**Awards:**
- i) Nat. Scholarship 1980-82 (C.U)
- ii) AvH Post doctoral Fellowship, 1995

**Essential strength of research/development output:**

My research activities are primarily concerned with strongly correlated electronic systems e.g. double perovskite compounds, colossal magnetoresistance material, high-T\textsubscript{c} superconductors (HTSC), etc., as well as conducting nano-composite systems. While exploring the basic physics of the technologically important half-metallic double perovskite compounds exhibiting substantial low field magneto-resistance around room temperatures, we observe evolution of anti-ferromagnetism below the randomly frozen spin glass state in the doped Sr\textsubscript{2}FeMoO\textsubscript{6} system. This is quite an interesting behaviour as it goes contrary to the popular belief. Furthermore, in the nano-metric (Sr/Ca)\textsubscript{2}FeMoO\textsubscript{6} samples, we have found the signature of disorder enhanced quantum interference effects at low temperatures. To facilitate diverse types of experimental measurement, we have also designed and fabricated (using the SINP & VECC workshop facilities) variable temperature insert for measurements of various physical parameters viz. magneto-resistivity, Hall voltage, thermo-electric power, specific heat, etc. in the temperature interval 2-300K, and in the magnetic field range 0-10 Tesla. My earlier research work under Alexander von-Humboldt fellowship deals with the improvement of the quasi-crystallinity in the icosahedral Al\textsubscript{30.4}Pd\textsubscript{20.3}Mn\textsubscript{8.8} that causes a drastic increase in resistivity accompanied by a very small decrease in the electronic specific heat coefficient. This leads to a significant reduction in the electronic density of states suggesting only a very small fraction of Mn atoms carries magnetic moment while the majority being non-magnetic. One of the noteworthy research work during my doctoral research is the establishment of “two dimensional character of the Thallium based HTSC”. Another interesting result, that may also be mentioned, is the observation of dome-shape like phase diagrams (\(T_c\) versus \(p\)-hole concentration per Cu-ion) for Tl\textsubscript{2}Ba\textsubscript{2}Ca\textsubscript{2}Cu\textsubscript{2}O\textsubscript{8} systems.

**Future research/development plan:**

The physics of ordered and disordered magnetic oxides have attracted a world wide attention from basic theory, novel experiment and application point of view. In these materials, appropriate correlations between lattice, spin and electronic structure are yet to be established properly. An important characteristic of these materials is the presence of several competing interactions of comparable energy scales similar to that found in many heavy fermion systems. In this context, it would be of interest to study the phase diagram of the selected oxides of potential interest and some of those heavy fermion systems through different measurements of their physical properties (e.g., electrical, thermal, thermodynamic and magnetic properties) under extreme physical situations viz. low temperatures (mK), high magnetic field and high pressure.

Another important property that is of current interest is the exciting and technologically important phenomenon of multi-ferroelectricity as these materials are useful in making magnetic sensor, solid state fuel, and spintronic devices. In this context, we propose to synthesize multi-ferroic materials by mechanical milling as well as chemical routes. Since multiferroicity is connected to both electronic (ferroelectric) and magnetic (ferro/antiferromagnetic) properties of a material, attempt will also be made to formulate the origin of multi-ferroelectricity by correlating with structural, magnetic, dielectric and magnetotransport (magnetoresistance, magnetoimpedance) properties of the materials.
Selected list of important publications starting with recent ones:

1. Spin glass-like behaviour in Fe-rich phases of Sr$_2$Fe$_{1-x}$MnxMoO$_6$ (0.1≤x≤0.4), Asok Poddar and Chandan Mazumdar, *J. Alloys Comp.* **502** (2010) 15.
**SURFACE PHYSICS DIVISION (SPD):**

**Permanent Members of the Division**

<table>
<thead>
<tr>
<th>Scientific</th>
<th>Technical</th>
<th>Administrative/Auxiliary</th>
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<tr>
<td>M. K. Sanyal, Senior. Prof. &amp; Head</td>
<td>Avijit Das, Sc. Officer</td>
<td>Mukul Das, Superintendent</td>
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<td>P. Chakraborty, Senior. Prof.</td>
<td>Subir Roy, Sc. Officer</td>
<td>Harendra Nath Jana, Helper</td>
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<td>D. Ghose, Senior. Prof.</td>
<td>Sushanta Banerjee, Sc. Officer</td>
<td>Gobardhan Jana, Helper</td>
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<td>S. R. Bhattacharyya, Prof.</td>
<td>Souvik Banerjee, Sc. Assistant</td>
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<td>T. K. Chini, Prof.</td>
<td>Gautam Sarkar, Sc. Assistant</td>
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<td>K. S. R. Menon, Associate Prof.</td>
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<td>S. Bhunia, Associate Prof.</td>
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**Post-Doctoral Fellows (2007 onwards)**

Mrinmay Kumar Mukhopadhyay, Subarna Mitra, Subhendu Mondal and Sayanee Majumdar

**PhD Students (2007 onwards)**


(* have joined Applied Material Science Division from 2010)
**Major Equipment and Resources in the Division**

1. Rotating anode x-ray laboratory for reflectivity and diffuse scattering
2. Versatile x-ray facility for diffraction and scattering
3. Scanning Probe Microscopes (Three)
4. UHV Scanning Probe Microscope
5. XPS-UPS facility
6. Environment SEM facility
7. SQUID magnetometer
8. SIMS facility
9. 200KeV high current Ion implantation facility
10. 30KV Ion accelerator facility
11. Broad beam high current ion etching facility (Installed February, 2010)
12. Molecular Beam Epitaxy (MBE) for Si-Ge
13. Magneto/Optic Transport properties of organic nanostructures
14. Facility for semiconductor characterization (PL, DCXRD, ECV, I-V, C-V, Hall)
15. Cathodoluminescence (CL) microscopy facility (Installed March, 2010)
16. Low energy Nanocluster ion beam facility (Installed May, 2010)
17. Angle Resolved Photoemission system for the development of spintronics materials
18. MOCVD facility for growing III-V semiconductor nanostructures (to be completed)

**Research Activities:**

Surface physics division (SPD) is pursuing basic research in the frontline areas of synthesis, characterization and study of physical properties of surfaces and interfaces of ultra thin films and nanomaterials. The molecules situated at the surfaces and interfaces dictate properties of nanomaterials in most cases and the number of these molecules increases as the size of particles gets reduced. Hence physics of surfaces and interfaces is essential to carry out research in nanoscience and nanotechnology. In the last two plan periods (IXth and Xth) SPD has set up some advanced experimental facilities and generated a strong research base in this area through significant funding from Department of Atomic Energy (DAE), keeping in focus the futuristic developments and the fast pace of progress in the fields of nanoscience and surface physics. Faculty members of SPD, with their diversified fields of expertise, work in a unified manner sharing a common interest to understand the role of surfaces and interfaces in nanomaterials. A new Center for Nanoscience and Surface Physics (CENSUP) has been created in SPD to promote national and international scientific exchanges involving cutting-edge research on nanoscience and surface physics.

**Important Results:**

i) **Morphology and structure of surfaces/interfaces – X-ray scattering and Scanning Probe Microscopy studies:**

One of our primary research activities is to understand growth mechanism of various nano-structured materials through studies of morphology and structure of grown materials using various x-ray scattering techniques like reflectivity, grazing incidence diffraction and diffuse scattering and using scanning probe microscopy (SPM) techniques. We are also utilizing SPM techniques to investigate elastic properties, chemical changes in thin films and to study wetting property of surfaces and edges. In addition to facilities available in our division, we use various synchrotron and neutron scattering facilities for this purpose. We also use scanning and transmission electron microscopy techniques some times to get additional information.
We use various techniques to grow these films like magnetron sputtering for metallic systems, MBE and MOCVD for semiconductors, spin-coating for polymer and Langmuir-Blodgett growth for organo-metallic systems. For example, we have carried out x-ray scattering study to understand structure and morphology of monolayer of thiol-capped gold nanoparticles on the water surface and associated restructuring when these monolayer films are transferred to a solid substrate by Langmuir techniques. We have also studied formation and ordering of gold-nanoparticles through chemical reaction at the water-toluene interface. We have developed a method to study the swelling dynamics of water soluble polymer films using X-ray and neutron reflectivity techniques. We observed that the dynamics are strongly affected by the interaction of the substrate surface. To understand the driving force behind growth of different initial structures and their evolution with time, and its implication in different properties, especially transport properties and electronic structure, a systematic study has been initiated with Si surface having various passivation. For example, Au on Si shows inter-diffusion dominated growth while Ag on Si shows wetting/dewetting dominated growth.

ii) Modification of surface morphology and properties by ion beam:

Ion implantation is known to be an effective method for improving the surface properties of materials, such as hardness, elastic modulus, and wear and corrosion resistance. The defect generation, solution hardening and precipitate hardening are thought to be the main mechanisms to promote the surface hardening. We are studying the near-surface mechanical properties by a depth-sensing nano-indentation technique. The improved bonding at the interface of the film/substrate by implantation is measured by the scratch test.

We have carried out Ion implantation and sputtering related activities to modify materials properties like ion beam mixing and pattern formation on surfaces. We have shown that an initially rough surface has a profound influence on the ion-beam induced pattern formation. We are investigating the pattern formation with different degrees of pristine surface roughness as a function of ion fluence, angle of ion incidence, substrate rotation and temperature. The data will improve the continuum theories for better understanding of the underlying mechanisms. Nanopatterned structures are thought to provide functional architectures for future opto-electronic devices. With this view in mind, our study concerns the study of luminescence and surface plasmon from nanostructured patterned semiconductor and metallic films/particles grown on such patterned substrate. At present, employing a high resolution scanning electron microscope coupled with a cathodoluminescence (HRSEM-CL) system that allows simultaneous recording of spectroscopic and imaging information with sub micron spatial resolution, the role of nanostructured amorphous silicon phase on the fast electron excitation induced luminescence from ion patterned silicon surface ripples is being investigated. We have also initiated a new program for the production, characterization and investigation of novel properties of deposited nanocluster films.

Another area of research is ‘metal quantum dots in glasses’ for synthesizing novel photonic materials for switching applications. Various metal nanocluster-glass composites that we synthesized by ion implantations have provided significant third-order dielectric susceptibility ($\chi^{(3)}$) in the picosecond time domains. We are employing Z-scan and ARINS techniques for nonlinear optical measurements. Optical nonlinearity has been explained to be due to two-photon absorption in the nanocomposite glasses.
iii) Secondary Ion Mass Spectrometry (SIMS)

MC$_{n+}^+$ molecular ions ($n = 2, 3, \ldots$) in SIMS offers a significantly higher detection sensitivity compared to MC$^+$ ions and has a potential relevance in quantification without the aid of ‘standards’. We have recently explored the formation mechanisms of these molecular ion complexes through their emission kinematics and measurement of instantaneous local surface work function changes of the sputter-emission sites. The MC$_{n+}^+$-SIMS method has been successfully used for direct compositional analysis of surfaces and interfaces of low-dimensional structures including MBE grown Si/Ge multilayer and Si$_{1-x}$Ge$_x$ alloy structures.

iv) Electrical and magnetic properties of nano-materials

We have found novel electronic transport properties in conducting polymer (Polypyrrole) nanowires. Low temperature transport study of these nanowires having low electron densities have exhibited characteristics of charge density waves observed in structurally ordered materials. A switching transition to highly conducting state has been observed above a threshold voltage, which can be tuned by changing the diameters of the nanowires and the temperature. Negative differential resistance and enhancement of noise have been observed above the threshold.

Magnetization measurements with conventional low temperature magnetometry and with polarized neutron scattering have been performed on a multilayer stack of noninteracting monolayers of gadolinium ions formed by the LB technique. This system is showing clear signature of two-dimensional ordering of spins.

v) Structure – property correlations at the surfaces of strongly correlated materials

Since 2005, we have initiated a program on the structure-property correlations at the surfaces of strongly correlated materials. Our studies have been focused on the surfaces of oxide materials in the form of single crystals, micro/nano particles and on the epitaxially grown thin films, as well as on low dimensional surfaces and metal/semiconductor surfaces and overlayers. We are interested in studying the surface structure and morphologies, electronic structure and magnetism at the surfaces. We have been employing various tools for studying the surface properties including electron and x-ray spectroscopic techniques, scattering techniques as well as spectro-microscopic techniques. We have been successful in elucidating the electronic structure and magnetic structures and their structural and morphological origins at some of the strongly correlated material surfaces. Interesting new results in the antiferromagnetic domain structures at the surface of Nickel Oxide (NiO) were obtained in a study with the help of x-ray magnetic linear dichroism (XMLD) technique using a Photoemission Electron Microscopy (PEEM) system. The surface electronic structures of low dimensional materials such as Graphite, MoS$_2$ etc are being explored using Angle-resolved Photoemission Spectroscopy (ARPES) along with their surface structural studies.

vi) Electron spectroscopy of novel materials

As surface properties are strongly dependent on the nature of the interaction, understanding of the nature of interaction between the substrate and the polymer chains becomes a key issue. We have developed a state of the art XPS/UPS facility in our lab during 2004 in this direction. Problem comes with the fact that these polymers are insulators and gets charged when exposed to the X-rays. We have developed a novel method namely controlled neutralization technique (CNT) to understand charging and neutralization in polymers. Later we have developed another technique to use this
charging to understand structure of organic multi layers. Orientation of polymer chains on a substrate is a direct outcome of polymer substrate interaction. Near Edge X-ray Absorption Fine Structure (NEXAFS) which is a synchrotron based technique is one of the best tools to study the interaction and the orientation of the molecules simultaneously. We are using this technique along with XPS to understand chemical nature of the substrate and the polymer molecules with their mutual interaction.

vii) Growth of compound semiconductor nanostructures

We have recently initiated a research program in the areas of semiconductor materials and devices, especially in the area of III-V and II-VI compounds. Particularly, we are interested in epitaxial growth of such compounds and different low dimensional nanostructures using Metalorganic Vapor Phase Epitaxy (MOVPE) system and chemical vapor deposition (CVD) methods, and characterization of these materials using optical and electrical methods. A MOVPE system, aimed at growing Ga-In-Al-As-P system is at its last phase of installation to pursue this research interest. We have also built a CVD system for growing ZnO thin films, nanowires and other type of self organized hierarchical nanostructures. Vertically aligned as well as randomly oriented nanowires of ZnO have been successfully grown by varying the controlling parameters in the CVD process.

List of Publications (2007 – date)

2010


16. Effect of Ionic Environment on the Transport of Cesium ion in alkali chloride solutions from Radio Tracer Studies, H Chakrabarti and S Kundu, Accepted, Applied Radiation and Isotopes, June17, 2010, Ref.: ARI5072,

17. A Novel attempt to calculate the velocity correlation coefficients in ternary electrolyte solution", H Chakrabarti and S Kundu, Accepted, Journal of Solution Chemistry, .Ref. JOSL1144R2, April 7, 2010,


44. Strain induced non-equilibrium magnetoelastic domain structure and spin reorientation on NiO(100), S. Mandal, K. S. Menon, F. Maccherozzi and R. Belkhou, Phys. Rev. B 80, 184408 (2009).


2008


70. Effect of Annealing Induced Polymer Substrate Attachment on Swelling Dynamics of Ultrathin Polymer Films, M. H. Mondal and M. Mukherjee, Macromolecules 41, 8753 (2008).


2007


NAME: Milan Kumar Sanyal (DOB: 6 January 1954)
Ph. D. (1987) University of Bombay

Academic profile:
Prof. Sanyal (MKS) joined the faculty of the Saha Institute of Nuclear Physics (SINP) in 1995. He presently is a Senior Professor and Head of Surface Physics Division. He is also the Director of the institute. He was working as Scientific Officer in Bhabha Atomic Research Centre from 1977 to 1995 before joining this institute. MKS did his postdoctoral research in Physics Department of Brookhaven National Laboratory (BNL) as a Research Associate from 1989 to 1992.

AWARDS:
• J.C. Bose Fellow
• Fellow, Indian National Science Academy.
• Fellow, Indian Academy Sciences.
• Fellow, The National Academy of Sciences, India.
• Fellow, Asia-Pacific Academy of Materials
• Fellow, West Bengal Academy of Science and Technology, India
• Medal of Material Research Society, India 2000.
• First prize in the Fifth Colloquium for Young Physicists (1987) Indian Physical Society.
• N.S. Satya Murthy memorial Young Scientist award of the Indian Physics Association, 1987.

Essential strength of research / development output
MKS started his research work in the field of grazing incidence scattering of x-rays and neutrons to probe the structure of surfaces and interfaces during his stay in BNL. One of the prime contributions of MKS is to develop basic understanding of specular and diffuse scattering process from a liquid surface (Phys. Rev. Lett. 66, 628 (1991)). The developed formalism and experimental techniques of this paper has been used extensively to study varieties of liquid-vapour and liquid-liquid interfaces and this work is the most cited one in the field of scattering study of liquid surface. He has recently used this technique to probe nanoparticle formation in liquid-liquid interfacial reaction (Phys. Chem. C 112, 1739 (2008)). MKS developed a research group to work in the field of surface physics involving nanomaterials and low dimensional systems in SINP. This research group in SINP has obtained novel results on structure, growth mechanism and properties of metal-organic multilayered films deposited using Langmuir–Blodgett (LB) techniques and of ultra thin polymer films. Another recent finding by MKS is a novel electronic transport property of conducting polymer (Polypyrrole) nanowires. Low temperature transport study of these nanowires having low electron densities have exhibited characteristics of charge density waves (Adv. Mater. 19, 3956 (2007)) observed in structurally ordered materials. MKS and his collaborators have also performed conventional magnetization and polarized neutron scattering measurements on a multilayer stack of gadolinium ions formed by the LB technique to understand two-dimensional magnetic ordering.

Future research/development plan
Prof. Sanyal will continue to work in the fields of surface scattering to understand ordering of various nanomaterials on liquid and solid surfaces. He is also actively involved in structural studies of various semiconductor quantum structures. MKS will continue to work on novel electronic transport properties of organic nanostructures and plans to extend this work in the field of organic photovoltaic systems. His group is also spending considerable amount of time in development of synchrotron based material research in the country. This group have set up a surface scattering and magnetic scattering beamline in INDUS-2 synchrotron at Raja Ramanna Centre for Advanced Technology, Indore, India. They have also set up an “Indian Beamline” in Photon Factory synchrotron, Japan.
List of important publications

1. Name: Purushottam Chakraborty
   Qualifications: M.Sc. (Physics), Ph.D. (Calcutta University)

2. (a) Academic Profile including earlier appointments:
   Senior Professor ‘H’ (since Aug 2009), SINP
   Professor ‘G’ (2005 - 2009), SINP
   Professor ‘F’ (Aug 2000 – Aug 2005), SINP
   Associate Professor ‘E’ (Feb 1995 – Aug 2000), SINP
   Reader ‘D’ (Feb 1989 – Jan 1995), SINP
   Lecturer ‘C’ (Feb 1986 – Jan 1989), SINP
   Scientist ‘B’ (July 1983 – Jan 1986), SINP
   Ph.D. Fellow, SINP, Kolkata, India (September 1977 to June 1983)

(b) Postdoctoral Visits
   Department of Materials, Imperial College, London, UK (June 13-22, 2010), Department of Physics, Newcastle University, Newcastle, Australia (November-December 2008), Visiting Professor, Osaka Electro-Communication University, Osaka, Japan (March 1-31, 2008), Physics Department, University of Pretoria, South Africa (2007-2008), Physics Department, Padova University, Italy (1993 – 1994), Universite Laval, Quebec, Canada (1994 – 1995), Friedrich-Schiller University, Jena, Germany, Bielefeld University, Germany (November 1993), Maria Curie Sklodowska University, Lublin, Poland and the Polish Academy of Sciences, Poland (September 1987), ICTP, Italy (June -August 1987), FOM-Institute for Atomic and Molecular Physics, Amsterdam, Netherlands (1984-1985)

(c) Selected Awards and Professional Honors
   • Appointed as ‘Adjunct Honorary Professor of Physics’, University of Pretoria, South Africa (2010)
   • Delivered an invited talk at the Special Broadcasting Service (SBS), Sydney Radio, Australia (November 30, 2008)
   • Elected Fellow, West Bengal Academy of Science and Technology
   • Most Eminent Mass Spectrometrist of India, awarded by the Indian Society for Mass Spectrometry (ISMAS) for meritorious and significant contributions in SIMS
   • Felicitated with Gold Medal by Dr. Anil Kakodkar, Chairman, Atomic Energy Commission, Government of India (January 27, 2003)
   • Honorary Member in the Council of the NANOAFNET (Nanosciences African Network) in 2008
   • Recipient of the “Mouat Silver Medal” of Calcutta University (1988)
   • ICTP Research Fellowship (1992-94)
   • ‘Rashbehari Ghose Foreign Travelling Fellowship’ awarded by Calcutta University (1984)
   • ‘Premchand Roychand Scholarship’ (PRS), awarded by Calcutta University (1979)

3. Essential strength of research/development output
   Essential strength of research comes from my wide experience and expertise in the area of Atomic Collisions in Solids; to be precise in ‘ion-beam analysis of materials’ in all complexities. Of my earlier works, the most notable was the design and fabrication of an indigenous SIMS (Secondary Ion Mass Spectroscopy) instrument during 1978-83 as a part of my Ph.D. work. Broadly, my research encompasses from the ‘fundamentals of inelastic ion-surface collisions in sputtering’ to the ‘applications of SIMS’ in elemental/compositional analysis of materials like metallic/semiconductor multilayers, interfacial alloys, quantum wells, self-assembled quantum dots, etc. Recently, we have made significant advances in materials quantification by introducing \( \text{MC}_n^+ \) (n=1,2,3,...) mode of SIMS analysis that circumvents the ‘matrix effect’. We have been successful in understanding the complex formation mechanisms of \( \text{MC}_n^+ \) molecular cluster ions and in using \( \text{MC}_n^+ \) SIMS method for making compositional analysis of quantum structures and interfacial alloys without the aid of calibration standards.

   Another major area of my research is the fabrication of ‘X-UV mirrors’, ‘optical waveguides’ and ‘ion beam induced metal glass nanocomposites’. We were amongst the first pioneering groups involved in the fabrication of aspherically curved mirrors for x-uv imaging applications. Recently, we have synthesized ‘metal quantum dots in glasses’ by ion implantations and achieved significant nonlinear optical responses (large optical Kerr susceptibility with fastest temporal responses). Our work has remarkable impact on photonic materials for switching applications.
I took a major role in commissioning our new state-of-the-art MBE machine and have prime responsibility in running this facility. I have been one of the principal investigators in working on Molecular Beam Epitaxy (MBE) - grown Ge quantum dots, Si/Ge multilayers and Si1.5Ge0.5 alloys.

4. Future research/development plan

(a) Complete quantitative chemical analysis of surfaces/interfaces using a combined SNMS-SIMS

In view of performing a complete quantitative chemical analysis of interfaces, major up-gradation of the existing SIMS facility with a combined SIMS-SNMS and ion imaging is under execution. The use of elemental/molecular SNMS signals will allow the absolute depth calibration.

(b) Installation of a 20 keV RHEED gun and Sb/B dopant cells in the existing MBE system.

The upgrading of the existing MBE system with a new complete 20 keV RHEED gun assembly will allow us to monitor RHEED oscillations and electron diffraction patterns characterizing real-time surface crystallography of the growing epitaxial films. Sb and B effusion cells are being assembled in view of elemental boron and antimony doping of MBE Si and SiGe structures for device applications.

(c) Silver diffusion in SiC and pyrolytic graphite at elevated temperature

Work on the PBMR (pebble bed modular reactor) materials concerns the optimization in the design parameters of multilayer-coated HTGR (high temperature gas cooled reactor) nuclear fuel particles through study of diffusion kinematics of fission fragments in SiC and graphite at high temperatures. It is an ongoing collaborative work with the Physics Department, University of Pretoria, South Africa

5. Few Important publications

1. Name: Debabrata Ghose

2. Present Position: Senior Professor ‘H’


4. Earlier appointments:

<table>
<thead>
<tr>
<th>Sl. #</th>
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<th>Years spent</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Lecturer ‘C’</td>
<td>1986 - 1990</td>
</tr>
<tr>
<td>4.</td>
<td>Associate Professor ‘E’</td>
<td>1995 - 2000</td>
</tr>
<tr>
<td>5.</td>
<td>Professor ‘F’</td>
<td>2000 - 2005</td>
</tr>
<tr>
<td>7.</td>
<td>Senior Professor ‘H’</td>
<td>2009 - ........</td>
</tr>
</tbody>
</table>

5. Essential strength of research/development output:

Over the past years we have studied various phenomena related to energetic ion bombardment of solids. Some of the important highlights are described below.

Formation of self-organized nanoscale pattern has potential applications in electronic, magnetic and optical devices fabrication. Ion beam sputtering of materials is a top down process where morphology can spontaneously develop with well-ordered periodicity over a large area of the surface. We are the first to report periodic ripple structure formation on polycrystalline metal films by grazing incidence sputtering. The critical angles of ripple rotation were experimentally measured for a number of ion-target combinations. It was shown that the initial surface roughness can accelerate the ripple formation via the activation of shadowing instability.

It is known that ion beam implantation modifies the near surface mechanical properties, especially, hardness and elastic modulus. This we have measured by nanoindentation technique for Cr⁺ implanted Si and O₂⁺ implanted Al film. We also noted that the friction coefficient changes dramatically due to ion bombardment.

The bombardment induced light emission set-up was developed to study the oxygen dependence of the yield of excited sputtered species such as the transient phenomena from elemental metals and alloys as well as from semiconductor surfaces. It was shown that Fe was preferentially oxidized than Ni in the FeNi surface under oxygen environment.

In the studies of slow multiply charged ion – surface interaction phenomena, we provided new experimental data of potential electron emission from Al and Cu single crystal targets. In another experiment, we measured the potential sputtering of Ar⁺⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻⁻㈠
6. **Future research/development plan:**

(i) Formation and characterization of Si nanodots using broad-beam high current ion source.

(ii) Synthesis of Si-nanocrystals (NCs) and Ge-NCs using the negative ion implanter as these NCs are thought to be the promising light emitting sources.

(iii) Studies of refractory metal silicides and SiGe alloys formed by direct Si ion implantation into Ta and Ge single crystals, respectively.

7. **List of recent publications:**

1) **IBS nanostructuring of thin polycrystalline metal films (Invited Article)**

2) Formation and characterization of perpendicular mode Si ripples by glancing angle O$_2^+$ sputtering at room temperature

3) Effect of initial target surface roughness on the evolution of ripple topography induced by oxygen sputtering of Al films

4) The rotation of ripple-pattern in ion sputtered thin metal films
   - Nanoindentation of single-crystal Si modified by 100 keV Cr$^+$ implantation
   - The energy dependence of sputtering induced ripple topography in Al film

5) Role of initial surface roughness on ion induced surface morphology

6) Formation of nanoripples in Al films during O$_2^+$ sputtering

7) The hardness study of oxygen implanted aluminium thin films

10) Electrical characterization of oxygen-induced nanosized ripples on aluminium thin films by conductive atomic force microscopy
Areas of research:

- Development of new analysis schemes for grazing incidence x-ray reflectivity. And, use these schemes on real system to understand the growth kinetic study of these material (ultra thin films).
- SPM beyond topography: Developing new scanning probe microscopic (SPM) technique to use SPM beyond topography such as: elastic measurement, chemical changes, fabrication of nano-structures, electrical and magnetic measurements at nano-scales.
- Electrical and magnetic properties of nano-materials such as dilute magnetic system (DMS), graphene etc. and metallic alloys and transition metal oxides
- Magnetocaloric Effect (MCE) of certain rare earth intermetallic compounds and manganates based compounds.
- Nano-bio Sensors: some preliminary work on magnetic property of Ferretin has been reported and some preliminary work on non-enzymatic base glucose sensors are being developed.

Talks delivered in International Conference/Workshop/Schools- 9
Invited talk and courses in National workshops and conferences: 22
Invited Seminars Abroad: 18

Organisational work: Organized and Convener for NN DasGupta memorial workshop on microscopic technique (Sept. 19th – 22nd, 2000, SINP) organized by Microscopic Society of India.

Academic award & Honours:

- Scientific committee member in International Conference: European - Material Research Society (E-MRS 2005, May 31—June 3) Symposium P.
- Nominated for Theoretical Physics Seminar Circuit (TPSC) – 2002 –2003, Category B – Senior Faculty
- Invited and participated as a Judge for promotion case of a faculty (Asst. Prof.) in Montpellier University, France- February 2001
- Japan Science and Technology Agencies Fellowship (STA, Japan) 1999

Out of 75 papers published only some 25 selected publications in international refereed Journals is below:

1) Name Satyaranjan Bhattacharyya

Educational background

(i) B.Sc. (Honours) (Bacheler) degree in Physics from the University of Calcutta (1980)
(ii) M.Sc.(Postgraduate or Master) degree in Pure Physics from the University of Calcutta (1982)
(iii) Post M.Sc. Associateship Course (1983-84) of Saha Institute of Nuclear Physics, Calcutta, India.
(iv) Ph.D. in Physics from the University of Calcutta (1993) for the thesis entitled Studies on topographical modifications of solid surfaces due to energetic ion bombardment

2) Academic Profile (Earlier appointments, Academic Assignments, Awards)

a) Earlier Appointments

(i) Lecturer ‘C’, Saha Institute of Nuclear Physics (1996-98)
(iii) Associate Professor ‘E’, Saha Institute of Nuclear Physics (2002-06)
(iv) Professor ‘F’, Saha Institute of Nuclear Physics (2006-09)
(v) Professor ‘G’, Saha Institute of Nuclear Physics (2009 - to date)

b) Academic Assignments

(i) Post Doctoral Research Associate, Saha Institute of Nuclear Physics (1993-95)
(ii) Post Doctoral Fellow, Physics Dept., University of Bielefeld, Germany (1995-96)
(iii) Nominated scientist from India in the INSA-DFG Exchange Programme, deputed for a visit to Institut für Physik, Universität Greifswald, Germany for three months (1999-2000)
(iv) Visiting Scientist in Max-Planck Institute for Plasmaphysics, EURATOM Association, Munich (Garching), Germany for three months (2005-06)
(v) Nominated scientist from India in the INSA-DFG Exchange Programme, deputed for a visit to Hahn-Meitner-Institute, Berlin, Germany for three months (2005-06)

c) Awards

(ii) Obtained a certificate of merit for the best oral presentation of a paper in the Symposium on Crystal Growth, Solution and Morphology held in Jan. 8-9, 1990, Anna University, Madras, India.
(iii) Awarded (as Principal/Project Investigator) the approval from DST, India for Joint Research Project entitled “Nanostructuring surfaces by ion sandblasting” under Indo-Italian Program of Cooperation in Science and Technology for 2002.

3. Essential strength of research/development output

The researches that are undertaken mainly fall in the ion-solid interaction studies. The following topics of the studies have been carried out.

1. Energy dependence of sputtering yields of GaAs bombarded by mass analysed $^{40}$Ar$^+$, $^{84}$Kr$^+$ and $^{132}$Xe$^+$ ions. This work showed that spike effect in sputtering has a projectile dependent component apart from energy dependence as proved for higher masses projectiles. This investigation is considered as one of the pioneering works for spike effect of sputtering for

2. Surface morphology studied for metals, semiconductors and insulator (glasses) bombarded by energetic ions (keV range). Cone formation on metals for normal incidence and ripple formation on Si, GaAs and glasses for oblique incidence. Energy dependent wavelength of nanoscale ripples has been predicted. Ion beam mixing and interface alloying of thin films have been studied using medium energy keV ions of inert gases.

3. Light emission from ion bombarded solid surfaces was studied for metals, semiconductors and insulators. Relative sputtering and desorption yields were measured from Si surfaces under polyatomic and highly charged ions respectively.

Apart from these researches, I was involved in one of the biggest projects of SINP namely, High Current Isotope Separator and Ion Implanter in 9th five-year plan. In 11th five-year plan, a sub-project (Low Energy Nanocluster Ion beam facility for novel film deposition and characterization) under CENSUP has been executed in my leadership.

4. Future research/development plan

Currently we are involved in a new emerging field of investigating novel properties of nanoclusters and of the films composed by nanoclusters deposition. We are particularly interested in morphology, composition, structure and properties like thermodynamic, magnetic etc. of nanoclusters to be deposited using our newly installed system. In this respect we have already started strong collaborations with theoreticians and experimentalists of world’s leading groups in this filed and got interesting results depicted in our recent publications.

5. List of important publications starting with recent publications

1) Name: Tapas Kumar Chini

Educational background:
- Passed B. Sc. (Honours in Physics) (Bachelor) degree in Physics from the University of Calcutta (1980-1983).
- Obtained M. Sc. (Postgraduate or Master) degree in Physics from the University of Calcutta (1983-1985).
- Obtained Ph. D. degree in Physics from the University of Calcutta (1994) for the thesis entitled “Studies on the Ion impact phenomena in solids”.

2) Academic profile:
- Academic assignments (Post Doctoral / Visiting position/ Awards etc.)

<table>
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<tr>
<th>Sl. #</th>
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<tr>
<td>(i)</td>
<td>Awarded MONBUSHO Scholarship</td>
<td>Nagoya Institute of Technology, Nagoya, Japan</td>
<td>October '93</td>
<td>March '95</td>
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<td>(ii)</td>
<td>Postdoctoral Fellow</td>
<td>Saha Institute of Nuclear Physics, Calcutta</td>
<td>June '95</td>
<td>July '97</td>
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<td>(iii)</td>
<td>Postdoctoral Fellow</td>
<td>University of Houston, USA</td>
<td>August '97</td>
<td>December '97</td>
</tr>
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<td>(iv)</td>
<td>Senior Postdoctoral Fellow</td>
<td>Institute of Physics, Bhubaneswar</td>
<td>April '98</td>
<td>March '2000</td>
</tr>
<tr>
<td>(v)</td>
<td>Awarded AIEJ (Japan) Research Scholarship</td>
<td>Nagoya Institute of Technology, Nagoya, Japan</td>
<td>December '01</td>
<td>March '2002</td>
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<tr>
<td>(vi)</td>
<td>Visiting Scientist</td>
<td>Universidad Carlos III De Madrid, Spain</td>
<td>November 1 '05</td>
<td>November 30 '05</td>
</tr>
<tr>
<td>(vii)</td>
<td>Guest Scientist</td>
<td>Institute of Ion Beam Physics and Materials Research, FZR, Germany</td>
<td>December 1 '05</td>
<td>March 31 '05</td>
</tr>
</tbody>
</table>

- Earlier Appointments:
  b) Associate Professor 'E' in Saha Inst. Nucl. Phys. (February 1, 2003 to January 31, 2007).
  c) Professor 'F' in Saha Inst. Nucl. Phys. (February 1, 2007 to January 31, 2010).
  d) Professor 'G' in Saha Inst. Nucl. Phys. (February 1, 2010 to till date)

3) Essential strength of research / development output:
Studies on the physical synthesis of low dimensional novel surface and interfaces of semiconductor material (mainly silicon) is one aspect of our research. The other aspect relates the search for a structure-
physical property relation based on the knowledge obtained after detail morphological, structural and compositional analysis using electron microscopy and scanning probe microscopy. With this view in mind, our first kind of studies involve the experimental investigation of dynamics and microstructure of ion-beam induced ripple pattern growth on silicon surface using medium energy inert gas ion beam. From the fundamental point of view, our studies on ion-beam induced nanoscale patterning have impact onto many fields, from nonequilibrium Physics to Applied Mathematics. From technological point of view, the ability of tuning the pattern morphology by varying the ion beam parameters has opened up the possibility of using such patterned surface as a template for growing new electro-optic and magnetic devices or in the application of nanofluidic systems and in Biotechnology. In the second kind of experiment, we demonstrate porous like light (visible, ultraviolet and infrared) emitting behaviour from such ion-induced ripple patterned amorphous silicon when excited by photon or electron beam, i.e., observation of photoluminescence (PL) or cathodoluminescence (CL) and this initiates a possibility of establishing a structure physical property relation of the system we are using.

4) Future research plan:

Nanopatterned structures are thought to provide functional architectures for future opto-electronic devices but the challenge lies in analysing the local electronic defects arising out from various kinds of defects or imperfections in the crystal structure with very high spatial resolution. In our future research plan, we will basically concentrate on establishing a structure – physical property correlation which in the present case concerns the study of luminescence and surface plasmon from nanostructured patterned semiconducting and metallic systems. The scanning electron microscope (SEM) has versatile capability because the interaction of a focused nm size electron beam with a specimen can be monitored in a variety of ways, allowing topographical, chemical, optical and electrical information to be obtained at a high spatial resolution. Cathodoluminescence (CL) within a high resolution (HR) SEM are among the most versatile and widely used techniques for electronic materials characterisation. The site specific spectroscopy and imaging data obtained from CL technique will be valuable to develop our understanding of local electronic structure in mesoscopic length scale.

5) List of important publications starting with recent publications:


NAME: SATYAJIT HAZRA

E-mail: satyajit.hazra@saha.ac.in
URL: http://www.saha.ac.in/surf/satyajit.hazra
Phone: 91 33 2337 5346 (ext: 4219)
DoB: 10 December, 1967

EDUCATIONS
1996: Ph.D. in Science, Jadavpur University
1990: M.Sc. in Physics, University of Calcutta; 1st class
1988: B.Sc. with Hons. in Physics, University of Calcutta; 1st class
1985: H.S. in Science, WBCHSE; 1st division
1983: Madhyamik, WBBSE; 1st division

RESEARCH POSITIONS
2007- ...: Professor F, Saha Institute of Nuclear Physics
2004-2007: Associate Professor E, Saha Institute of Nuclear Physics
2000-2004: Reader D, Saha Institute of Nuclear Physics
1998-2000: Postdoctoral Fellow, Universite du Maine, Le Mans, France
1997-1998: Postdoctoral Fellow, Saha Institute of Nuclear Physics
1992-1997: Research Fellow, Indian Association for the Cultivation of Science

HONOURS
Delegation member for Indo-US Workshop on Nanotechnology, USA, Nov. 2001
National Merit Scholarship by University of Calcutta on the basis of B.Sc. result

PUBLICATIONS
Journals: 47 [Total citation: 524, Average citation: 11, h-index: 13; for details see http://www.saha.ac.in/surf/satyajit.hazra/cite.htm]
Conference: 37; Chapter of Books: 2; Others: 2

SELECTED PUBLICATIONS
HIGHLIGHTS OF RESEARCH/DEVELOPMENT OUTPUT

- Understanding of interfacial dynamics and its effect on nanolayer using GIXS and SPM techniques.
  - Si surface passivated or terminated differently, shows interesting behavior towards nanolayer.
    - When nanolayer is made of Au, which reacts easily with Si, then openness and blocking (due to growth of native oxide layer) nature of passivated Si surfaces control the interdiffusion. Formation and movement of interdiffused nanolayer at room temperature is a clear signature of atmospheric pressure induced atomic diffusion into solid crystal and provides unique concept of inherent pressure inside a crystal structure. Such diffusion also depends on the crystal structure and freeness of the diffusing atoms.
    - When nanolayer is made of Ag, which form sharp interface with Si, then surface free energy, surface mobility, and surface instability of the passivated Si surfaces govern and control the growth and evolution of wetted-dewetted structures of Ag on Si with or without epitaxy.
    - When nanolayer is made of Cu, then the passivated Si surface and its dynamics control both the interdiffusion and the wetting-dewetting behavior.
    - When nanolayer is made of metal-organic molecules, which have hydrophilic headgroups and hydrophobic tails, then hydrophilic, hydrophobic or coexisting nature of the terminated Si surfaces control the structure of the Langmuir-Blodgett films.
- Understanding of the growth mechanism of Langmuir-Blodgett films and lay out a way in which its head-group can be manipulated.
- Shown the effect of metal-ions on monolayer collapse and proposed the growth mechanism of collapsing Langmuir monolayer.
- Demonstration of underlying ripple-like modulation in ion-beam modified Si surface using nondestructive GIXD technique and its correlation with top surface as reviled by AFM.
- Determination of morphology of nanocermet films using GISAXS (laboratory and synchrotron sources), and observation of substrate induced layering and cumulative disordered structure. Demonstration of linear dependence of absorption peak position with volume fraction of metal in nanocermet films.
- Formation of unconventional glassy systems, determination of their structure and physical properties.
  - Development of complementary expertise namely SPM for imaging top surface in real space and GIXS for mapping surface and interfaces in reciprocal space. This has been done by setting up ambient SPM first, then VT-UHV-SPM after gathering experience. While working with GIXS here as well as in different synchrotron facilities not only helped in setting up versatile XRD here but also helped to develop SINP beamline in INDUS-2 synchrotron source.

FUTURE RESEARCH/DEVELOPMENT PLAN

- Understanding the role of interfacial interaction in the growth of organic-inorganic mesostructured films by the process known as evaporation induced self-assembly (EISA). Growth of one dimensional objects on such mesostructured templates. Study of individual and collective properties, with emphasis on transport (both conventional and local) and optical properties, of such interesting nanoobjects to find out and/or to test basic physics of low dimensional systems.
- Controlling the self-organization and electronic properties of molecular and macromolecular systems on surfaces is among the most challenging quests of molecular and organic electronics. To date, STM and its spectroscopic mode, STS in clean environment and control temperature are the major tools to study various molecular systems to access molecular conformation, their organization and electronic states, which can be complemented with other experimental and theoretical tools.
- Adsorption/desorption and self-diffusion of atoms can produce interesting structure on a surface. Study of topography and electronic structures, using STM and STS in clean environment and control temperature; essentially enable us to understand the underlying fundamental interactions other than direct manifestation.
  - Development of dedicated SAXS/GISAXS facility to determine the morphology of mesostructured films and its evolution from solution state.
  - Attachment of a growth chamber with a provision of growth at variable temperature, with the existing VT-UHV-SPM system for the study of self-organization and electronic properties of molecular and macromolecular systems. Also attempt will be made to develop a dedicated LT-STM system.
Name: Manabendra Mukherjee

**Academic profile including earlier appointments**

**MSc.** Physics, Calcutta University, Kolkata, 1983.

**PhD.** Indian Association for the Cultivation of Science, Kolkata, 1989.

**Subject:** Theoretical atomic collision physics.

**Post Doc.** Indian Association for the Cultivation of Science, Kolkata, 1989-1996.
- (Synthesis and characterisation of nanocomposite materials)
- Instituto de Estructura de la Materia, CSIC, Madrid, Spain, Sept.’96-Feb.’98
  (Inelastic Neutron Scattering)
- National Synchrotron Radiation Research Center, Taiwan, Mar.’98-Feb.’99
  (Photoelectron spectroscopy using synchrotron radiation)
- Surface Physics Division, Saha Institute of Nuclear Physics, Mar.’99-Mar.’00
  (Surface Physics and Nanomaterials)

**Permanent Position**

**Reader D,** Mar.’00 - Jul.’03, **Associate Professor E,** Aug.’03 – Feb ’07, **Professor F,** Feb ’07 – till date

**Essential strength of research/development output:**

For more than a decade now, we are dealing with polymers. It is needless to say that this material has become an essential article from birth to death of our life. A large majority of application of polymers are in the form of thin films applied on some substrate surface. Therefore it is extremely important to know their structure and how the nature and interaction of the substrate influences the structure and dynamical behaviour of the films coated on them. Towards this objective we investigate surface and interface properties of polymers and other organic materials such as Langmuir-Blodgett films.

We have developed a method to study the swelling dynamics of water soluble polymer films using X-ray and neutron reflectivity techniques. We have demonstrated that the dynamics are strongly affected by the interaction of the substrate surface. We have also shown that tiny modifications like presence a small amount of nanoparticles in the films or a minute change in the nature of solvent which does not reflect in the structural properties can produce a strong difference in the dynamical behavior in swelling of the polymer films. In other words we have shown that swelling dynamics is a very sensitive probe to study small but important changes in the behaviour of polymer films.

The application of swelling has a vital ramification in the area of drug delivery and their application in the medical research. Protein is a natural polyelectrolyte and of prime importance for the drug delivery application. We are presently working with synthetic polyelectrolytes and proteins. We have observed several interesting behaviors that are unique to the charge centers present in the polymer backbone unlike neutral polymers.

As surface properties are strongly dependent on the nature of the interaction understanding of the nature of interaction between the substrate and the polymer chains becomes a key issue. We have developed a state of the art XPS/UPS facility in our lab during 2004 in this direction. Problem comes with the fact that these polymers are insulators and gets charged when exposed to the X-rays. We have developed a novel method namely controlled neutralization technique (CNT) to understand charging and neutralization in polymers. Later we have developed a technique to use this charging to understand structure of multi layer films. Orientation of polymer chains on a substrate is a direct outcome of polymer substrate interaction, we have ventured into this field as well. Near Edge X-ray Absorption Fine Structure (NEXAFS) which is a synchrotron based technique is one of the best tools to study the interaction and the orientation of the molecules simultaneously. We are using this technique along with XPS to understand chemical nature of the substrate and the polymer molecules with their mutual interaction and orientation.

It is necessary to have a theoretical background regarding the electronic density of states (DOS) or X-ray excitations to avoid doubts in the interpretation of the valence band XPS/UPS and NEXAFS data. In this direction we perform the density functional theory (DFT) simulations of DOS and NEXAFS transitions using STOBE package for completeness of our study.
Future research/development plan:
After about a decade of basic studies with polymers, we have decided to use our understanding towards applied research as an additional area of our activities. We have chosen the modern field of organic semiconductor devices for this purpose. We have recently installed a UHV preparation chamber with the XPS/UPS facility. This will enable us to develop organic semiconductor materials in UHV and study them in situ without breaking the vacuum. NEXAFS study of such systems will be done at synchrotron facilities.

List of important publications starting with recent publications
Effect of Annealing Induced Polymer Substrate Attachment on Swelling Dynamics of Ultrathin Polymer Films, M. H. Mondal and M. Mukherjee, Macromolecules 41, 8753 (2008).
Effect of Polymer-Particle Interaction in Swelling Dynamics of Ultrathin Nanocomposite Films, Amarjeet Singh and M. Mukherjee, Macromolecules 38 8795 (2005)
X-ray photoelectron spectroscopy studies of MgB: for valance state of Mg; A. Talapatra, S.K. Bandyopadhyay, Pintu Sen, P.Barat, S. Mukherjee, M. Mukherjee, Physica C 419 141 (2005)
1. Name - SRINANDA KUNDU

2. Photograph –scanned and attached

3. Educational background – M.Sc., PhD

2. Academic profile including earlier appointments – Joined SINP, Calcutta as Lecturer in 1993

3. Essential strength of research/development output –

Extensive studies are made on sputter deposited thin films and their studies are published in different journals.

A. Growth dynamics study of 2D ultrathin films and multilayers, their characterisation by x-ray scattering, scanning probe microscopy, scanning and transmission electron microscopy and squid magneto meter.

Some important observations are made –

i) We showed by x-ray scattering, scanning probe microscopy that in case of Au, Ag, growth takes place via layer with mounds (~ nm size -i.e. SK-type) and in the initial stages they are highly porous

ii) It was also demonstrated that mounds aggregate laterally and then vertically with time (thickness) with different exponents.

iii) At nascent state ultrathin Ag or Au films can be modified to 1 D nano lines by hard AFM tip

iv) The Fe films are so porous that in case of multilayer growth the film grown on it (e.g. V), can easily penetrate Fe film with the kinetic energy associated with sputtered V.

B. Comparative studies are made on the modifications of surface and interfaces are made on post treated as grown films, such as ion beam irradiation and high vacuum annealing

C. Magnetic Multilayers are fabricated and characterized with XRR, AFM and SQUID- Two M.Tech. project- thesis are done –

i) Sputter deposited (co/pt)$_3$ are studied with SQUID and showed ferromagnetism at 5$^\circ$K and 10$^\circ$K

ii) structural and magnetic property study of sputter deposited (Fe/V)$_{14}$ where antiferromagnetic transition is observed at 45$^\circ$K (2009 -2010)

D. Dilute Magnetic Semiconductor - Transition metal doped oxides have attracted considerable interest as promising diluted magnetic semiconductors owing to the possibility of inducing room temperature ferromagnetism for advanced spintronics applications. Thin films grown by sputtering ZnO and Co simultaneously and also sequentially are characterized with x-ray reflectivity, SEM-EDAX, XRD and transport measurements are made with 4-probe method. Dependence Co’s percentage is very much evident.

i) M.Tech. project thesis is done. Zinc Cobalt Oxide doped with Co and Al traces. (2007-2008)

E. Ion transport in electrolyte solution is of immense significance particularly for biophysical systems. Ionic Transport studies in alkali halide solutions are made using Radio Tracer technique
and theoretically the velocity correlation coefficients are calculated for ternary electrolyte solutions. H. Chakrabarti collaborated with me.

F. Acoustic Study of Electrolytic Solutions – Aqueous NaCl solution is an integral part of all living bodies and ultrasonic is an important tool for studying their cluster formation under different solute concentration (ongoing). S Kundu and B Pal.

4. Future research/development plan:

In the context of Eleventh Five Year Plan (2007-2012), in our division “Center for Nanoscience and Surface Physics” (CENSUP) project is approved. Under CENSUP, I have a project titled ‘UHV multi-deposition system for depositing thin films and their insitu characterization by Brillouin light scattering’ (BLS). The UHV unit comprises a few Knudsen cells, e- beam source and other accessories for growing well controlled thin films. In BLS, inelastic scattering of light occurs by thermally excited phonons waves in any material or by magnetic spin waves present in magnetic structures. From the shift of light frequency one can have an insight into elastic constants in general and of magnetic fluctuations of buried magnetic layers, especially of nanostructures and their confinement effects. Advent of high quality laser and modern day multipass interferometer made it possible to study especially magnetic nanostructures.

5. A few recent important publications:


2. A Novel attempt to calculate the velocity correlation coefficients in ternary electrolyte solution", H Chakrabarti and S Kundu, accepted for publication in Journal of Solution Chemistry.#JOSL1144R2, April 7, 2010, 10:31 PM


6. Structural and magnetic property of ultra thin [Fe (15 Å)/V (15 Å)]14 multilayer – S.Maity,S.Kundu, B. Ghosh and S. Banerjee
1. Name: **Satyaban Bhunia**

2. Educational Background:
   - Secondary Exam: 1986 with 1st div.
   - 5 years integrated M.Sc. in Physics (spl. Solid State Phys), 1993 from Indian Institute of Technology, Kharagpur. CGPA 8.18/10
   - Ph.D. from Indian Institute of Technology, Kharagpur in 1999, Thesis title “Crystal growth, characterization and device applications of ZnTe”

3. Academic profile including earlier appointments, awards etc.
   - Researcher, 1999 – 2002, The University of Electro-Communications (UEC), Tokyo, Japan
   - Post-Doctoral fellow 2002 – 2003 NTT Basic Research Laboratories, NTT Corporation, Atsugi, Japan
   - Reader ‘D’, Saha Institute of Nuclear Physics, Kolkata, India (2004 – 2007)
   - Assoc. Prof. ‘E’, Saha Institute of Nuclear Physics, Kolkata, India (2007 – present)

Investigator – Sponsored Projects:
   1. Main investigator of the project “**Nanoscience Unit at SINP**” under “Nanomaterials Science and Technology Initiative (NSTI) of Department of Science and Technology (DST)”.
   2. Co-Principal Investigator of the national project “Indian Beamline at Photon Factory, KEK, Japan” sponsored by DST, Govt. of India
   3. **“SINP Beamline (BL.13)” at INDUS 2 synchrotron facility, RRCAT, Indore**
   4. Principal Investigator of India-Japan (DST-JSPS) joint project entitled “**Novel Semiconductor and Magnetic Properties in Nano-Structured Materials**” under India-Japan Science Cooperative Programme.

3. Essential strength of research/development output
   - The core of my research plan and strength is on semiconductor materials and devices, especially in the area of III-V and II-VI compounds. Particularly, I am interested in epitaxial growth of such compounds and different low dimensional nanostructures using Metalorganic Vapor Phase Epitaxy (MOVPE) system and chemical vapor deposition (CVD) methods, and characterization of these materials using optical and electrical methods. A MOVPE system, aimed at growing Ga-In-Al-As-P system is at its last phase of installation to pursue this research interest. We have also built a CVD system for growing ZnO thin films, nanowires and other type of self organized hierarchical nanostructures. Vertically aligned as well as randomly oriented nanowires of ZnO have been successfully grown after systematic variation of the controlling parameters in the CVD process.
   - Synchrotron x-ray based nanomaterials characterization has been another area of my research interest. In this respect, I am involved as co-principal investigator of a national project entitled “Indian Beamline at Photon Factory, KEK, Japan”. The experimental station has been developed at this synchrotron facility in Japan to carry out powder diffraction at low temperature and high pressure, grazing incidence x-ray diffraction, single crystal x-ray diffraction and x-ray reflectivity. I have also taken a major role in the national synchrotron project of INDUS 2 at RRCAT, Indore. Here, the “**SINP Beamline**” has been successfully assembled to carry out grazing incidence x-ray scattering studies of surfaces and interfaces in solids and liquids, reflectivity, diffuse scattering, two-dimensional diffraction, small angle scattering in reflection geometry, high resolution diffraction studies as a function of temperature, structural & morphological characterization of nanomaterials etc.
   - Successfully completed the modular Photoluminescence (PL) set up in my laboratory at SINP for measuring optical properties of semiconductor materials and nanostructures at 300 K – 4 K.

4. Future research/development plan
   - The initial focus of our MOVPE related activity is to grow III-V compound nanowires. Though the growth technique has advanced a lot to obtain such structures, still many issues remain regarding site specific growth, multiheterostructure growth and coupled quantum structures for integrated optoelectronic physics and application. After growth, I am particularly interested in electrical transport and optical emission properties of individual nanowires and heterostructures. We would also like to start major activity towards growth of GaInP/GaAs based heterostructure bipolar transistor as part of high speed device applications. I
plan to establish a major semiconductor processing facility at SINP in the coming plan period which should enable us to do basic device fabrication using photolithography, metallization, ion etching, and testing under clean room environment.

5. List of important publications starting with recent publications


Papers already published (Sorted according to the time of publication)


Name: Dr. Krishnakumar S. R. Menon  
Position: Associate Professor -F  
Address: Surface Physics Division, Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata – 700 064 INDIA  
e-mail: krishna.menon@saha.ac.in  
Age and Date of birth: 39 Years; May 30, 1971  
Sex: Male  
Nationality: Indian  
Education: Doctor of Philosophy (Ph.D), 1999; Indian Institute of Science (IISc), Bangalore, INDIA. Thesis Title: “Electronic structure and metal-insulator transitions in transition metal sulphides and oxides”.  
Master of Science (M.Sc.) in Physics, 1993; Indian Institute of Technology (IIT), Madras (Chennai), INDIA.  
Bachelor of Science (B.Sc.) in Physics, 1991; University of Calicut, Kerala, INDIA  

Professional Experience:  
- Associate Professor-F at Saha Institute of Nuclear Physics, Jan. 2010 – Present.  
- Associate Professor-E at Saha Institute of Nuclear Physics, Feb. 2007 – Jan. 2010.  

Recent research/development output in brief:  
My research interest is in the structure-property correlations at surfaces and ultrathin films of simple oxide materials, metal/semiconductor overlayers and low-dimensional materials. The surface structural properties of interest includes surface strain, dislocations, defect structures besides the surface relaxations and reconstructions. Along with Low-energy Electron Diffraction (LEED), we use Low energy Electron Microscopy (LEEM) and surface EXAFS (in TEY mode) for the surface structural studies. The surface electronic structure is investigated using X-ray Photoemission Spectroscopy (XPS) and Angle-resolved Photoemission Spectroscopy (ARPES) while surface magnetism is probed with synchrotron based spectroscopic and spectromicroscopic techniques such as X-ray Magnetic Circular Dichroism (XMCD), X-ray Magnetic Linear Dichroism (XMLD) and Photo-emission Electron Microscopy (PEEM).  

For the study of surface electronic structure of crystalline materials, recently we have setup an ARPES laboratory at SINP. This state-of-the-art facility provides high energy and angular resolutions for modern day ARPES measurements of band-structure/Fermi-surface mapping besides X-ray Photoelectron Spectroscopy and Photoelectron Diffraction measurements. Initial results and characterization of this ARPES system has been published recently [1]. New ARPES results on some low-dimensional materials are being analysed and further investigated by synchrotron measurements.  

The preparation chamber of ARPES facility is used for the epitaxial growth of metal/oxide films in a controlled way and characterized by the LEED prior to the spectroscopic measurements. At SINP, we are developing mini e-beam evaporators so that we can use them for depositing the materials in the UHV. These are developed at a fractional cost of the commercial ones and will be customized for our use. Initial test results are quite satisfactory and have been the subject of an M-Tech thesis project.  

In order to study the structure-property correlations of Nickel Oxide (NiO) system, we have been performing synchrotron experiments primarily at beamlines of ELETTRA synchrotron at Trieste, Italy. We have been quite successful in studying the surface antiferromagnetic domain structure of NiO single crystals using XMLD-PEEM spectromicroscopies. Moreover, we have developed a new method of surface antiferromagnetic domain imaging using unpolarized electrons, termed as Antiferromagnetic Low-energy Electron Microscopy (AFM-LEEM). This is essentially a Dark-Field (DF) imaging method using the antiferromagnetic (half-order) reflections in the LEED and is expected to be published soon. We have also performed extensive experiments using EXAFS, X-ray Absorption Spectroscopy and Powder X-ray Diffraction measurements on the polycrystalline/nano-particles of NiO system. Many publications from the study of the NiO system is in progress and two articles have appeared recently [2,3].
I have been a part of the x-ray scattering beamline construction activities of SINP at INDUS-II, RRCAT as well as at Photon Factory, Japan. At RRCAT, the beamline construction is nearly completed and awaiting commissioning. Indian Beamline at Photon Factory has started functioning and initial scattering and diffraction experiments have been performed. At present, I am designing a UHV system for performing on-line growth studies and structural characterization of metal/oxide thin films which will be mounted on a heavy-duty 8-circle diffractometer at the beamline.

Under the Centre for Advanced Research & Education (CARE-II) project, I have started developing an experimental system for measuring variable temperature (300 – 4.2 K) transport and Magneto-Optical Kerr Effect (MOKE) properties. This will enable the users of the institute to perform resistivity and MOKE measurements down to 4.2 K under a magnetic field of 0.5 Tesla. Currently, the procurement of cryostat and other components are in progress.

**Future research/development plan in brief (For next 6 years):**

At present we are able to grow epitaxial oxide films in the preparation chamber of the ARPES system using molecular oxygen source only. Due to this, we are limited to growing only a few oxide systems such as NiO, MgO etc. In order to grow other interesting simple oxide films, we propose to procure an atomic oxygen source. This will also enable us to gain more control on the stoichiometry and reproducibility of the individual phases. In order to study the kinetics of the growth process as well as to monitor the quality of the films, a RHEED system will be attached with the growth chamber. The preparation chamber is already designed with all these future developments in mind. We plan to undertake this activity in the 5th year (2010-2011) of the current XIIth plan period.

Using ARPES, we are able to probe the electronic band dispersions in the occupied part of the valence band. It would be very interesting and appropriate also to study the dispersions in the un-occupied density of states (conduction band) which will provide the complete electronic structure information. Thus, we plan to develop an Angle-resolved Photoemission Spectroscopy (ARPES) setup for the study of the un-occupied band dispersions, integrated onto the existing ARPES setup. This will be developed in-house and I have the direct experience of developing an instrument at the Indian Institute of Science during my Ph.D period. The existing ARPES setup is designed so that an ARPES can be easily integrated into it. We propose to execute this project during the XIIth plan period (2012-2017).

In order to study the surface structure and morphology of the ultra-thin films and single crystal surfaces with a spatial resolution better than 10 nm, we propose having a Low-energy Electron Microscope (LEEM) facility at SINP during the XIIth plan period. Over last 3 years, we have gained immense experience in using this microscope (along with Photoemission Electron Microscope (PEEM)) at the Eletra synchrotron centre. We have even developed a novel way to image the surface antiferromagnetic domains (AFM-LEEM) and we would like to continue to develop this field and to study the magnetic domain structure of antiferromagnetic thin films and surfaces at SINP. Micro-LEED can be used to study the micro-structural aspects of the surfaces while the surface morphologies and dislocation networks can be studied by LEEM. This instrument will enhance the quality of our research substantially as now we will have a clear understanding of the microscopic surface structure and even study real-time dynamic processes at surfaces. Such phenomena include tomography, phase transitions, adsorption, reaction, segregation, thin film growth, etching, strain relief, sublimation, and magnetic microstructure. Currently, there is no LEEM microscope available in India and we can bridge this gap with the proposed LEEM facility at SINP.

**List of Important Publications (Since 2004):**

Theoretical Condensed Matter Physics Division

Permanent Members:

<table>
<thead>
<tr>
<th>Faculty members</th>
<th>Technical staff</th>
<th>Auxiliary/Admins. staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. K. Chakrabarti (Head, Sr. Prof.)</td>
<td>K. Das (Sci. Asst.)</td>
<td>A. K. Nayak (Officer)</td>
</tr>
<tr>
<td>A. N. Das (Sr. Prof.)</td>
<td></td>
<td>P. S. Bhattacharya (Supr.)</td>
</tr>
<tr>
<td>A. K. Sen (Prof.)</td>
<td></td>
<td>J. Mallick (Helper)</td>
</tr>
<tr>
<td>S. Yarlagadda (Prof.)</td>
<td></td>
<td>A. Ram (Helper)</td>
</tr>
<tr>
<td>S. N. Karmakar (Prof.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. K. Mohanty (Prof.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Basu (Prof.)</td>
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</tbody>
</table>


Major equipments and resources:
IBM-Power 5 Server, IBM Blade Server with 14 blades, Individual desktops.

RESEARCH ACTIVITY:

The activity of theoretical condensed matter physics (TCMP) division can be broadly classified under the categories (a) Physics of Strongly Correlated Systems and (b) Statistical Physics. The division has seven faculty members at present and each of them leads their respective group of students and post-doctoral fellows. The divisional activity also includes a centre for interdisciplinary research, namely the Centre for Applied Mathematics and Computational Sciences (CAMCS).

For a brief introduction to the present activities of the TCMP division and of the CAMCS, we give below a summary of the investigations carried out by the TCMP faculty essentially in the ongoing plan period (last few years). In the Appendix a list of publications from 2007 onwards is given.

Physics of Strongly Correlated Systems
(A. N. Das, S. Yarlagadda, S. N. Karmakar)

Atindra Nath Das’s group studied Bose-Einstein condensation in an optical lattice to obtain interaction-induced depletion of bose condensate. At strong interaction, the condensation temperature decreases with filling for \( n \geq 0.5 \), where \( n \) is the number of bosons per site, and it becomes zero at \( n = 1 \) [PRB 72, 094301 (2005)]. They studied the condensation of bosons in optical lattices under harmonic and quartic traps in different dimensions [EPJD 42, 309 (2007); ibid 47, 203 (2008)], as well as for anisotropic harmonic traps. Next, study of polaronic properties showed that site-diagonal disorder reduces the kinetic energy, Drude weight and spatial extent of the polarons. Increasing temperature also reduces the preceding quantities for weak and intermediate coupling. For strong coupling the effect of temperature is small but opposite [JPCM 20, 345222 (2008)].
Sachin Karmakar’s group, in the recent past, have focused attention on nanoscience. They have studied the effects of electron-electron interaction and disorder on persistent current in mesoscopic normal rings. They have shown that the long-standing anomaly between theory and experiment regarding the amplitudes of persistent currents in the mesoscopic rings can be resolved by including second-nearest-neighbor hopping integrals in the usual nearest-neighbor tight-binding Hamiltonian [J. Phys.: Condens. Matter, 18, 5349 (2006)]. Their exact numerical calculations revealed that electron-electron interactions produce anomalous Aharonov-Bohm oscillations in the persistent currents which corroborate the experimental findings [Phys. Lett. A, 332, 497 (2004)]. Karmakar et al., to understand the behavior of magnetic multilayers, obtained the ground state phase diagram and magnetoconductance of such superlattices using Hubbard model [Phys. Rev. B, 75, 235117 (2007)]. In a recent work they have proposed a magnetic quantum device which acts as a spin filter [Phys. Lett. A, 374, 1522 (2010)].

Sudhakar Yarlagadda et al. solved (using novel approaches) the long-standing problem of analytically obtaining the Peierls instability condition in the Holstein model [PRB, 75 035124 (2007) and PRB, 71, 235118 (2005)] by considering quantum phonons and predicted the phase diagram away from half-filling. They were the first to show, using the Peierls instability framework, that the ground state orbital ordering of LaMnO$_3$ can be explained using even weak electron-phonon coupling [PRB 80, 235123 (2009)]. Next, a new model was proposed to understand cooperative Jahn-Teller effect for quantum phonons. The model involves an enhanced next-nearest-neighbor (NNN) hopping and nearest-neighbor (NN) repulsion and predicts a dramatic first-order transition at a critical repulsion. Sudhakar’s group also derived an effective d-dimensional Hamiltonian for a system of hard-core-bosons coupled to optical phonons in a lattice (arXiv:0907.3543). They demonstrated that the presence of NNN hopping and NN repulsion leads to supersolidity.

**Statistical Physics**

(B. K. Chakrabarti, A. K. Sen, A. Basu, P. K. Mohanty)

Bikas K. Chakrabarti completed some major work and reviewed thoroughly their contributions in Quantum Annealing (with a student) and Failure Dynamics in Fiber Bundles (with a student and a collaborator) in two papers in Rev. Mod. Phys. (in 2008 and 2010). Two more reviews in Rev. Mod. Phys. have recently been commissioned; one on Quantum Critical Phenomena in Transverse Ising and XY models (with students and collaborators) and the other one is on Statistical Physics of Fracture, Friction and Earthquakes (with a student and collaborators). His group introduced the Kinetic Exchange Models of Markets; published a textbook on Econophysics (2010, Wiley-VCH) and he has been invited for a Monograph on Econophysics from Cambridge Univ. Press, Cambridge.

In Asok K. Sen’s group, studies on their semi-classical RRTN (Random Resistor cum Tunneling-bond Network, proposed in 1993-94) model continued [EPL 71, 797 (2005)]. These studies include (i) nonlinear response, (ii) breakdown, (iii) two early power-law dynamics (e.g., in many natural phenomena like earthquakes, some protein-folding dynamics); and (iv) very strong memory (associated hysteresis), useful for cryptography and natural computation (CFS, IEEE Comp Soc, Los Alamitos, CA 2008). An extensive pedagogical review on the RRTN, with many open problems, has recently been written in Quantum and Semi-classical Percolation and Breakdown in Disordered Solids, Lect. Notes in Phys., Vol-762 (Springer, Berlin, 2009), edited by A. K. Sen et al.

Abhik Basu’s group, inspired by the physics of magnetohydrodynamics (MHD), proposed a simplified coupled Burgers-like model in one dimension (1d) to describe 1dMHD. In addition
to MHD, this model serves as a 1d reduced model for driven binary fluid mixtures. In particu-
lar, they determine the scaling exponents and the amplitude-ratios of the relevant correlation
and collaborators) are investigating the statistical properties of homogeneous and isotropic
three-dimensional binary fluid turbulence and the role of topological defects in determining the
statistical properties of two-dimensional nonequilibrium systems. They are also looking at the
macroscopic effects of coupling driven directed motion (simple nonequilibrium dynamics) with
diffusive motion in a 1d model proposed by them. In another work, beginning with biophysical
motivations, they proposed two-dimensional coarse-grained equations for active gel systems as
generic models for cytoplasmic dynamics in cells.

of non-equilibrium lattice models. The method has been used successfully in Extended Katz
Lebowitz Spoon model, Restricted Asymmetric Exclusion Process [PRE, 2008], exclusion pro-
cess with internal degrees of freedom [arXiv:2010], Tonks gas and DNA denaturation transition
(working) to reveal novel spatial correlations. The group is trying to understand absorbing
state phase transitions which do not belong to the generic Directed Percolation universality
class. In another recent work they showed that random walk in a bounded domain can produce
regular patterns, and the non-trivial distribution of returning walkers on the repeated pattern
is caused by hidden non-linearity [EPL 2009]. Recently Mohanty and co-workers have studied
[OJB, 2009] the micro RNA (miRNA) co-target network and claim that miRNAs deregulate
gene expression group-wise (contrary to the current view, i.e., individual regulation). This
would help biologists to predict miRNAs those are possibly involved in any specific phenotype.
The group is planning to set up a miRNA cluster data base at SINP.
APPENDIX

List of publications of TCMP members (2010-2007):

2010


2009


44. Why only few are so successful ?, P. K. Mohanty, Physica A 384, 75 (2007)


NAME: Bikas K. Chakrabarti (DOB: 14.12.'52)

EDUCATIONAL BACKGROUND:
B. Sc. (1971), M. Sc. (1973; degree in 1975 due to Political disturbances),
Ph. D. (1979): all from Calcutta University; Post-Doc at Oxford University (1979-'80)
and Cologne University (1980-'81)

Academic profile including earlier appointments, awards etc

ACADEMIC PROFILE INCLUDING EARLIER APPOINTMENTS:
Chakrabarti joined the faculty of the Saha Institute of Nuclear Physics in 1983, where he presently is a
Senior Professor. He is also a Visiting Professor of Economics in Indian Statistical Institute. He also visited
many esteemed Universities and Laboratories as Invited Visiting Scientist; also as Professeur Invité in

AWARDS etc:
• Young Scientist Award of Indian National Science Academy, New Delhi (1984)
• Shanti Swarup Bhatnagar Award of the Council of Scientific and Industrial Research, India (1997)
• Fellow, Indian Academy of Sciences, Bangalore (Elected, 1997)
• Fellow, Indian National Science Academy, New Delhi (Elected, 2003)
• Outstanding Referee (Lifetime) Award of the American Physical Society (2010)

Essential strength of research/development output

RESEARCH/DEVELOPMENT:
The research activity of Chakrabarti is mainly focused on statistical physics, condensed matter physics,
computational physics, and their application to social sciences. He is specifically interested in
• Fracture, Breakdown and Earthquake,
• Statistics of Polymers in Random Media,
• Dynamic Hysteresis and Transitions under Periodic and Stochastic Fields,
• Quantum Phase Transition, Quantum annealing & Computation in Spin Glass Models
• Physical and Computational Models of Mind and Brain
• Econophysics and Sociophysics

He has published many papers, reviews (and three books) in Physics, Economics and interdisciplinary
journals, including three reviews in Reviews of Modern Physics (Am. Phys. Soc.). He is an author of about
160 scientific papers in leading international scientific journals. According to Web of Science, his papers
have received more than 1700 citations and his Hirsch index is 23.

Future research/development plan

Apart from developing further the studies on Fracture/Breakdown properties of disordered solids and on
Quantum Glasses/Computation, Chakrabarti intends to develop (along with others in the country) a
strong group in Econophysics research in India. Econophysics researches of the SINP group, in particular,
is quite well appreciated internationally & some of the recent citations include (mention of "Kolkata
School" here might be noted!):
121-125, incorporating 2 of SINP group, in an Editorial Choice-list of 21 "exemplifying pioneering"
publications (earliest in 1872) in "Economy & Political Economy";
• Discussions on “pioneering” papers from "Chakrabarti’s research group" (p 187; pp 185-206) in
 Applied Partial Differential Equations (by Peter A. Markowich, DAMTP, Cambridge) Springer-verlag, Berlin (2007);
• Entry by economist J. Barkley Rosser, Jr. on “Econophysics” in The New Palgrave Dictionary of
Economics, 2nd Ed., Vol 2, Macmillan Publishers, NY (2008), pp 729-732, beginning with “According to Bikas Chakrabarti (...), the term ‘econophysics’ was neologized in
1995 at the second Statphys-Kolkata conference in Kolkata (formerly Calcutta), India ...",

List of important publications starting with recent publications

BOOKS:
• *Quantum Ising Phases & Transitions in Transverse Ising Models* (with A. Dutta & P. Sen), Springer-Verlag, Heidelberg (1996) [Second Edition, on request from the Publisher Springer, with new set of coauthors, J-I. Inoue & S. Suzuki; Contract signed last year].

REVIEWS:
• *Quantum Annealing and Analog Quantum Computations* (with A. Das), Rev. Mod. Phys. 80 (2008) 1061-1081
• *Dynamic Transitions and Hysteresis* (with M. Acharyya), Rev. Mod. Phys. 71 (1999) 847-863

LAST FIFTEEN (JOURNAL) PUBLICATIONS:
1. Name: Atindra Nath Das

**Educational qualifications:** M.Sc. (1974), Post M.Sc. (SINP, 1975-76),
Ph.D.(Phys.) (Calcutta University, 1982).

2. **Academic profile:**

<table>
<thead>
<tr>
<th>Position</th>
<th>Institution</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Fellow</td>
<td>SINP</td>
<td>1976-77</td>
</tr>
<tr>
<td>Lecturer</td>
<td>Kandi Raj College, Kandi</td>
<td>1978-85</td>
</tr>
<tr>
<td>Faculty member</td>
<td>SINP</td>
<td>1985 to date</td>
</tr>
<tr>
<td>Visiting Scientist</td>
<td>Universite Paris Nord, France</td>
<td>1990-91</td>
</tr>
</tbody>
</table>

3. **Essential strength of research/development output:**

In the field of structural phase transitions explained (i) the anomalous thermal expansion below the transition temperature ($T_c$), (ii) the change in the frequency and linewidth of an internal mode in some Fluotitanates near $T_c$, (iii) the pressure dependence of the thermal hysteresis as observed for many first order transitions.

The superconducting phase diagram and other relevant properties in the context of high-$T_c$ systems were studied using Hubbard and Holstein-Hubbard models. An improved pair tunneling model was developed. Phonon-based pairing using extended van-Hove singularity was also studied.

In the field of polarons a cross-over from small-to-large polaron crossover is shown in context to high-$T_c$ systems. A perturbation method based on modified Lang-Firsov phonon basis was developed for Holstein model to achieve very good convergence in almost entire region of coupling. Possibilty of a ferromagnetic insulating phase between ferromagnetic metallic and AF insulating phase is shown theoretically for manganites. The effect of dispersive phonons on the polaron crossover, the coherent and incoherent motion of polarons and the effect of disorder on polaronic properties were studied.

Bose condensation and specific heat were studied for Bosons in optical lattices under harmonic and quartic potentials for different dimensions. The effect of anisotropic trap has been found to be very interesting for optical lattices.

4. **Future research/development plan:**

(i) Anisotropic harmonic trap yields a very interesting density of states. We have planned to study various properties of fermions and mixture of fermions and bosons under such trap in presence of different interactions.

(ii) Planned for detailed exact studies of Holstein polarons including the effect of extended interaction, off-diagonal coupling, second nearest-neighbor hopping on size, effective mass, band dispersion, coherent and incoherent part of the kinetic energy, etc. of polarons.
5. **List of important publications starting with recent publications:**

Published Seventy eight (78) papers in reputed International Journals with the ‘sum of the times Cited’ = 678 and ‘h-index’ = 15. A list of some of the important papers is given below:


Asok K Sen

Education

- 1975  M.Sc. (Applied Mathematics) Jadavpur University, Kolkata, India
- 1982  M.S. (Physics) Ohio State University, Columbus, OH, USA
- 1985  Ph.D. (Physics) Ohio State University, Columbus, OH, USA

Career Profile:

- 1985 - 1986 Visiting Scientist, Cornell University, Ithaca, NY, USA
- 1986 - 1988 Post-doctoral fellow, N.C. State Univ., Raleigh, NC, USA
- 1988 - 1989 Post-doctoral fellow, Univ. of Houston, TX, USA
- 1989 - 1993 Reader, SINP, Kolkata, India
- 1993 - 1998 Assoc. Professor, SINP, Kolkata, India
- 1998 - 2007 Professor 'F', SINP, Kolkata, India
- 2007 - to date Professor 'G', SINP, Kolkata, India

Awards/Distinctions:

- Elected SENIOR ASSOCIATE of the Abdus Salam International Centre for Theoretical Physics (AS-ICTP), Trieste, Italy (1998 - 2004)
- Awarded a 3-years' Indo-Ukrainian Research Project (DST) on "Electronic Transport in Low-dimensional Meso/Nano-sized Quantum Systems" as Principal Investigator with co-investigator, Prof. Abhijit Mookerjee of SNBNCBS (2001).

Research Interests:


Selected publications:

1. New possibilities for obtaining a steep nonlinear current-voltage characteristics in some semiconductor structures
Sheka DI, Tretyak OV, Korol AM, Sen AK, Mookerjee A
INTERNATIONAL JOURNAL OF MODERN PHYSICS B, to be published (2010); available as arXiv:0905.2142v1 [cond-mat.mes-hall]
2. Two early-stage inverse power law dynamics in nonlinear complex systems far from equilibrium
Bhattacharya S, Sen AK
EUROPHYSICS LETTERS  Volume: 71, 797 (2005)

3. Frequency-dependent conduction in disordered composites: A percolative study
Sen AK, Gupta AK
PHYSICAL REVIEW B  Volume: 59, 9167 (1999)

4. The effect of non-linearity on one-dimensional periodic and disordered lattices

5. Amplification or reduction of backscattering in a coherently amplifying or absorbing disordered chain
Sen AK

6. Amplification and disorder effects in a Kronig-Penney chain of active potentials
Zekri N, Bahlouli H, Sen AK
JOURNAL OF PHYSICS-CONDENSED MATTER  10, 2405 (1998)

7. Aspects of dielectric breakdown in a model for disordered non-linear composites
Gupta AK, Sen AK
PHYSICA A247, 30 (1997)

8. Phase distribution in a disordered chain and the emergence of a two-parameter scaling in the
quasiballistic to the mildly localized regime
Sen AK
MODERN PHYSICS LETTERS B11, 555 (1997)

9. Backscattering and the decay of transmittance in a coherently absorbing or amplifying ordered chain
Sen AK
MODERN PHYSICS LETTERS B10, 125 (1996)

10. Conductance and its fluctuations in disordered systems: Scaling behavior from ballistic to localized
limit, Ganguli MN, Sen AK,
PHYSICAL REVIEW B52, 17342 (1995)
1. **Name:** SACHINDRA NATH KARMAKAR

2. Division: Theoretical Condensed Matter Physics Division
3. Present position and grade: Professor ‘G’
6. Employments: Permanent faculty of SINP since December 6, 1990
7. Academic recognitions: Enrolled as referee for the following journals
   - Physical Review Letters
   - Physical Review B
   - Journal of Physics: Condensed Matter
   - Journal of Physics A: Math & Gen
   - Journal of Optics: Pure & Applied Optics
   - New Journal of Physics
   - Physica B
   - Indian Journal of Pure & Applied Physics
8. Research output:
   - Articles in referred journals: 35
   - Total citation: 367
   - Average citation: 10.49
   - H-index: 10
9. Ph.D. students:
   - Completed: 3
   - Ongoing: 3
10. Other academic records:
    - Teaching regularly in the Post-M.Sc. Physics Course of SINP, and, the M.Sc. Physics course of Tripura University, Agartala and Bengal Engineering & Science University, Kolkata
    - Invited speaker in several conferences
    - Paper-setter and examiner for the M.Sc. examinations of Jadavpur University, Burdwan University, Tripura University and Bengal Engineering & Science University
    - Moderator in physics for the M.Sc. Physics Examination of Tripura University
    - Examiner of the Ph.D. thesis of seven students
    - Member, Selection Committee for Reader, Department of Physics, Tripura University, Agartala
    - Member, Ph.D. Committee in Physics, Tripura University, Agartala
    - Convener, International Workshop on the Physics of Zero and One Dimensional Nanoscopic Systems" held at SINP, Kolkata-700 064, India (February 1-9, 2006)
12. Highlights of research:

    Proposed a magnetic quantum device which acts as a spin filter. Exact numerical calculations revealed that in the mesoscopic normal metal rings electron-electron interaction produces anomalous Aharonov-Bohm oscillations in the persistent currents and these findings corroborate the experimental observations. Shown that the anomaly between theory and experiment regarding the amplitudes of the persistent currents in the
mesoscopic normal metal rings can be resolved by including second-nearest-neighbor hopping integrals in the usual nearest-neighbor tight-binding Hamiltonian. Obtained the ground state phase diagram and magnetoconductance of a one-dimensional Hubbard super-lattice at half-filling. Shown analytically that contrary to the common notion, the aperiodic Thue-Morse lattice supports only extended electronic eigenstates due to the presence of a new type of correlated disorder. Hierarchies of extended states appear in the quasiperiodic copper-mean and period-doubling lattices due to the existence of dimer-type correlation among the atoms. Introduced an exact renormalization group technique for finding the dynamic structure factor of the quasiperiodic lattices. Developed an exact decimation scheme for evaluating the eigenvalues and eigenfunctions of the quasiperiodic systems.

13. Future research plan:
Recently we have focused our interests on nanoscience, a rapidly emerging field that will most likely have a significant impact on the future of science and technology. We will study the conduction behavior of quantum dots, quantum wires, and molecular bridge systems. We will also work on spintronics and address spin transport problem in the presence of both Coulomb and spin-orbit interactions. The physics of graphene is very fascinating and we have an intention to study the behavior of massless Dirac fermions of graphene taking into account electron-electron interaction. We will also address the fundamental questions about metal-insulator transition in the presence of electron-electron interaction in disordered two-dimensional systems, quantum Hall conductance in heterostructures, and Kondo conductance in quantum dots. We will investigate the behavior of persistent current in quantum networks where interplay between disorder, electron-electron interaction and quantum coherence becomes very important.

14. List of important publications:

Educational Background:
1) Bachelors: IIT Kanpur (9.3/10.0 CPI)
2) MS & Phd (1989) in Cond. Mat. Phys. (5.96/6.0 GPA, Purdue Univ., USA)
3) Postdoc at MPI (Stuttgart) and NTT Basic Research Labs

Academic Profile (earlier appointments, awards, etc.):
1) Asst. Prof. at IIT Delhi; 1995–1996
2) Visiting faculty at Univ. of Houston for about 2 years (starting Jan. 2000)
3) Visiting Fellow at Univ. of Cambridge for 1 year (starting April 2007)
4) Visitor at KITP, Santa Barbara for 2 months (Oct. to Dec., '07) and for 6 weeks (May-June, '09)
5) Center for Applied Mathematics and Computational Science (CAMCS) was a result of my proposal being selected by the DAE-collective-vision-development-for-future meeting held at BARC.
6) David Ross Fellowship at Purdue Univ.; Certificates of Merit at IIT Kanpur; State Special Merit Scholarship, 1973-1980; and National Science Talent Scholarship in Mathematics.
8) Referee for PRL, PRB, etc; Chaired sessions in intl. confs. (at IISc, TIFR, IMSc, SN Bose, IITK)
9) Gave more than 10 talks at international conferences and 10 talks at national confs.
10) Taught advanced courses in many-body physics, condensed matter physics, magnetism, etc.

Essential strength of research output:
We derived a quasiparticle pseudo Hamiltonian of an infinitesimally polarized electron gas which fully takes into account the many-body effects of both charge and spin density fluctuations. We calculated self-consistently Fermi liquid parameters like the effective mass, the effective g-factor, spin susceptibility in 2D systems and found fair agreement with experiments. My works on electron gas [see especially PRB 38 10966 (1988); PRB 40 5432, (1990); PRB 49 7887 (1994); PRB 49 14188 (1994); PRB 61 12556 (2000)] are well recognized and many distinguished scientists (including Nobel prize winners) cite them. In fact, in the book “Quantum Theory of the Electron Liquid” (Cambridge 2005) by G. F. Giuliani and G. Vignale, my works form a major theme of Chapter 8.

I had predicted a novel magnetization instability in the quantum Hall effect regime [PRB 44 13101 (1991)] and the proposed experiment (measuring diagonal resistivity) was carried out by K. von Klitzing et al. [PRB 47 4048 (1993)] and the instability was explicitly demonstrated. The prediction was also verified by Mike Pepper et al. [PRL 79, 4449, (1997)] through activation transport studies. Several Nobel prize winners (such as H. L. Stormer, D. C. Tsui, K. v. Klitzing, and H. Kroemer) and Buckley prize winners (such as J. K. Jain, A. H. MacDonald, and S. M. Girvin) cite this work.

We develop a framework to analyze the distribution of wealth in societies [Physica A, 353 529 (2005)] by using Boltzmann transport theory. We derive the distribution of wealth analytically by proposing a new trading model for the wealthy and obtain power-law (Pareto-like) behavior.

My paper on colossal magnetoresistance [PRB, 62 14828 (2000)] contains some interesting ideas.

Recently, (using novel approaches) we solved the long-standing problem of analytically obtaining the Peierls instability condition in the Holstein model [PRB, 75 035124 (2007) and PRB, 71, 235118 (2005)] and predicted the phase diagram away from half-filling. We corrected serious errors in the effective polaronic Hamiltonian derived by Hirsch and Fradkin [PRB 27, 4302 (1983)]. We showed that the ground state orbital ordering of LaMnO$_3$ can be explained using even weak electron-phonon coupling [PRB 80, 235123 (2009)]. We determined the orbital ordering by extending to the LaMnO$_3$ Jahn-Teller system our recently developed Peierls instability framework for the Holstein model.

I proposed a new model (arXiv:0712.0366) to understand cooperative Jahn-Teller effect. The model involves a next-nearest-neighbor (NNN) hopping and nearest-neighbor (NN) repulsion. The model predicts a dramatic first-order transition at a critical interaction strength.

We derived an effective d-dimensional Hamiltonian for a system of hard-core-bosons coupled to optical phonons in a lattice (arXiv:0907.3543). We demonstrated that the presence of NNN hopping and NN repulsion leads to supersolidity (i.e., homogeneous coexistence of CDW and a superfluid).
Future research plan:
1) Study the Hubbard-Holstein model so as to take into account both electron-electron interactions and electron-phonon interactions. Many strongly correlated systems have both interactions.
2) Study coexistence of diagonal long range order (CDW or SDW) and off diagonal long range order (superconductivity/superfluidity). Possible real system examples are dichalcogenides, helium-4, bismuthates, iron based superconductors, etc.
3) Study cooperative Jahn-Teller interaction in manganites. To understand orbital ordering along with other orderings (i.e., charge and spin) one needs to model cooperative electron-phonon interaction taking into account quantum phonons.
4) Study of entanglement around phase transitions. Entanglement may yield additional information beyond usual correlation functions and order parameters. Understanding entanglement is useful in non-equilibrium processes as well.
5) Econophysics of wealth distribution of nations and many-body correlations.

List of important publications:
I. CAREER PROFILE

• Ph.D. in August 2000 from Harischandra Research Institute, Allahabad, India • Postdoctoral Fellow, Tata Institute of Fundamental Research, Mumbai, India (Aug’00- Sept’02) • Feinberg Fellow, Weizmann Institute of Science, Israel (Sept’02- Sept’04) • Visiting Scientist, MaxPlank Institute (PKS), Dresden, Germany (Sept’04-Oct’05) • Associate Professor, Saha Institute of Nuclear Physics (Nov’05- Aug’08) • Professor, Saha Institute of Nuclear Physics (Aug’08- )

II. RESEARCH INTERESTS

I am a theoretical physicist working in the general area of non-equilibrium statistical physics and its application to some interdisciplinary science, like econo-physics and bio-physics. Summary of some of my selected research works follows. I would like to pursue future research in three important directions: i) Novel correlations in non-equilibrium steady states, ii) Absorbing state phase transitions beyond directed percolation (DP), and iii) microRNA co-target network and its implications.

Exact Solutions: Classical non-equilibrium systems do not ensure existence of the state functions like Hamiltonian and entropy as these systems are known to have non-zero current in the configuration space. Thus the steady states of these systems posses interesting and non-trivial correlations which are usually absent in equilibrium. One of my main research interest is to unfold these novel correlations. Recently we propose a method[14] which can provide an exact steady state and spatial correlations in a class of non-equilibrium models. The method has been used successfully in Extended Katz Lebowitz Spoon (EKLS) model, Restricted Assymetric Exclusion Process (RASEP)[11], Exclusion process with internal degrees of freedom[17], Tonks gas, DNA denaturation transition etc..

Explosive Percolation: In general, the nonequilibrium systems are modeled by the stochastic dynamics, which dictates the transition from one configuration to the other. Sometimes one encounters configurations which are absorbing: once in such a configuration the system never escapes. A transition from an inactive state to an active phase is usually termed as an active absorbing phase transition (AAPT), which generically belongs to the Directed Percolation (DP) universality class. Many other non-equilibrium phase transitions, like synchronization, roughening are known to be in the DP class. Recently a generic Langevin equation is proposed [Muñoz et. al., PRL 2003] to capture these seemingly different phenomena under one umbrella. These theories predict that such transitions are either continuous, belonging to the DP or Karder Parisi Zhang universality class, or it is discontinuous. Discontinuous transitions have been seen in the context of surface growth. In 2004, we demonstrated[20] the first order synchronization transition and recently we have been able to show that such first order transitions can appear as a bond percolation[18] in any dimension (including 1-d).

Sand pile models and DP: Sand-pile models (SPM) are prototype examples of self organized critiality. If sand grains are dropped at the the top of the conical sand-pile, grains flow down wards. The propagation of activity on the surface of a sand pile is similar to that of the percolation of infection in DP, however the universality classes of SPM are known to be different from DP. We claim that the SPM are unstable against certain specific kinds of perturbations called “stickiness” and generically flow to the robust DP fixed point.

AAPT beyond DP: It is important to note the following. Even though, the generic AAPT belongs to DP class, the queen of non-equilibrium phase transitions, there are several other AAPT which are different from DP. Departure from DP is a less understood area and I am trying to understand these systems by studying some simple tractable models. Recently we introduce a model, namely RASEP[11], where hard core particles on a ring can move to one of the neighbouring vacant sites when the other neighbour is occupied. This model shows AAPT different from DP at density \( \rho = 1/2 \). The spatial correlations and the exact critical exponents are obtained analytically. The orderparameter of the model satisfies the requirements of DP-conjecture and we are trying to reason why this class of models shows non-DP behaviour.

Econo-physics: A year old law in economics, namely Pareto law, states that the wealth of rich people in any society follows a power-law distribution, which is modelled recently [Chatterjee et. al., Physica A 2004]. We could solve these models exactly[1] and show why one gets a power law distribution of wealth, even when agents interact through a conserving dynamics. In a later work, we emphasize that conservation of wealth is not an important criterion[8] in modelling Pareto distribution and...
show an explicit example of growing market which results in same phenomenon.

**Bio-physics** : In the application front we have modelled some of the biological systems. In a recent article we show how (1200 different kinds of) axons from the nasal epithelium of manals grow[10] in the postnatal stage and organize into fascicles in the absence of chemical guiding cues. In a different study we have modelled[4] the contractile ring that is formed by actines at the center of the cell during cell division and explained what makes the contractile ring to shrink.

**miRNA co-target network** : One of the main research activity which I am going to pursue in future is the microRNA co-target networks in Biology. microRNAs (miRNA) are small (about 23 base long) RNAs transcribed from the DNA. These miRNAs usually downregulate gene-expression by binding themselves to the UTRs of the miRNAs which translates into proteins. The diversity of miRNA targets offer enormous level of combinatorial possibilities by forming complex regulatory networks; constructed from the pairwise co-targets of miRNAs. It turns out that these relevant set of miRNAs form several small clusters. We claim that the miRNA clusters are building blocks of biological functions as many of these clusters are expressed maximally in specific tissues[13]. These miRNAs which are known to deregulate the genes involved in genetic diseases are also found to be cluster specific. Our recent study of 20 other animals also indicate that the clustering of miRNAs is a universal feature. Thus, we propose that the genes are better regulated by co-targeting of clusters of miRNAs, compared to individual regulation. We are planning some experiments here (SINP) to verify this.

We sincerely believe that these studies will help biologists in their search for miRNAs that target the genes involved in any specific phenotypes. Recently we started collaborating with U. Kolthur in TIFR, Mumbai on glucose metabolism. We are also trying to study (with A. Erzan and E. Gungor ITU, Istanbul) the the relevant set of miRNAs involved in Mediterranean Fever.

In all these studies the weighted network of miRNA pairs is created from the number of common targets (genes) they have. One can construct similar networks from the common disease or the common transcription factors and obtain miRNA clusters. It is important to compare these clusters obtained from different scenarios. We are planning to built a database of miRNA clusters at SINP.

[•] **Publications** :


**Older works (selected)**


• Name: Abhik Basu

• Education qualification:
  – Ph.D at Indian Institute of Science, Bangalore, India (2000).

• Professional experience (a) Professor F, Saha Institute of Nuclear Physics, Calcutta, India (February 2009 - present).
  (a) Associate Professor E, Saha Institute of Nuclear Physics, Calcutta, India (August 2006 - February 2009).
  (b) Distinguished PKS postdoctoral Fellow, Max-Planck-Institut f"ur Physik Komplexer Systeme, Dresden, Germany (January 2005 - August 2006).
  (c) Guest Scientist, Max-Planck-Institut f"ur Physik Komplexer Systeme, Dresden, Germany (September 2004 - December 2004).
  (d) Alexander von Humboldt Fellow
  (e) Fellow, Poornaprajna Institute of Scientific Research, Bangalore (September 2002 - September 2005).
  (f) Guest Scientist at the Hahn-Meitner Institute, Berlin, Germany, from July 1 to September 30, 2001, and from March 28 to May 22, 2002.
  (g) Poornaprajna Research Scientist, working as a post-doctoral fellow at the Department of Physics, IISc, Bangalore, India (1999- August 2002).

• Research Strength
Our research strength has been the broad areas of physics of systems driven out of equilibrium. All natural systems are nonequilibrium systems (typically) due to external energy supplies. We have studied such systems from the perspectives of nonequilibrium statistical mechanics. In particular, we have been involved in problems of statistical mechanics of driven, dissipative system such as fluid and magnetohydrodynamic (MHD) turbulence, and surface growth models. We have investigated scaling properties of different time independent and time dependent correlation functions of the relevant dynamical variables in the models. More recently, we have been interested in theoretical studies of driven soft-matter and biological systems, e.g., dynamics of semiflexible polymers under various kinds of fluid flows, mode-coupling theories of self-diffusing colloids interacting via a pairwise potential and the dynamics of visco-elastic active gels.

• Future Research Plan
In the near future we intend to focus on the nonequilibrium dynamics and phase transitions of two-dimensional (2d) systems. Equilibrium systems in 2d do not undergo usual order-disorder phase transitions, which can be explained within the
framework of the Mermin-Wagner theorem. In contrast to more conventional phase transitions in 3d, phase transitions in 2d are induced and controlled by topological defects. Classical 2d XY is a simple model exhibiting such topological phase transitions. Compared to the extensive studies of 2d phase transitions, such studies for nonequilibrium are still in their infancies. Biological and soft-matter systems provide natural examples where nonequilibrium analogues of equilibrium topological phase transitions are expected to be of importance. Specific examples include dynamics of cortical actins in eukaryotic cells, fluctuation properties of biomembranes, dynamics of shear induced melting of laser induced freezing etc. Our preliminary studies in the context of simple model systems already yield qualitatively new results in the form of continuously varying universality classes. We believe studies of realistic 2d systems of biological or soft-matter origin, should shed further light on the physics of collective phenomena in such systems and will yield results all of which may be tested in controlled experiments.

• Head, Max-Planck Partner Group at the Saha Institute of Nuclear Physics, Calcutta, India, supported by the Department of Science and Technology (India) and Max-Planck-Society (Germany) for a period 2009-2011.

• List of important publications
Applied Materials Science Division

Permanent Employees

<table>
<thead>
<tr>
<th>Scientific</th>
<th>Technical</th>
<th>Administrative/Auxiliary</th>
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| Alokmay Datta  
Professor & Head | Avedananda  
Bhattacharya  
Scientific Assistant | Suvashis  
Sanyal  
Superintendent |
| Abhijit Sanyal  
Scientist | Shyamaprasad  
Mullick  
Technician | Provash  
Haldar  
Helper |
| Madhusudan Roy  
Associate Professor | | |
| Supratic Chakraborty  
Associate Professor | | |

PhD Students: Smita Mukherjee, Nupur Biswas

Major Equipments and Resources:

1. Thermogravimetry Analyzer
2. Differential Scanning Calorimeter
3. Semiconductor Parameter Analyzer and Probe station
4. Fourier Transform Infrared Spectrometer (Mid and Far Infrared)
6. Spinning Drop Tensiometer
7. RFand DC Magnetron Sputter Deposition Unit

Research Activities:

This division has been created in May 2010 from the erstwhile Microelectronics Division, inducting Prof. Datta from the Surface Physics Division, with the following research areas

1. Micro-electronics and ultrasonic device research – Madhusudan Roy and Supratic Chakraborty
2. Image processing and hardware development – Abhijit Sanyal
3. Nanomaterials – Alokmay Datta, Madhusudan Roy and Supratic Chakraborty
4. Soft materials and nano-bio interfaces – Alokmay Datta
Publications

2010


2009


2008


Name: Alokmay Datta

Educational background
1978  B.Sc. (Physics Hons)  Calcutta University (St Xavier’s College)
1980  M.Sc. (Physics)  Calcutta University
1982  Post M.Sc.  Saha Institute of Nuclear Physics
1989  Ph.D. (Physics)  Calcutta University

Official Positions
1981-82  Post M.Sc. Associate, Saha Institute of Nuclear Physics
1982-89  Research Fellow, Solid State and Molecular Physics Division, Saha Institute of Nuclear Physics
1990-94  Lecturer, Solid State and Molecular Physics Division, Saha Institute of Nuclear Physics
1994-2000  Reader, Solid State and Molecular Physics Division and Surface Physics Division, Saha Institute of Nuclear Physics
2000-04  Associate Professor, Surface Physics Division, Saha Institute of Nuclear Physics
2004-07  Professor F, Surface Physics Division, Saha Institute of Nuclear Physics
2007-10  Professor G, Surface Physics Division, Saha Institute of Nuclear Physics
Present  Professor G and Head, Applied Material Science Division, Saha Institute of Nuclear Physics

Awards
1998-2000  National Science Foundation Postdoctoral Fellow, Northwestern University, USA
2008-09  Japan Society for Promotion of Science Fellow and Visiting Professor, Kyoto University, Japan
2006-date  Fellow, West Bengal Academy of Science and Technology
2009  Eminent Materials Scientist of the Year, Institute of Engineers (India)

Essential strength of research/development output
1. Understanding the role of metal ions on two-dimensional nanoscale organization of organic molecules in monolayers and multilayers, with following major results:
self-assembly of two-dimensional lattices of metal ions at air-water interface (b) Spontaneous evolution of bi-molecular layer on water surface with membrane-like mechanical response and drastic reduction of surface tension (c) Near perfect growth of multilayer structures (d) Non-covalent, ‘weak’ bonding deciding structural evolution over polar or covalent bonding

2. Understanding the effect of confinement of simple and complex fluids to nanoscales, with following major results:
(a) Emergence of spontaneous one-dimensional order (b) Emergence of a short-range intermolecular repulsive potential in complex fluids (c) Change in molecular conformation in complex fluid due to confinement (d) Control of two-dimensional surface aggregation and thus nanoparticle growth through degree of fluid confinement

3. Observation of non-extensive dynamics in molecular systems
4. Observation of cell wall-nanoparticle interaction in viral envelopes, with specific biological functionalities
5. Development of Beamline BL-13 at the INDUS-2 Synchrotron at RRCAT, Indore (team member)

Future research/development plan
1. Understanding the role of Large Amplitude Motions in the dynamics of biological systems, nano-bio composites and non-extensive molecular systems
2. Understanding the competition between different short-range and long-range forces in complex fluids under confinement
3. Understanding the phase transitions in the two-dimensional lattices of metal ions self-assembled in presence of organic monolayers

Development
1. Radiation-pumped Imaging Ellipsometry and Microscopy
2. Surface Acoustic Wave Microscopy
3. Imaging Ellipsometry at the BL-13 beamline

List of 10 important publications (last 5 years)
1. Name, Passport size photograph and educational background:
   a. Name : Supratic Chakraborty
   b. Educational Qualifications : Ph. D. (Physics)
   c. Educational background : B.Sc. (Burdwan Univ.), M. Sc. (Banaras Hindu Univ.), Ph. D. (Kalyani Univ.)

2. Academic profiles including earlier appointments and awards etc. :
   b. Invited by the Department of Electrical and Electronic Engineering, the University of Hong Kong, Hong Kong for three months in the year 2006.
   d. Employed as a Research Fellow in the Microelectronics Division of the School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore.
   e. Employed as a Research Assistant – I in the Department of Electrical and Electronic Engineering, Hong Kong University, Hong Kong.
   f. Employed as a Research Assistant – II in the Department of Electrical and Electronic Engineering, Hong Kong University, Hong Kong.
   g. Earlier worked as a Research Assistant – II in the Department of Electrical and Electronic Engineering, Hong Kong University, Hong Kong.
   h. Visited as a Research Student to the Department of Electrical Engineering. Tokyo Denki University, Tokyo, Japan for six months.

3. Essential Strength of Research and development output:

   The account on strength of research and development output, after the appointment in the grade Reader – D in the Microelectronics Division of the Saha Institute of Nuclear Physics, has been described in brief in the following. The strength and justifications of submitting such a proposal during XI-th five year plan period is also mentioned below.

   After joining the Institute, it is observed that a project on medical imaging and related image processing techniques, already approved by the Department of Atomic Energy, was being carried out by the Divisional members in the X-th plan period. One direction of the project was dealt with the improvement of quality of ultrasound images, grabbed through conventional ultrasound scanner, through various algorithms. Another dimension of the project was development of ultrasound probe. Considering the expertise in the field of VLSI design and fabrication, the direction in developing the ultrasound probe was preferred. Accordingly, in Vision 2004, a concept of development of Micro Electro Mechanical System (MEMS)-based ultrasound transducer and sensor were proposed. Considering the then on-going projects, personal skill and profession and objectives of the National Science and Technology Policy and its expectation from the Indian Scientific Community working with the academic and R&D Institutions in India, stated below, the job of MEMS-based transducer design and fabrication of ultrasound transducer was decided to be taken up. The National Science and Technology Policy, adopted in 2003, mentioning role of all academic and R&D Institution, states –

   “To provide necessary autonomy and freedom of functioning for all academic and R&D institutions so that an ambience for truly creative work is encouraged, while
ensuring at the same time that the science and technology enterprise in the country is fully committed to its social responsibilities and commitments.”

Setting a target for the betterment of mankind and self-reliance for indigenous technological development, such a challenging job was taken up. The objective of the project was to deliver a small linear array-based capacitive transducer, replacing conventional piezo-electric-based transducer with many technical and operational advantages. Apart from this job, the temperature dependent ultrasound attenuation properties of agarose, a material widely used for preparing tissue mimicking phantoms, was studied in detail.

The approved project on development of ultrasound probe was taken up in the XI-th five-year Plan period. The design of the transducer was completed. Semiconductor grade device fabrication facilities are being established comprising of different instruments and a clean room. The process of creating the facilities will be completed by July 2010. The fabrication process will start with a month or so after installation of the essential instruments.

4. Future Research/Development plan:

An appraisal on SiC-based particle counter has already been accepted by the Specialist Group during the mid-term appraisal presentation. Since, most of the instruments are common to both the projects, such a project on development of SiC-based particle counter may be submitted in the XII-th plan period.

5. List of important publications starting with recent publications:

i. Rod-like ferrites obtained through thermal degradation of a molecular ferrimagnet
   A. Bhattacharjee, D. Roy, M. Roy, S. Chakraborty, A. De, J. Kusz, W. Hofmeister

ii. Density profiles and electrical properties of thermally grown oxide nanofilms on p-type 6H-SiC(0001)
    S. Hazra, Supratic Chakraborty and P. T. Lai

iii. Interface properties of N2O-annealed SiC MOS devices
    Supratic Chakraborty, P. T. Lai, J. P. Xu, C. L. Chan and Y. C. Cheng
    Solid State Electronics, 45, 471-474 (2001)

iv. Effects of nitridation and annealing on interface properties of thermally oxidized SiO2/SiC MOS system
    P. T. Lai, Supratic Chakraborty, C. L. Chan and Y. C. Cheng

v. New micro humidity field effect transistor sensor in ppm, level
    Supratic Chakraborty, Kazuhiro Hara and P.T.Lai
    Review of Scientific Instruments, 70, 1565 (1999)

vi. Moisture sensitive field effect transistors using SiO2/Si3N4/Al2O3 gate structure
    S. Chakraborty, K. Nemoto, K. Hara and P. T. Lai
    Smart Materials and Structures, 8, 274 (1999)
1. Name: **Madhusudan Roy**

**Educational background:** Passed undergraduate examination with honours in Physics from the Calcutta University in 1980 and postgraduate examination with electronics as special paper from the North Bengal University in 1983. Worked in the field of Experimental Plasma Physics and Gas Discharge Electronics as a research scholar and awarded Ph.D. from the North Bengal University in 1989.

2. Academic profile including earlier appointments, awards etc.

Joined the Indian Association for the Cultivation of Science (IACS) as Research Associate in 1988 and carried out research works in the field of Laser Raman Phonon Spectroscopy study of Photoreaction Dynamics in Organic Crystals. After a brief stay at IACS I took an appointment as a Lecturer in 1989 in a central university, North-Eastern Hill University. I was promoted to Senior Lecturer in 1994 and Reader in 1999. I spent some time as Visiting Scientist in Indian Statistical Institute and as Visiting Fellow in Mizoram University. Imparted teaching to the postgraduate students of Vidyasagar University as a guest faculty. In the year 2002 I joined the Microelectronics Division, Saha Institute of Nuclear Physics (SINP). By now I have completed more than twenty years in service.

3. **Essential strength of research/development output**

(a) In the first phase of implementation of the project entitled, “Development of Linear Ultrasonic Transducer Array for Medical Imaging and Related Image Processing Techniques(LINUT)”, approved by Department of Atomic Energy during current XI\textsuperscript{th} five year plan period, our objective i.e. setting up a Clean Room of Class 100 and Class 1000 surrounded by Class 10000 corridors for housing micro/nano fabrication facilities to carry out research and developmental activities is on the verge of completion. The total area of the clean room, considering the AC plant room, AHU room and utilities, is about 2100 sq ft. The detailed configurations of the major instruments, namely, mask aligner, PECVD, ICP – RIE, sputtering, plasma asher, electron beam evaporation etc. to be housed under micro/nano facilities are made and purchased procedure by our end are completed. They are all in shipping/inspection/installation stage.

A Capacitive Micro-machined Ultrasonic Transducer (CMUT) using finite element method (FEM)-based software, PZFlex has been designed. Since use of such transducer is for medical imaging, a damped output of the transducer necessary for pulse-echo mode is of our primary interest. The design also puts stress on its effective power output for better echo signal. It is observed that above properties of a transducer inherently depend on its membrane thickness, cavity thickness and pillar width supporting the membrane. Considering above objectives, the effect of membrane thickness, cavity thickness and pillar width on the transducer output has been studied and accordingly, physical dimension for MEMS based CMUT has been completed.

(b) Synthesis of nano-materials with molecular magnetic materials as precursor(under a collaboration project, entitled, INVESTIGATIONS INTO THE MULTIFUNCTIONALITY OF SOME MOLECULAR MATERIALS AND THEIR APPLICATION POTENTIAL and approved by the Department of Science and Technology, DST No. SR/S2/CMP-0036/2006):

In recent years the magnetic properties of nano-particles have attracted much interest due to their significance in both technological applications and fundamental research. Among different
synthetic routes for the preparation of metal oxide nano-particles thermal decomposition of metal complexes becomes increasingly important mainly due to the easy control of process conditions, particle size, particle crystal structure, and purity. We have carried out investigation on the thermal decomposition of an oxalate ligand based molecular ferrimagnet - \( \{N(n-C4H9)4[FeIIFeIII(C2O4)3]\} \). From the physical characterization (XRD, IR, SQUID) of the decomposed material it is found that the decomposed material is basically hematite along with a small fraction of magnetite. The iron oxides are composed of particles of mean crystallite size of 62 nm. This result is the first ever report of synthesis of nano-ferrites from a molecular magnet precursor. The result underlines a new route for synthesis of nano-materials with molecular magnetic materials as precursor.

(c) A systematic investigation has been initiated to identify the air pollutants and characterize their physical properties to understand how dangerous their effects could be on health and environment.

4. Future research/development plan

Amorphous silicon nitride (Si3N4) thin layers are the most widely applied dielectric layers in modern semiconductor devices. Excellent properties such as high chemical inertness, high thermal stability and corrosion resistance of silicon nitride make their extensive use in semiconductor industry. Moreover, Si3N4 also exhibits remarkable mechanical, optical and dielectric properties. Although there are several chemical vapor deposition (CVD) techniques, namely low pressure CVD (LPCVD), atmospheric pressure CVD (APCVD) and plasma enhanced CVD (PECVD) to grow the Si3N4 and SiO2 films, the PECVD technique has become very popular for its advantages in growth of amorphous SiO2 and Si3N4. Doping of p- and n-type dopants in silicon is also possible using the PECVD. The advantages of PECVD are: i) the growth may be carried out at lower temperatures (< 400°C); ii) control of residual stress of the grown film during deposition; iii) control of composition of the grown film by controlling the ratios of gases. The ultimate aim is to grow oxide and nitride films of silicon of very low residual stress using pulsed PECVD technique. Electrical and optical properties of the films will also be investigated.

5. List of important publications starting with recent publications

- M Roy and S Chakraborty, Polymer 46, (2005) 3535-37
NAME: ABHIJIT SANYAL
DATE OF BIRTH: 26th JULY, 1963
DIVISION: APPLIED MATERIAL SCIENCE
DESIGNATION: ENGINEER(G)

EDUCATIONAL QUALIFICATION AND EXPERIENCE: Btech in Electrical Engineering with more than 25 years experience in the area of Computer Engineering. More than 16 year experience in R&D work in Microelectronics, VLSI Design, Image processing, Programmable logic based system development etc.

INDUSTRIAL EXPERIENCE: Four years in Data General Corporation (U.S) subsidiary in India as Computer Engineer, Senior Computer Engineer and Computer Specialist, prior to joining SINP.

R&D ACTIVITIES IN SINP

DEVELOPMENT OF FRONT END COPROCESSOR ON FPGA FOR HIGH LEVEL TRIGGER(DHLT) PROJECT OF DIMUON ARM IN ALICE EXPERIMENT AT CERN

I have designed a Front end Coprocessor chip for the Dimuon High Level Trigger Project (DHLT) for the ALICE experiment at CERN. This design was based on Xilinx Field Programmable Gate Array (FPGA). This design has undergone extensive review and has been accepted by CERN. DHLT project was started to improve the selectivity of the central trigger and consequently to decrease the amount of data to be stored. In the DHLT architecture the data from the Dimuon Arm Detector gets transferred via Optical fiber into a ReadOut Receiver card (RORC) of the DAQ system. These data streams are also replicated into the HLT-RORC. The HLT-RORC has an embedded Field Programmable Gate Array (FPGA) co-processor which does all data intensive task for local pattern recognition. Also embedded in the architecture of the HLT-RORC is an external memory to be used as a storage of look-up tables and these can be used to perform a variety of application.

IMPLEMENTATION OF IMAGE PROCESSING ALGORITHMS ON RECONFIGURABLE HARDWARE FOR MEDICAL IMAGE PROCESSING.

Design of adaptive filter for speckle suppression in ultrasound images
Speckle noise poses a hindrance in visual assessment of the ultrasound images required for diagnosis purposes. I have designed a filter which employs an adaptive post filtering technique to remove the speckle noise by identifying the speckle corrupted pixels. The filter provides an useful tool to improve the image quality along with feature retention of the ultrasound medical images.

Improved edge detection using Canny edge detector employing exponential filter
Canny edge detector is one of the widely used edge detection tool employing gaussian filter for smoothing of the input image. This results in a loss of information for images with high mean gray
value which have slight variations. I have designed an exponential filter which is employed before the actual Canny edge detection process and it helps in information retention and better edge detection.

**FPGA implementation of binary threshold decomposition using multiprocessor architecture**

In an image, salt and pepper noise occurs due to randomly occurring white and black pixels which can be reduced using median filter. Direct median filtering of an image by sorting is very time consuming. I have implemented a filter using binary threshold decomposition technique which decomposes the pixel values into a set of binary sequences making the study of deterministic and statistical properties of median filters easier. I have also designed a hardware architecture of it for FPGA implementation.

**Design of Dual Asynchronous Receiver Transmitter (DUART) on FPGA with special Hamming error correction**

I have designed the above mentioned communication chip for system on Chip (SOC) application. This can help in flawless serial transmission of image data. This design will be incorporated as a part of embedded systems with real time set up, dedicated for medical image processing.

**FUTURE R&D PLANS**

- Development of an embedded platform for general image processing algorithm implementation.
- Real-time Operating System (RTOS) – embedded system integration for real-time Ultrasound image processing.
- Hardware implementation of developed medical image processing algorithms.
- Implementation of the developed algorithms on images, e.g.: ultrasound and Echo cardiograph images.

**PUBLICATION**