Project report –XI th plan:

1. Project: **Physics of complex system under extreme conditions (PIC no: 11-R&D-SIN-5.02-0100)**
2. Sanction reference no.**15/4/2007-R&D-II /3406 dt 23May'2008**
3. Brief report about achievement /highlights with reference to programme as proposed in XIth plan DPR. **(Annexure- I):**
4. List of major capital equipment's procured as proposed in DPR and present status.

   The following major capital Equipment's have been procured and Installed successfully.

   a. Atomic Force Microscopy-Magnetic Force Microscopy, Mask aligner
   b. DC-RF sputtering under high vacuum (UHV system)
   c. XRD at low temperature with 18KW power
   d. Cryostats for Physical property measurements system (5 T- 9T)
   e. Room Temp. Bore magnet (9 T) with VTI
   f. Furnaces- small and medium
   g. Field Sweep magnet for NMR (9T)
   h. High pressure – Hydrostatic- 3GPa (max.) at LT, Dimond Anvil Cell
   i. SQUID-VSM
5. **Reasons for not achieving the target as fixed for the project (any major deviation)**

   Scanning electron microscope with elemental analysis could not be procured for technical reasons and as and when required this measurements have been carried out in collaboration with other institute. Some of the experiments are possible with newly installed 300TEM equipment at SINP.
6. List of publications year wise (2007-12). **Enclosed in Annexure II**
7. Details of Overall expenditure :

   Consolidated expenditure statement : 1-Apr-2007 to 10-Sep-2013
   Project: Physics of Complex System Under Extreme Conditions
   Ref: (PIC no: 11-R&D-SIN-5.02-0100 sanction letter ref: no15/4/2007-R&D-II /3406 dt 23May'08)

Annexure I

Project (XIth plan): Physics of complex system under extreme conditions
(PIC no: 11-R&D-SIN-5.02-0100 sanction letter ref: no15/4/2007-R&D-II/3406 dt. 23 May 2008)

Salient Scientific/Technical features of the Project as in DPR:

[1] Experimental investigations of super-hard materials, composite magnets, negative TCR & negative thermal expansion materials at high pressure with a focus on isotropic cubic materials. Experimental investigations of exchange coupling between grains and dipoles in composite magnets consisting of soft and hard phases for high energy product, $(BH)_{max}$, material.

[2] Microwave absorption properties of one-dimensional materials and their composites and subsequent development of electromagnetic interference shields

[3] Time dependent universal conductance fluctuation for interacting electronic systems

[4] Magnetism in linear chain spin trimers/group IV clathrates

[5] Physics of transition metals focusing on rare earth containing systems for giant magnetostriction, spin relaxation at the ferrmagnetor-superconductor interface Magnetostriction, thermal expansion and thermal conductivity including single crystal – super conducting materials

[6] Magnetoresistive and Magnetocaloric materials focusing on rare earth compounds.

[7] Theroretical studies in relevance to above focusing on Polaron Physics and Manganites, Bose Einstein Condensation (BEC) and Organic Superconductivity, Nanoscopic and Mesoscopic Systems, Tools for Many-body Problems.

The following are the specific programmes covering the above mentioned research area as proposed in the project.

1. Programmes focusing on Intermetallic alloys:

1.01 Intriguing properties of cubic intermetallic inverse perovskite containing Rare-earths and low-Z elements excluding oxygen
1.02 Experimental investigations of exchange coupling between grains and dipoles in composite magnets consisting of soft and hard phases for high energy product, (BH)max, material.
1.03 Effect of Si/Ge ratio on resistivity and thermoelectric power in $Gd_5Si_xGe_{4-x}$ magnetocaloric compounds:
1.04 Electronic transport minimum in $SmCuAs_2$ at low temperature and structural anomalies.
1.05 Large variations in the magnetic ordering behavior of $EuCu_2As_2$ with the application of external pressure and magnetic field.
1.06 ^{27}Al and ^{63}Cu NMR studies in polycrystalline sample of $CeCu_3Al_2$
1.07 ^{93}Nb NMR studies in single crystal $NbSe_2$
1.08 ^{75}As NMR study of oriented CeFeAsO and $CeFeAsO_{0.84}F_{0.16}$
1.09 Interplay between Co 3d and Ce 4f magnetism in CeCoAsO
1.10 Effect of Pt on the superconducting and magnetic properties of $ErNi_2B_2C$
1.11 Crystalline electric field effects in $PrNi_2B_2C$: Inelastic neutron scattering
1.12 ^{27}Al and ^{63}Cu NMR studies on intermetallic Kondo compound $CeCu_3Al_2$
1.13 ^{11}B and ^{195}Pt NMR study of heavy-fermion compound $CePt_2B_2C$
1.14 Comparative studies of magnetocaloric effect and magnetotransport behavior in $GdRu_2Si_2$ compound
1.15 Contribution of energy-gap in the ferromagnetic spin-wave spectrum on magnetocaloric parameters of $CeRu_2Ge_2$
1.16 Magnetoresistance studies on RPd_2Si (R = Tb, Dy, Lu) compounds
1.17 Giant magnetocaloric effect in antiferromagnetic $ErRu_2Si_2$ compound

2. Programmes focusing on oxide materials:

2.01 Magnetism of AFM Nano particles: Core-shell model and "Unconventional relaxation in antiferromagnetic $CoRh_2O_4$ nanoparticles"
2.02 Complex magnetic materials focusing on oxide nano particle in crystalline and amorphous samples
2.03 Suppression of spin-lattice coupling for the observation of Geometrically frustrated magnets in magnetic ordering and JT ion system- as an example $NiCr_2O_4$.
2.04 Glassy behavior of the phase segregated state of the layered perovskites $La_{2-x}Sr_xCoO_4$ ($1.1 \leq x \leq 1.3$)
2.05 Disordered spin liquid ground state of the Haldane gap compound $SrNi_2V_2O_8$
2.06 ^{31}P nuclear-magnetic-resonance in trimer spin chain compound $Ca_3CuNi_2(PO_4)_4$
2.07 Resistivity and ^{75}As nuclear magnetic resonance (NMR) of superconducting $CeFeAsO_{0.84}F_{0.16}$
2.08 NMR studies on LaCoPO
2.09 Studies of interfacial hydrogen bonding organic liquids, ethylene glycol [(CH2OH)2] and isopropanol [CH3CH(OH)CH3]
2.10 Anisotropic spin-fluctuations in SmCoPO revealed by ^{31}P NMR measurement
2.11 ^{31}P NMR studies on $Ca_3Cu_2Ni(PO_4)_4$
2.12 Magnetic, transport and thermal properties of $Sm_{0.52}Sr_{0.48}MnO_3$ single crystal
2.13 Transport, magnetic and thermal properties of Iron based superconductors
2.14 Anisotropic magnetic properties and giant magnetocaloric effect in antiferromagnetic $RMnO_3$ crystals (R = Dy, Tb, Ho, Yb)
2.15 Phase transition and magnetoelectronic phase separation in the $La_{1-x}Sr_xCoO_3$ ($0.10 \leq x \leq 0.33$) single crystals

2.16 Cluster glass behaviour in Co-substituted double perovskite Ca_2FeMoO_6
2.17 Spin glass like behaviour and magnetic enhancement in nanosized Ni-Zn ferrite system
2.18 Spin glass-like behaviour in Fe-rich phases of $Sr_2Fe_{1-x}Mn_xMoO_6$ $(0.1 \le x \le 0.4)$
2.19 Magnetic frustration effect in Mn-rich $Sr_2Mn_{1-x}Fe_xMoO_6$ system
2.20 Thermoelectric power of RFeAsO (R = Ce, Pr, Nd, Sm, and Gd)
2.21 Magnetism of crystalline and amorphous $La_{0.67}Ca_{0.33}MnO_3$ nanoparticles
2.22 Evidence of disorder induced magnetic spin glass phase in Sr_2FeMoO_6
2.23 Studies of the magnetic frustration effect in $Sr_2Fe_{1-x}Mn_xMoO_6$ $(0.1\le x\le 0.4)$ system
2.24 Exchange bias effect in $LaFeO_3$ nanoparticles
2.25 Electrical transport and magnetic properties of Co-substituted Ca_2FeMoO_6
2.26 Surface Spin Glass and Exchange bias effect in nano particles of $Sm_{0.5}Ca_{0.5}MnO_3$ manganites
2.27 Evidence of exchange bias effect and surface spin glass ordering in electron doped $Sm_{0.09}Ca_{0.91}MnO_3$ nanomanganites
2.28 Field induced ferromagnetic phase transition and large magnetocaloric effect in $Sm_{0.55}Sr_{0.45}MnO_3$ phase separated manganites:
2.29 Scaling of non-Ohmic conduction in strongly correlated systems
2.30 Evidence of a structural phase transition in superconducting $SmFeAsO_{1-x}F_x$ from ^{19}F NMR
2.31 NMR study of rare-earth transition metal oxypnictides
2.32 NMR study of spin-trimer compound $Ca_3CuNi_2(PO_4)_4$
2.33 Freezing/melting behavior of nanoconfined liquids probed by ^1H NMR
2.34 NMR study of rare-earth transition metal oxypnictides
2.35 The metal–insulator transition in nanocrystalline $Pr_{0.67}Ca_{0.33}MnO_3$: the correlation between supercooling and kinetic arrest
2.36 Inverse magnetocaloric effect in polycrystalline $La_{0.125}Ca_{0.875}MnO_3$
2.37 Magnetocaloric properties of nanocrystalline $La_{0.125}Ca_{0.875}MnO_3$
2.38 Low temperature conductivity in ferromagnetic manganite thin films: quantum corrections and inter-granular transport
2.39 Colossal enhancement of magnetoresistance in $La_{0.67}Sr_{0.33}MnO_3$ thin films: possible evidence of electronic phase separation
2.40 Colossal enhancement of magnetoresistance in $La_{0.67}S_{r0.33}MnO_3/Pr_{0.67}Ca_{0.33}MnO_3$ multilayers: Reproducing the phase separation scenario
2.41 Influence of charge ordering on magnetocaloric properties of nanocrystalline $Pr_{0.65}(Ca_{0.7}Sr0_{.3})_{0.35}MnO_3$
2.42 Magnetocaloric properties of nanocrystalline $Pr_{0.65}(Ca_{0.6}Sr_{0.4})_{0.35}MnO_3$
2.43 Observation of large low field magnetoresistance and large magnetocaloric effects in polycrystalline $Pr_{0.65}(Ca_{0.7}Sr_{0.3})_{0.35}MnO_3$
2.44 Low-temperature magnetotransport properties in granular ferromagnetic manganites
2.45 Unified description of spin-dependent transport in granular ferromagnetic manganite
2.46 Magnetic and transport properties of nanocrystalline $Nd_{0.5}Sr_{0.5}MnO_3$
2.47 Magnetocaloric effect in Ho_5Pd_2: Evidence of large cooling power
2.48 Magnetotransport properties of nanocrystalline $Pr_{0.65}(Ca_{1-y}Sr_y)(_{0.35})MnO_3$ (y similar to 0.4,0.3): Influence of phase coexistence

3. Other related programmes:

3.01 Soft condensed Matter
3.02 Studies on broadband microwave absorption and dielectric properties of low-d materials and their composites and development of electromagnetic interference (EMI) shields.
3.03 Microwave spectroscopy studies
    3.03.1 Conventional microwave and millimeterwave spectroscopic studies of organic molecules of chemical and astrophysical interest
    3.03.2 Millimeter-wave spectroscopic studies of DC discharge produced stable and transient molecules of chemical and astrophysical interest
    3.03.3 Studies on broadband microwave absorption and dielectric properties of low dimensional materials.

4. Programmes focusing on theoretical studies:

4.01 Studies of nonequilibrium continuum model systems using field theoretic tools with an aim to uncover their universal scaling properties and their dependences (if any) on the nature and strength of the external drives.

4.02 Studies of statistical mechanics aspects of fluid and magnetohydrodynamic turbulence with a focus to find the universal multiscaling exponents and setting up the exact hierarchical relations among the structure functions of various orders

4.03 Studies of active or “living matter” in terms of continuum descriptions for driven nematic or polar ordered systems to understand a coarse-grained picture of several cell biology experiments concerning fluctuations in the cytoplasm-cell membrane combine.

4.04 Studies of simple one-dimensional discrete lattice-gas based driven models executing exclusion process using mean-field theories and Mon-Carlo simulations to explicitly calculate the nonequilibrium steady states in simple systems and contrast them with corresponding equilibrium systems.

4.05 Exact studies on the properties of Holstein polarons and JT polarons: effect of disorder and second nearest-neighbor hopping.

4.06 Stability of Holstein and Frohlich bipolarons in presence of extended electron-electron interaction.

4.07 Fermions in optical lattices under anisotropic harmonic trap.

4.08 Bose condensation and other thermodynamic properties of Bosons in optical lattices under harmonic and quartic traps and the effects of Aubry potential on properties of lattice bosons.

4.09 Physics of Fracture: Study of earthquake dynamics & models

4.10 Study of Quantum Annealing and thermal annealing for new generation of quantum (annealing) computers

4.11 Econophysics: A new area of research has been developed for the first time as an interdisciplinary subject of Economics and Statistical Physics.

4.12 An exact solution of the CCM model and explained the origin of Pareto’s law have been provided.

4.13 A method has been proposed to obtain steadystate weights and the spatial correlations exactly in a class of non-equilibrium models.

4.14 Studies of Protein production in the cell is inhibited by micro RNAs.

4.15 Studies and development of APT models.

4.16 Studies of coexistence of superconductivity and charge-density-wave using Hubbard-Holstein model in one-dimensions.

4.17 Studies of cooperative electron-phonon interaction physics in one-dimensions.

4.18 Studies of supersolidity for a system of hard-core-bosons coupled to optical phonons in a lattice.

4.19 Studies of the ground state orbital ordering of $LaMnO_3$ at weak electron-phonon coupling.

4.20 Analytically study of the Peierls instability condition in the Holstein model.

Annexure II

List of publications- Experimental studies

2007

1. Microwave spectrum of trans 3-fluorophenol in excited torsional states: A. I. Jaman, J.Mol.Spectrosc. **245**, 21 (2007).
2. Millimeterwave spectrum of ICN, a transient molecule of chemical and astrophysical interest: A. I. Jaman, J.Phys: Conference Series **80**, 012006 (2007).
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4. 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).
5. Magnetization and ^{63}Cu NMR studies on granular FeCu alloys: B. Bandyopadhyay, B. Pahari, and K. Ghoshray, Phys. Rev. **B76**, 214424 (2007).
6. ^{27}Al NMR in grain aligned $PrNi_2Al_5$: A.Ghoshray, R.Sarkar, B.Pahari, K.Ghoshray and B. Bandyopadhyay, J. Mag. Magn. Mat. **310**, 371 (2007).
7. Crystal field calculation of Pr^{3+} in orthorhombic $PrNi_2Al_5$ from ^{27}Al NMR Knight shift: R. Sarkar, A. Ghoshray and K. Ghoshray, J. Phys. Condens. Matter **19**, 086202 (2007).
8. Impurity induced antiferromagnetic order in Haldane gap compound $SrNi_{2-x}Mg_xO_8$: B. Pahari, K. Ghoshray, A. Ghoshray, T. Samanta and I. Das, Physica **B395,** 138 (2007).
9. ^{31}P NMR of trimer cluster compound $Sr_3Cu_3(PO_4)_4$: M. Ghosh, K.Ghoshray, B. Pahari, R. Sarkar and A. Ghoshray, J. Phys. Chem. Solids **68,** 2183 (2007).
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12. Magnetocaloric effect in Ho_5Pd_2: Evidence of large cooling power: Tapas Samanta, I. Das and S. Banerjee; Appl. Phys. Lett. **91**, 082511 (2007).
13. Magnetotransport properties of nanocrystalline $Pr_{0.65}(Ca_{1-y}Sr_y)_{0.35}MnO_3$ (y ~ 0.4,0.3):Influence of phase coexistence: Anis Biswas and I. Das, Appl.Phys. Lett., **91**, 013107 (2007).
14. Magnetic and transport properties of nanocrystalline $Nd_{0.5}Sr_{0.5}MnO_3$: Anis Biswas and I. Das; Journal of Applied Physics **102**, 064303 (2007).
15. Unified description of spin dependent transport in granular ferromagnetic manganites: Soumik Mukhopadhyay and I. Das Phys. Rev. **B76**, 094424 (2007).
16. Low temperature magnetotransport properties in granular ferromagnetic manganites: Soumik Mukhopadhyay and I. Das; Europhys. Lett **79**, 67002 (2007).
17. 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 and A. De; Phys. Rev. **B75**, 073202 (2007).
18. Silica Encapsulated Ni Nanoparticles: Variation of Optical and Magnetic Properties with Particle Size, Soumen Das, Subhendu K. Panda, Prithiwish Nandi, Subhadra Chaudhuri, Abhishek Pandey and R. Ranganathan; J. Nano science and technology **7,** 4447 (2007).
19. Unconventional relaxation in AFM $CoRh_2O_4$ nano particles, R. N. Bhowmik, R. Ranganathan; Phy. Rev. B**75,** 012410 (2007).
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23. Relaxation dynamics in small clusters: A modified Monte Carlo approach: Barnana Pal, J. Computational Phys., **227,** 2666 (2008).
24. Modification of the spin state in $Sm_{0.52}Sr_{0.48}MnO_3$ by external magnetic field, P. Sarkar and P. Mandal, Appl. Phys. Lett. **92**, 052501 (2008).
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33. Normal-state transport properties of PrFeAsOF superconductor: D. Bhoi, P. Mandal, and P. Choudhury: Physica **C468**, 2275 (2008).
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40. Time-resolved Fourier transform emission spectroscopy of laser ablation products: K. Kawaguchi, N. Sanechika, Y. Nishimura, R. Fujimori, T. N. Oka, Y. Hirahara, A. I. Jaman and S. Civis. Chem. Phy. Lett. **463**, 38 (2008).
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60. ‘Phase diagram of one-dimensional Hubbard-Holstein model at quarter-filling’, Sahinur Reja, Sudhakar Yarlagadda, Peter B. Littlewood, Phys. Rev. B, 84, 085127 (2011).

2012

61. N. Sarkar and A. Basu, Continuous universality in nonequilibrium relaxational dynamics of $O(2)$ symmetric systems, *Phys. Rev. E*, **85**, 021113, (2012).
62. A. Basu and J. K. Bhattacharjee, Fluctuating hydrodynamics and turbulence in a rotating fluid: Universal properties, *Phys. Rev. E* **85**, 026311 (2012).
63. Fermions in anisotropic harmonic trap, A. N. Das and S. Sil, Physics Letters A **376**, 1698 (2012).
64. Stability of Holstein and Frohlich bipolarons, Monodeep Chakraborty, B. I. Min, A. Chakrabarti and A. N. Das, Phys. Rev. B **85,** 245127 (2012).
65. Lattice bosons in a quasi-disordered environment, R. Ramakumar and A. N. Das, Physica A, communicated in 2012 (accepted).
66. Statistical physics of fracture, friction and earthquake, H. Kawamura, T. Hatano, N. Kato, S. Biswas and B. K. Chakrabarti, Rev. Mod. Phys. 84 (2012) 839-884.
67. Continuous transition of social efficiencies in the stochastic-strategy minority game, S. Biswas, A. Ghosh, A. Chatterjee, T. Naskar and B. K. Chakrabarti, Phys. Rev. E 85 (2012) 031104.
68. Phase transitions in crowd dynamics of resource allocation, A. Ghosh, D. De Martino, A. Chatterjee, M. Marsili and B. K. Chakrabarti, Phys. Rev. E 85 (2012) 021116.
69. Conserved mass models with stickyness and chipping, S. Bandyopadhyay and P. K. Mohanty, J. Stat. Mech. P07019 (2012).
70. Restricted exclusion processes without particle conservation flows to directed percolation, Urna Basu and P. K. Mohanty, Europhys. Lett. 99, 66002 (2012).
71. Does a thermally driven classical Heisenberg spin chain locally equilibrate ? D. Bagchi and P. K. Mohanty, Phys. Rev. B 86, 214302 (2012)
72. ‘A study of cooperative breathing-mode in molecular chain’, Ravindra Pankaj and Sudhakar Yarlagadda, Phys. Rev. B 86, 035453 (2012).
73. ‘Correlated singlet phase in the one-dimensional Hubbard-Holstein model’, Sahinur Reja,Sudhakar Yarlagadda, Peter B. Littlewood, Phys. Rev. B 86, 045110 (2012).

International conference – organized by Experimental faculties

1. Int. Conf. on Magnetic Materials (ICMM-2007) was held during Dec 11-16, 2007, proceedings published as Magnetic Materials, AIP Conf. Proc. vol.1003, (2008)
2. ICMM-2010 - held October 25 – 29, 2010, proceedings published as Magnetic Materials, AIP Conf. Proc. vol.1347, (2011).
3. 6th International Conference on "Unsolved Problems on Noise" –(UPON) February 20-24,2012

Conferences/Symposia/Workshops: organised by Theoretical faculties

1. International Workshop and Conference on Statistical Physics Approaches to Multi-Disciplinary Problems, 7-13 January 2008, Indian Institute of Technology Guwahati, India, organized jointly with IIT Guwahati, S N Bose National Centre for Basic Sciences, Kolkata and Institute of Mathematical Sciences, Chennai .

2. School on Low dimensional nanoscopic physics, 28 January - 9 February 2008, Harish-Chandra Research Institute, Allahabad, India, organized jointly with Harish-Chandra Research Institute, Allahabad, Institute of Physics, Bhubaneswar and Institute of Mathematical Sciences, Chennai

3. International Workshop on Quantum Phase Transition and Dynamics : Quenching, Annealing and Quantum Computation, 3 - 7 February, 2009, Saha Institute of Nuclear Physics, Kolkata, India

4. ECONOPHYSICS-KOLKATA IV : International Workshop on Econophysics of Games and Social Choices, 9 - 13 March, 2009, Indian Statistical Institute, Kolkata, India

5. ECONOPHYSICS-KOLKATA V : International Workshop on Econophysics of Order-driven Markets, 9 - 13 March, 2010, Saha Institute of Nuclear Physics, Kolkata, India

6. STATPHYS-Kolkata VII, 26 - 30 November, 2010, Saha Institute of Nuclear Physics, Kolkata, India

7. CMDS-12International Symposium on Continuum Models and Discrete Systems, 21-25 Feb 2011, Saha Institute of Nuclear Physics, Kolkata, India

8. International School and Conference on Functional Materials, March 28 to April 1, 2011 at HRI, Allahabad as a joint program of HRI SINP

9. ECONOPHYSICS-KOLKATA VI : International Workshop on Econophysics of Systemic Risk and Network Dynamics, 20 - 25 October, 2011, Saha Institute of Nuclear Physics, Kolkata, India

10. RCBAMM2012 - An Indo-Singapore Joint Workshop on Role of Computational Biology in Advancing Modern Medicine, February 2-3, 2012, Saha Institute of Nuclear Physics, Kolkata, India

Human Resource: No., of Ph.d produced: Experimental 8, Theory 7: Total 15

MEMORIAL LECTURES

1. The Sixth J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Allan H MacDonald , Sid W. Richardson Foundation Regents Chair Professor, Dept of Physics, University of Texas at Austin, USA on "Quantum Hall Superfluids" on 5th April, 2011.

2.The Fifth Ramanujan Lecture of the CAMCS, SINP, will be delivered by Prof. Masuo Suzuki, Professor of Applied Physics, Tokyo University of Science, Japan, on "Quantum-Classical Correspondence in Statistical Mechanics" on 25th November, 2010.

3.The Fifth J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Klaus von Klitzing , Max Planck Institute for Solid State Research, Stuttgart, Germany on "The Quantum Leap from Micro- to Nanoelectronics" on 2nd November, 2010.
4.The Fourth J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Sidney R. Nagel,Stein-Freiler Distinguished Service Professor, University of Chicago, USA on "Jamming and the Emergence of Rigidity" on 8th March, 2010.

5.The Fourth Ramanujan Lecture of the CAMCS, SINP, was delivered by Prof. Anthony J. Leggett, the John D. and Catherine T. MacArthur Professor and Center for Advanced Study Professor of Physics, University of Illinois, USA on "Superfluid 3-He: The early days as seen by a theorist [Nobel Lecture 2003] " on 29th January, 2010.

6.The Third J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Anthony J. Leggett, the John D. and Catherine T. MacArthur Professor and Center for Advanced Study Professor of Physics, University of Illinois, USA on "Bell's theorem, entanglement, quantum teleportation, and all that" on 28th January, 2010.

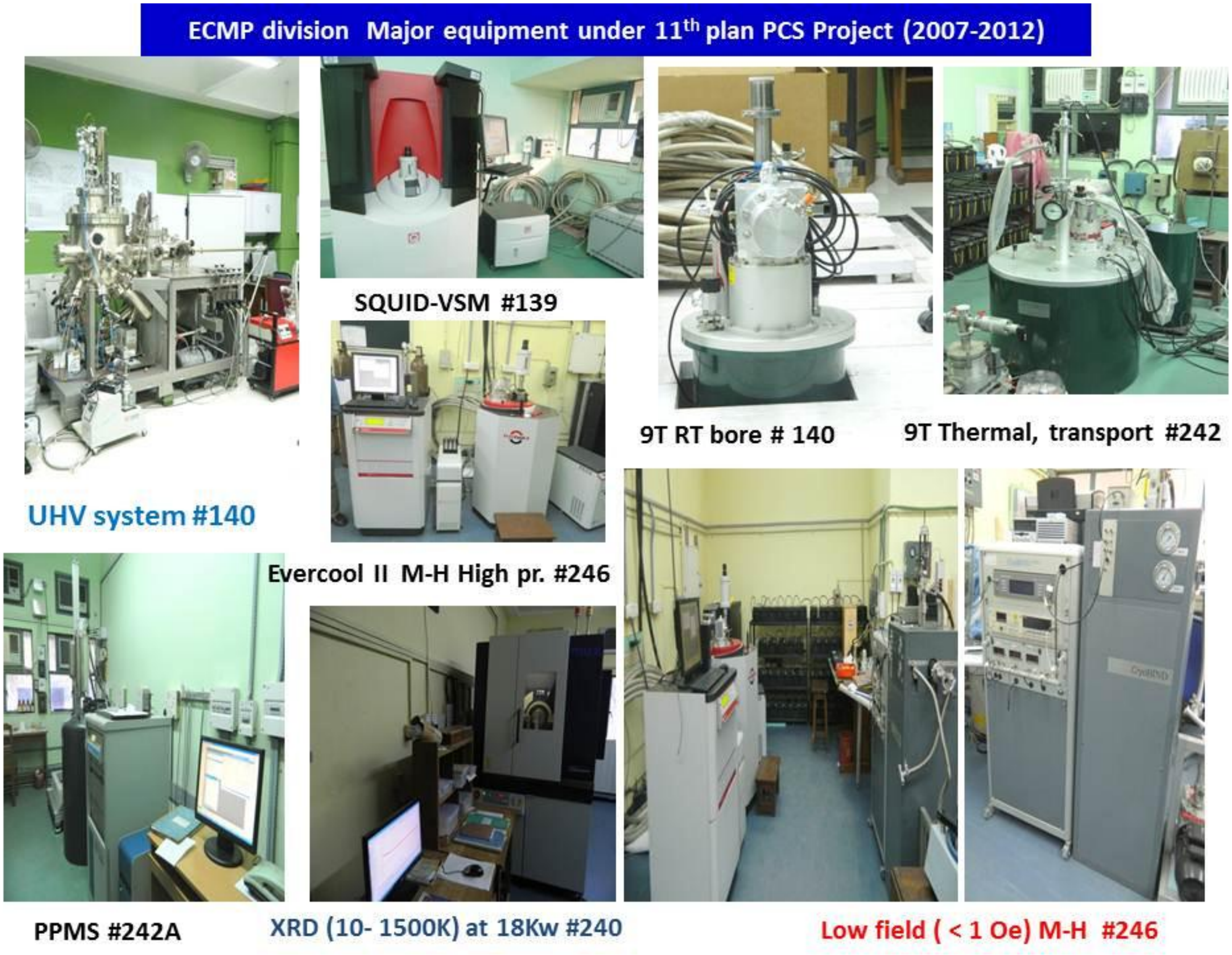
7. The Third Ramanujan Lecture of the CAMCS, SINP, was delivered by Prof. Peter A. Markowich, Professor of Applied Mathematics, Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK, and Professor of Applied Analysis,Faculty of Mathematics University of Vienna, Austria on "Reaction-Diffusion (-Convection) Equations, Entropies and Sobolev Inequalities" on 10th March, 2009.

8.The Second Ramanujan Lecture of the CAMCS, SINP, was delivered by Prof. Sir Michael Berry, Royal Society Research Professor of the University of Bristol, UK on "The music of the primes: quantum mechanics, chaos and the Riemann zeros" on 27th January, 2009.

9.The Second J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Gabriel Aeppli, Quain Professor of Physics and the Director of the London Centre for Nanotechnology, UK on "Interdisciplinarity continued from semiconductor physics to pharmaceutical assays" on 5th February, 2009.

10.The First Ramanujan Lecture of the CAMCS, SINP, was delivered by Prof. H. Nishimori of the Tokyo Inst. Tech., Tokyo, on "Spin Glasses and Information" on 9th January, 2007.

11. The First J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Jainendra Jain of the Penn. State Univ, Pensylvania, on "Lessons of the Fractional Quantum Hall Effect for Outsiders" on 3rd December, 2007.



ECMP division Major equipment under 11th plan PCS Project (2007-2012)

UHV system #140

SQUID-VSM #139

9T RT bore # 140

9T Thermal, transport #242

Evercool II M-H High pr. #246

PPMS #242A

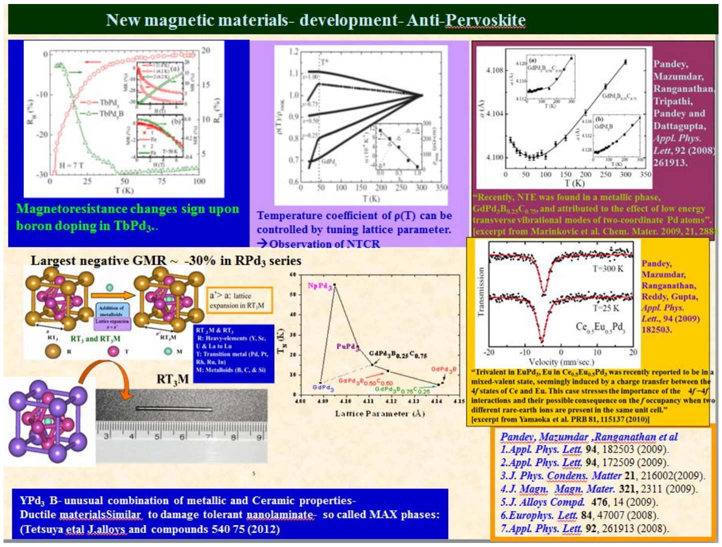
XRD (10- 1500K) at 18Kw #240

Low field (< 1 Oe) M-H #246

The following major capital Equipment’s have been procured and Installed successfully.

a. Atomic Force Microscopy-Magnetic Force Microscopy
b. DC-RF sputtering under high vacuum (UHV system)
c. MFM,Mask aligner
d. XRD at low temperature with 18KW power
e. Cryostats for Physical property measurements system (5 T- 9T)
f. Room Temp. Bore magnet (9 T) with VTI
g. Furnaces- small and medium
h. Field Sweep magnet for NMR 9T
i. High pressure – Hydrostatic- 3GPa (max.) at LT, Diamond Anvil Cell
j. SQUID-VSM

Some Important results- examples



New magnetic materials- development- Anti-Pervoskite

Magnetoresistance changes sign upon boron doping in $TbPd_3$..

Temperature coefficient of ρ(T) can be controlled by tuning lattice parameter.
→Observation of NTCR

Pandey, Mazumdar, Ranganathan, Tripathi, Pandey and Dattagupta, *Appl. Phys. Lett*, 92 (2008) 261913.

"Recently, NTE was found in a metallic phase, $GdPd_3B_{0.25}C_{0.75}$, and attributed to the effect of low energy transverse vibrational modes of two-coordinate Pd atoms". [excerpt from Marinkovic et al. Chem. Mater. 2009, 21, 288

Largest negative GMR ~ -30% in RPd_3 series

a'> a: lattice expansion in RT_3M

RT_3M & RT_3
R: Heavy-elements (Y, Sc, U & La to Lu
T: Transition metal (Pd, Pt, Rh, Ru, In)
M: Metalloids (B, C, & Si)

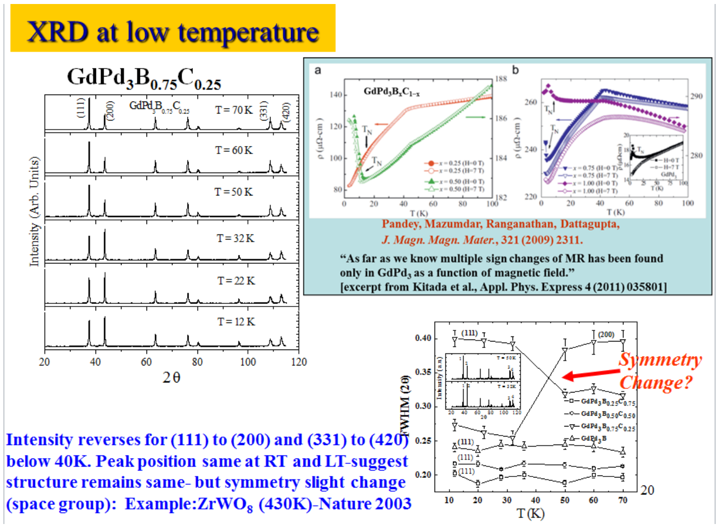
RT_3M

Pandey, Mazumdar, Ranganathan, Reddy, Gupta, *Appl. Phys. Lett.*, 94 (2009) 182503.

"Trivalent in $EuPd_3$, Eu in $Ce_{0.5}Eu_{0.5}Pd_3$ was recently reported to be in a mixed-valent state, seemingly induced by a charge transfer between the 4*f* states of Ce and Eu. This case stresses the importance of the 4*f*−4*f* interactions and their possible consequence on the *f* occupancy when two different rare-earth ions are present in the same unit cell."
[excerpt from Yamaoka et al. PRB 81, 115137 (2010)]

Pandey, Mazumdar ,Ranganathan et al
1. *Appl. Phys. Lett.* **94**, 182503 (2009).
2. *Appl. Phys. Lett.* **94**, 172509 (2009).
3. *J. Phys. Condens. Matter* **21**, 216002(2009).
4. *J. Magn. Magn. Mater.* **321,** 2311 (2009).
5. *J. Alloys Compd.* **476**, 14 (2009).
6. *Europhys. Lett.* **84**, 47007 (2008).
7. *Appl. Phys. Lett.* **92**, 261913 (2008).

YPd_3 B- unusual combination of metallic and Ceramic properties-
Ductile materialsSimilar to damage tolerant nanolaminate- so called MAX phases:
(Tetsuya etal J.alloys and compounds 540 75 (2012)

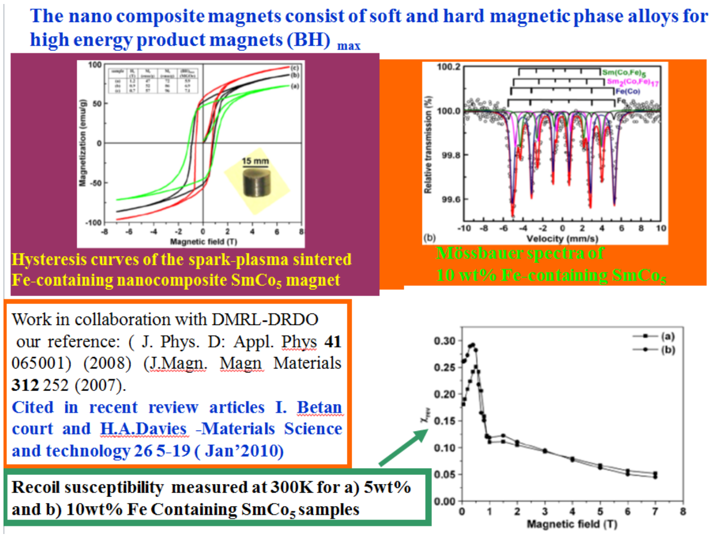


XRD at low temperature

Pandey, Mazumdar, Ranganathan, Dattagupta, *J. Magn. Magn. Mater.*, 321 (2009) 2311.

"As far as we know multiple sign changes of MR has been found only in $GdPd_3$ as a function of magnetic field."
[excerpt from Kitada et al., Appl. Phys. Express 4 (2011) 035801]

Intensity reverses for (111) to (200) and (331) to (420) below 40K. Peak position same at RT and LT-suggest structure remains same- but symmetry slight change (space group): Example:$ZrWO_8$ (430K)-Nature 2003



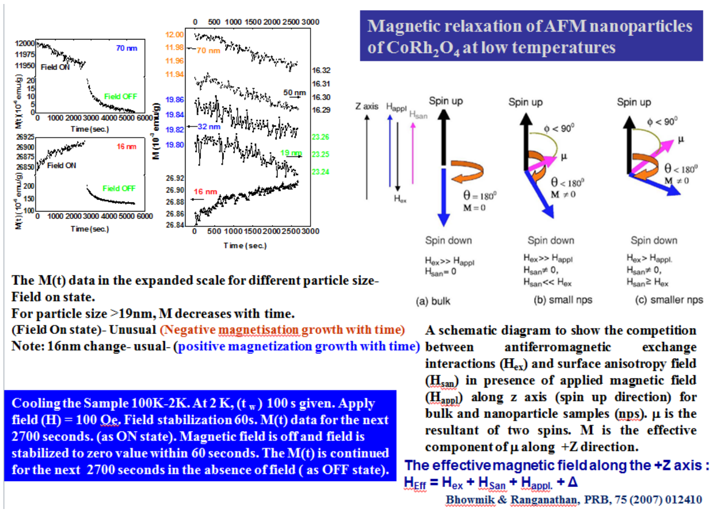
The nano composite magnets consist of soft and hard magnetic phase alloys for high energy product magnets $(BH)_{max}$

Hysteresis curves of the spark-plasma sintered Fe-containing nanocomposite $SmCo_5$ magnet

Mössbauer spectra of 10 wt% Fe-containing $SmCo_5$

Work in collaboration with DMRL-DRDO our reference: (J. Phys. D: Appl. Phys **41** 065001) (2008) (J.Magn. Magn Materials **312** 252 (2007).
Cited in recent review articles I. Betan court and H.A.Davies -Materials Science and technology 26 5-19 (Jan'2010)

Recoil susceptibility measured at 300K for a) 5wt% and b) 10wt% Fe Containing $SmCo_5$ samples



Magnetic relaxation of AFM nanoparticles of $CoRh_2O_4$ at low temperatures

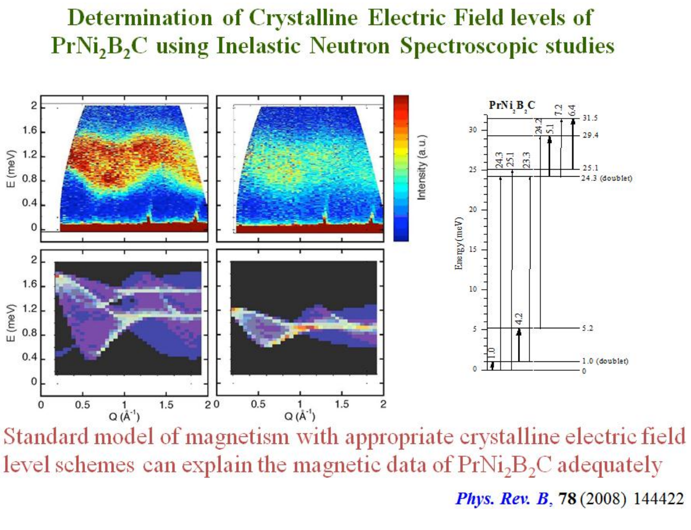
The M(t) data in the expanded scale for different particle size- Field on state.
For particle size >19nm, M decreases with time.
(Field On state)- Unusual (Negative magnetisation growth with time)
Note: 16nm change- usual- (positive magnetization growth with time)

Cooling the Sample 100K-2K. At 2 K, (t_w) 100 s given. Apply field (H) = 100 Oe. Field stabilization 60s. M(t) data for the next 2700 seconds. (as ON state). Magnetic field is off and field is stabilized to zero value within 60 seconds. The M(t) is continued for the next 2700 seconds in the absence of field (as OFF state).

A schematic diagram to show the competition between antiferromagnetic exchange interactions (H_{ex}) and surface anisotropy field (H_{san}) in presence of applied magnetic field (H_{appl}) along z axis (spin up direction) for bulk and nanoparticle samples (nps). μ is the resultant of two spins. M is the effective component of μ along +Z direction.

The effective magnetic field along the +Z axis :
$H_{Eff} = H_{ex} + H_{San} + H_{appl.} + \Delta$

Bhowmik & Ranganathan, PRB, 75 (2007) 012410



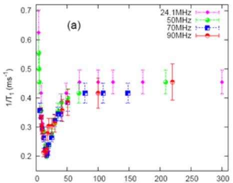
Determination of Crystalline Electric Field levels of $PrNi_2B_2C$ using Inelastic Neutron Spectroscopic studies

Standard model of magnetism with appropriate crystalline electric field level schemes can explain the magnetic data of $PrNi_2B_2C$ adequately

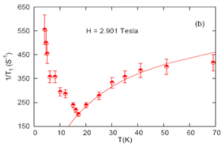
Phys. Rev. B, **78** (2008) 144422

Spin dynamics in 1D trimer cluster compound $Ca_3Cu_2Ni(PO_4)_4$ probed by ^{31}P NMR

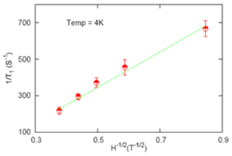
M. Ghosh, M. Majumder, K. Ghoshray, A. Ghoshray



The variation of $1/T_1$ with T shows negligible field dependence in the temperature range 50-300 K, suggesting Curie-Weiss type temperature dependence of the dynamic susceptibility.

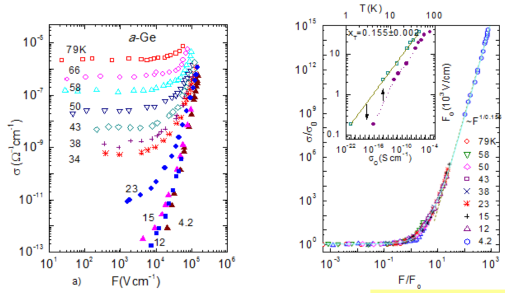


In the range 15-50 K, $1/T_1$ decreases exponentially as $e^{-\Delta/k_BT}$. In this temperature region $1/T_1$ shows a field dependence, with $1/T_1$ α $H^{1.5}$. Such a field dependence was predicted theoretically when the dominant contribution to $1/T_1$, is due to the two magnon mediated exchange enhanced Raman process over that of the three magnon process.



In the range 4-15K, $1/T_1$ shows continuous increment with $1/T_1$ α $H^{-1.5}$, which is a signature of the development of short range magnetic correlation, though the system does not show long range magnetic order down to 1.8 K as revealed from the magnetic susceptibility. The power law indicates spin diffusion process governs the nuclear relaxation below 15K.

Phenomenological Scaling – single field scale



cond-matt/arXiv:
1305.0031

Morgan & Walley, Phil. Mag. (1970)

Scaling relation:

$\sigma(F)/\sigma(0) = \Phi(F/F_O)$

$F_O \sim \sigma_O^x$, x – *non-linearity exponent*

At large field:

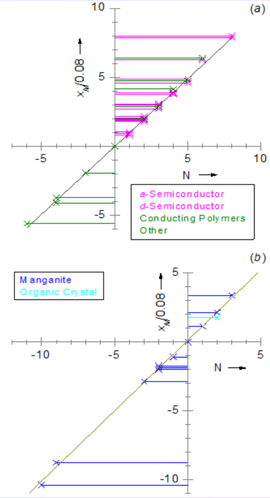
σ(F) independent of T or σ_O

$\Rightarrow \Phi(z) \sim z^{1/x}$

$\sigma \approx F^{1/x}$, Power Law

***Physical Review B**, 84*, 054205 (2011) : *86*, 165104 (2012).

Non-linearity exponents – Quantization!!!



x_M is an integral multiple of 0.08

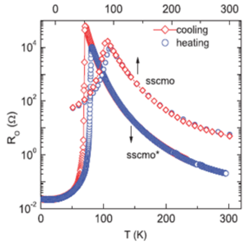
x_M= 0.08 N

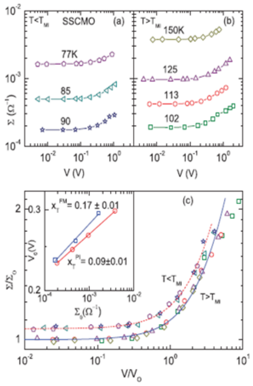
N=1 x_M = 0.08, N=2 x_M = 0.16 and so on

Experiments cover an wide variety of systems - amorphous/doped semiconductors, conducting polymers, organic crystals, manganites, composites, 'dirty metals', double perovskites

strongly localized systems to weakly localized ones to correlated systems

New scaling model for non-Ohmic transport in manganites





Scaling relation:

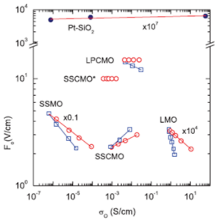
$\sigma(F)/\sigma(0) = \Phi(F/F_O)$

$F_O \sim \sigma_O^x$, x – non-linearity exponent

MIT in CMR manganites. I-V curves on both sides of the transition studied for single crystal and Polycrystalline Manganites

Phenomenological Scaling in manganites – Existence of a Single field scale for Nonlinearity

Non linearity exponents in various CMR manganites



Onset Field F_o follows a Power-law relation with Ohmic conductivity with an exponent x_T

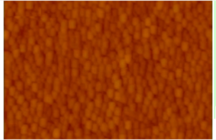
non-linearity exponent x_T for various CMR manganite systems.

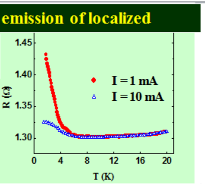
System	Abbreviation	Type	T_{MI}(K)	$\Delta T_{1/2}$(K)	x_T^{FM}	x_T^{PI}
$Sm_{0.55}(Sr_{0.5}Ca_{0.5})_{0.45}MnO_3$	SSCMO*	Single crystal	81			0
$Sm_{0.55}Sr_{0.3375}Ca_{0.1125}MnO_3$	SSCMO	Polycrystal	94	9	0.17 ± 0.01	0.09 ± 0.01
$Sm_{0.55}Sr_{0.45}MnO_3$	SSMO	Polycrystal	69.5	9.8	−0.23 ± 0.01	−0.14 ± 0.01
$La_{0.275}Pr_{0.35}Ca_{0.375}MnO_3$	LPCMO	Polycrystal	113	10.4	−0.09 ± 0.01	0
$La_{0.87}(Mn_2O_3)_{0.13}MnO_3$	LMO	Polycrystal	155	93	−0.83 ± 0.01	−0.16 ± 0.01
$La_{0.75}Ca_{0.25}MnO_3$	LCMO (C)	Thin film	267	10	0.27 ± 0.04	0.27 ± 0.04
$La_{0.75}Ca_{0.25}MnO_3/BaTiO_3$	LCMO/BTO (CB)	Multilayer film	210	30	−0.70 ± 0.01	−0.15 ± 0.03

Scaling of non-Ohmic conduction in strongly correlated systems
D. Talukdar, U. N. Nandi, A. Poddar, P. Mandal, and K. K. Bardhan Phys. Rev. B 86, 165104 (2012)

Spin polarized non-tunneling emission of localized

AFM Picture of strain relaxed $La_{0.67}Sr_{0.33}MnO_3$ film



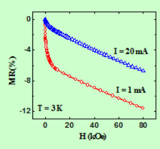


- Low temperature rise in resistance

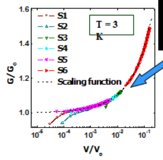
Non-ohmic transport below 6

→ Enhancement of
nductivity with applied bias

- Film Thickness 300 nm
- Deposited on Substrate $LaAlO_3$
- Average grain size 80 n



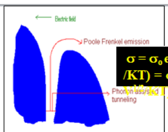
Unusually strong bias & temperature dependence of MR in the non-ohmic regime



Materials with different micro structure following the same scaling behaviour

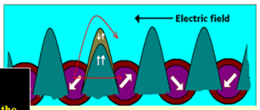
S1: LSMO nanoparticles
S2, S3: LSMO/ALO nanocomposites
S4: LSMO film on LAO substrate
S5: NSMO film on LAO substrate
S6: LSMO film on STO substrate

The voltage dependence of conductivity is described by universal scaling function G(V) = $G_0\,\exp(V/V_0)^{1/2}$, V_0 a parameter sensitive to magnetic field.



$\sigma = \sigma_0 \exp(\delta\Phi/KT) = \sigma_0 \exp(\beta_{PF} V^{1/2}/KT)$

Unified description of spin dependent transport in granular ferromagnetic manganites



Total transport probability → product of tunneling probability across the barrier & activation probability over the

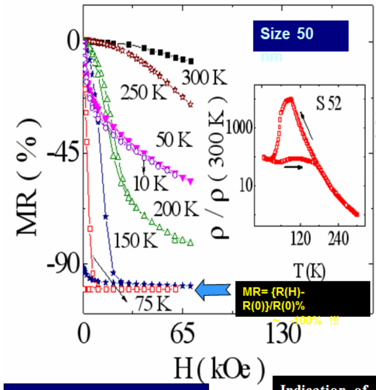
Total Electrical conductance

$$G = G_0 \exp\left(\frac{-A(H)}{V}\right) \exp\left(\frac{V}{V_0(H)}\right)^{1/2}$$

Phys. Rev. B 76 (2007) 094424
Soumik Mukhopadhyay & I.Das

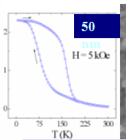
Europhys. Lett. 79 (2007) 67002
Soumik Mukhopadhyay & I. Das

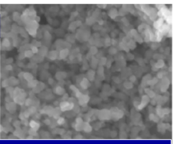
First observation of electronic phase co-existence in nano-particles and low field melting of charge ordered state by magnetic field



MR= {R(H)-R(0)}/R(0)%
~ -100% !!!

$Pr_{0.65}(Ca_{0.7}Sr_{0.3})_{0.35}MnO_3$ (Nanocrystalline Samples)





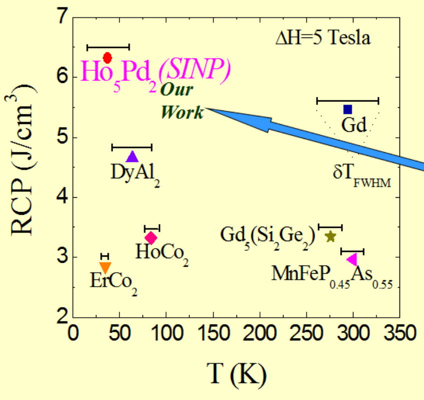
- Hysteresis in M(T) and R(T) is indication of phase co-existence
- Low Field MR decreases with decrease of temperature below T_{IM}
- Large LFMR due to charge order melting

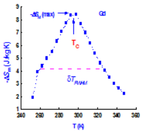
There exist hysteresis in M(T), R(T), MR(H) curve at the temperatures below T_{IM}

Indication of co-existence of FM & CO phase

Anis Biswas & I. Das
Appl. Phys. Lett. 91, 013107 (2007)

Largest Magnetic Cooling Power in Ho_5Pd_2





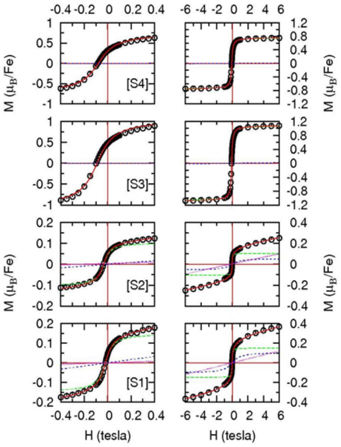
Relative cooling power:

RCP(S) = -$\Delta S_m(\max)*\delta T_{FWHM}$

Relative Cooling Power (RCP) is Largest among the reported best known magnetic refrigerant materials.

Appl. Phys. Lett. 91 082511 (2007)

Tapas Samanta, I. Das & S. Banerjee



$$M(H) = \frac{2M_S^{FM}}{\pi}\left[\frac{H \pm H_C}{H_C}\tan\left(\frac{\pi M_R^{FM}}{2M_S^{FM}}\right)\right] + M_S^{SPM}\left[\coth\left(\frac{\mu H}{kT}\right) - \left(\frac{\mu H}{kT}\right)^{-1}\right] + C^{PM}H.$$

Hysteresis of FeCu nano-granular alloy

Only the parts with descending magnetic field of the hysteresis loops measured at 5 K have been shown here for clarity. The open symbols in left panels show data in the expanded low field region from –0.4 to 0.4T of samples 1, 2, 3 and 4. The right panels show data for corresponding samples in between –6 to 6 T.

The simulations as described in the text are also shown. For samples 1 and 2, the FM (long dash), the SPM (short dash) and the PM (dot) components can be seen together with the sum (line).

Samples 3 and 4 are almost entirely FM, but addition of a very small PM component might be necessary for a better fit.

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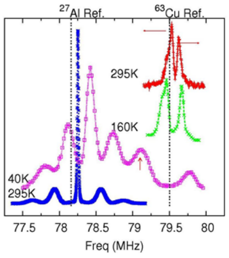
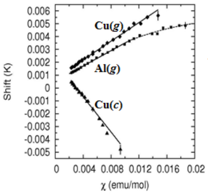
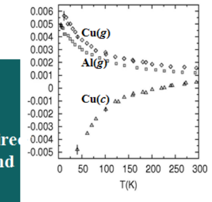
^{27}Al and ^{63}Cu NMR spectra and Knight shift (K) in $CeCu_3Al_2$





$K(T) = K(0) + H_{hf}\chi(T)/\mu_B$

Hyperfine field at Al or Cu nuclei from spin-polarized conduction electrons by the presence of *f*-electrons



H_{hf} = 1.67(5) kOe/μ_B at Al(g)
H_{hf} = 2.02(5) kOe/μ_B at Cu(g)
H_{hf} = -3.83(5) kOe/μ_B at Cu(c)

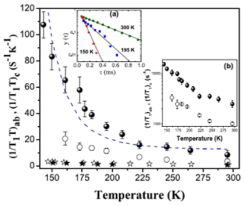
Usually, H_{hf} > 0, for $J=L-S$,
< 0, for $J=L+S$

Exceptions may occur if there is direct overlap between *f* orbital and ligand *s* orbital, which is possible, as, distance *a-c* is shorter than *a-g* by 0.03-0.04 nm.

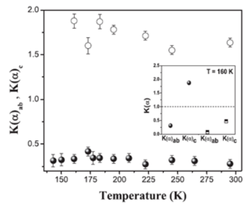
Anisotropic Spin-Fluctuations in SmCoPO Revealed by ^{31}P NMR Measurement

M. Majumder, K. Ghoshray, A. Ghoshray, A. Pal, and V. P. S. Awana**

SmCoPO undergoes three magnetic transitions: $T_{C,Co}$ at 80K, Sm^{4f}-Co^{3d} interplayed AFM transition at 20K and Sm^{3+} AFM ordering at 5.4K.



$1/T_1$ shows large anisotropy confirming a significant contribution of Sm-4f electron spin fluctuations to $1/T_1$, arising from indirect RKKY type exchange interaction indicating a non-negligible hybridization between Sm-4f orbitals and the conduction band, over the itinerant character of the Co-3d spins. This anisotropy originates from the orientation dependence of $\chi^{\|}$ (q, ω).



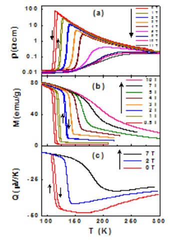
The 3d-spin fluctuations in the ab-plane is 2D FM (K(α) < 1) in nature, while along the c-axis, a signature of a weak AFM (K(α) > 1) spin fluctuations superimposed on weak FM spin-fluctuations even in a field of 7 T and far above T_N is observed. The enhancement of this AFM-fluctuations of the Co-3d spins along c-axis, at further low temperature is responsible to drive the system to an AFM ordered state.

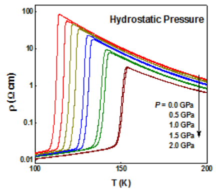
*National Physical Laboratory, Delhi, India

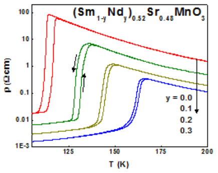
Role of internal and external perturbation on magnetic and electronic phase transition on narrowband $Sm_{0.52}Sr_{0.48}MnO_3$ (SSMO) single crystal

Magnetic, transport, and thermal properties of $Sm_{0.52}Sr_{0.48}MnO_3$ (SSMO) single crystal are very unusual due large quenched disorder and narrow bandwidth. Our study shows :

1. At ambient condition, SSMO exhibits a strong first-order ferromagnetic (FM) metal to paramagnetic (PM) insulator phase transition at the Curie temperature T_C=110 K with large thermal hysteresis [left panel].
2. The application of magnetic field increases T_C almost linearly at the rate of 11.3 K/T (up to H<4 T), diminishes the first-order character of the transition and above a critical point (H_{cr}≈4 T, T_{cr}≈160 K), the transition becomes a crossover.
3. Qualitatively similar behavior has been observed with increasing external pressure (P) and chemical or internal pressure (y), i.e., substitution of Nd at Sm site [$(Sm_{1-y}Nd_y)_{0.52}Sr_{0.48}MnO_3$] [middle and right panel].





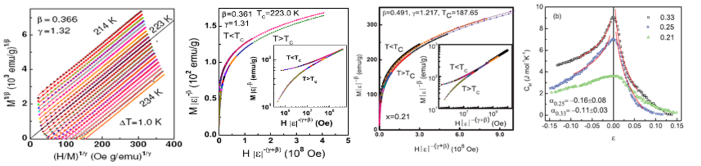


Phase transition and phase separation in $La_{1-x}Sr_xCoO_3$ (LSCO) single crystals

The nature of spin interaction in ferromagnetic and spin glass LSCO has been investigated by studying critical behavior of the magnetic phase transition. An unambiguous determination of the critical exponents as well as reduced critical amplitude reveals that

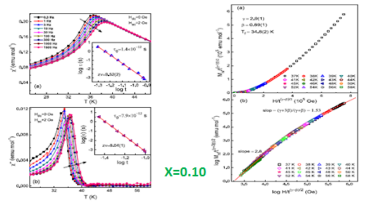
(i) The spin interaction is short range and belongs to 3D Heisenberg universality class for x>0.22 [panel 1,2,4].

(ii) Deviation from Heisenberg towards mean-field behavior is observed for x=0.21 . This deviation together with weaker λ-like anomaly in C_p and broadening of PM-FM transition are the indication of magnetoelectronic inhomogeneity for the x=0.21 sample, i.e., a spontaneous phase separation below x=0.22 [panel 3,4] .



X=0.33

(iii) For x<0.20, the analysis of both dc and ac magnetic data show that LSCO is a canonical 3D Heisenberg spin-glass [right side: x=0.10]

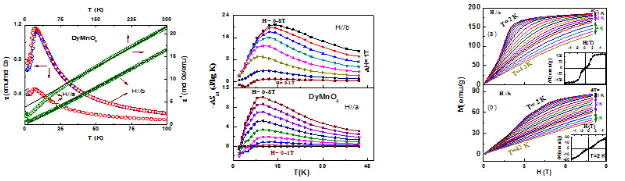


X=0.10

Anisotropic magnetic properties and huge magnetocaloric effect in $RMnO_3$ (R=Dy,Tb,Ho, Yb) crystals

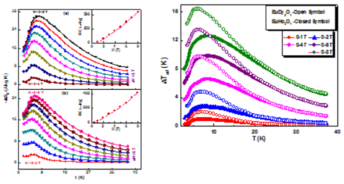
Plots of T and H dependence of M for $DyMnO_3$ with field parallel to c and a axes are shown below:

- i. Magnetic structure of $DyMnO_3$ is highly magnetically anisotropic and it exhibits a field induced metamagnetic transition.
- ii. Huge (negative) magnetic entropy change with increasing H suggests that $RMnO_3$ is suitable for magnetic refrigeration at low temperature.



Giant magnetocaloric effect in magnetically frustrated $EuHo_2O_4$ and $EuDy_2O_4$ compounds

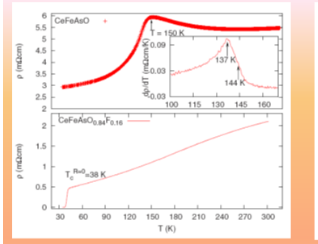
These compounds exhibit field-induced metamagnetic transition from AFM to FM state which leads to a giant negative entropy change. In both the cases, the entropy change remains very large down to 2 K. This unusually large magnetocaloric effect is due to the magnetic frustrations.

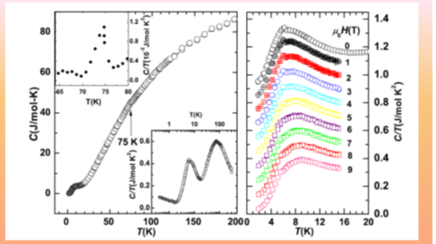


Pnictide Superconductors

$CeFeAsO_{0.84}F_{0.16}$ (T_c ~42K)

CeCoAsO





CeFeAsO →Spin density wave ~137K & Structural transition ~144K

No anomaly in $CeFeAsO_{0.84}F_{0.14}$ Superconductors.

Above Tc, *e-e* interaction plays dominant role.

CeCoAsO→FM ordering of Co~75K & Schottky anomaly atT=6.5K

Interplay between Ce 4*f* & Co 3*d* magnetism.

Increase in C/T (FM state)→Weak correlations among Ce ions.

Phys. Rev. B79 (2009) 144512

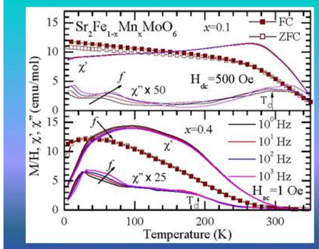
Phys. Rev. B82 (2010) 054423

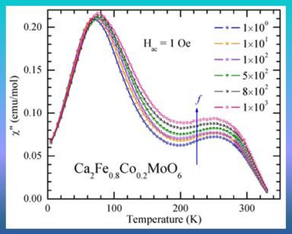
Physica C 469 (2009) 789

Spin Glass behavior in oxide systems

$Sr_2Fe_{1-x}Mn_xMoO_6$

$Sr_2Fe_{1-x}Co_xMoO_6$





•$Sr_2Fe_{1-x}(Mn/Co)_xMoO_6$ →Ferromagnetic Fe[↑]-Mo[↓]-Fe[↑] & Antiferromagnetic (Mn/Co)[↑]-(Mo)-(Mn/Co)[↓] interactions

Magnetic Frustration→Highly frequency dependent peak in χ"(T)

J. Appl. Phys. 106 (2009) 093908

Spin Glass behavior

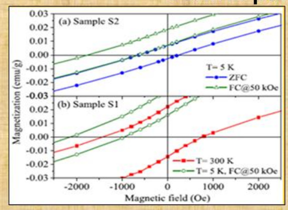
J. Alloys & Compds. 502 (2010) 13

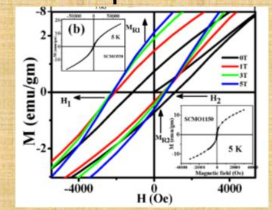
Exchange bias effect in oxide nanoparticles

$LaFeO_3$

$Sm_{0.5}Ca_{0.5}MnO_3$

Central part of the M-H loop





J. Phys. D: Appl. Phys. 43 (2010) 245002

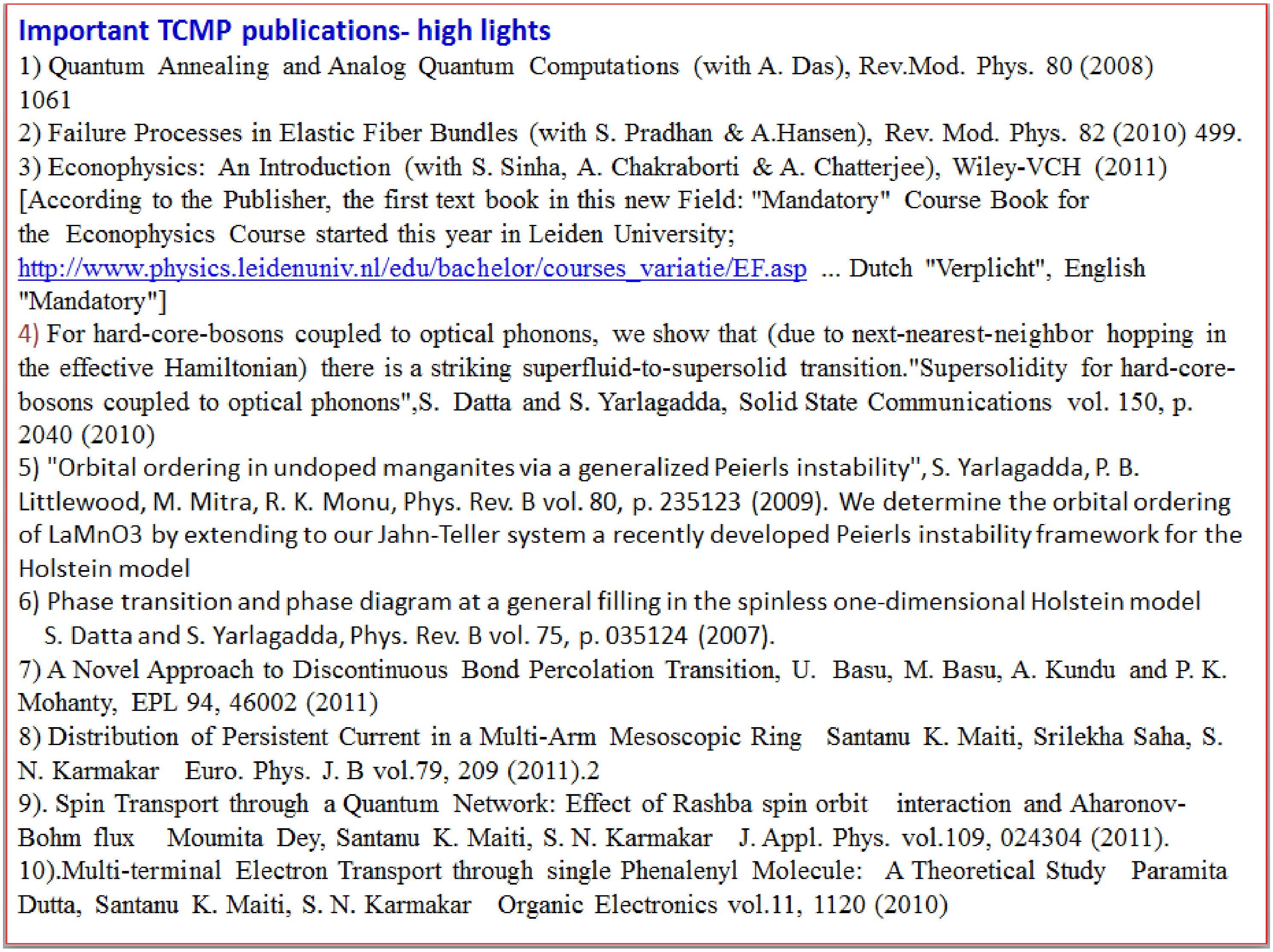
AIP Advances. 1 (2011) 032110

Field cooled (H_C) M-H loop→ Shifts in negative direction→EB effect

EB →Exchange coupling between FM shell & AFM core of particles

EB effect can be tuned by H_C→Useful in Multifunctional Devices

Some examples:



Important TCMP publications- high lights

1) Quantum Annealing and Analog Quantum Computations (with A. Das), Rev.Mod. Phys. 80 (2008) 1061

2) Failure Processes in Elastic Fiber Bundles (with S. Pradhan & A.Hansen), Rev. Mod. Phys. 82 (2010) 499.

3) Econophysics: An Introduction (with S. Sinha, A. Chakraborti & A. Chatterjee), Wiley-VCH (2011) [According to the Publisher, the first text book in this new Field: "Mandatory" Course Book for the Econophysics Course started this year in Leiden University; http://www.physics.leidenuniv.nl/edu/bachelor/courses_variatie/EF.asp ... Dutch "Verplicht", English "Mandatory"]

4) For hard-core-bosons coupled to optical phonons, we show that (due to next-nearest-neighbor hopping in the effective Hamiltonian) there is a striking superfluid-to-supersolid transition."Supersolidity for hard-core-bosons coupled to optical phonons",S. Datta and S. Yarlagadda, Solid State Communications vol. 150, p. 2040 (2010)

5) "Orbital ordering in undoped manganites via a generalized Peierls instability", S. Yarlagadda, P. B. Littlewood, M. Mitra, R. K. Monu, Phys. Rev. B vol. 80, p. 235123 (2009). We determine the orbital ordering of LaMnO3 by extending to our Jahn-Teller system a recently developed Peierls instability framework for the Holstein model

6) Phase transition and phase diagram at a general filling in the spinless one-dimensional Holstein model S. Datta and S. Yarlagadda, Phys. Rev. B vol. 75, p. 035124 (2007).

7) A Novel Approach to Discontinuous Bond Percolation Transition, U. Basu, M. Basu, A. Kundu and P. K. Mohanty, EPL 94, 46002 (2011)

8) Distribution of Persistent Current in a Multi-Arm Mesoscopic Ring Santanu K. Maiti, Srilekha Saha, S. N. Karmakar Euro. Phys. J. B vol.79, 209 (2011).2

9). Spin Transport through a Quantum Network: Effect of Rashba spin orbit interaction and Aharonov-Bohm flux Moumita Dey, Santanu K. Maiti, S. N. Karmakar J. Appl. Phys. vol.109, 024304 (2011).

10).Multi-terminal Electron Transport through single Phenalenyl Molecule: A Theoretical Study Paramita Dutta, Santanu K. Maiti, S. N. Karmakar Organic Electronics vol.11, 1120 (2010)