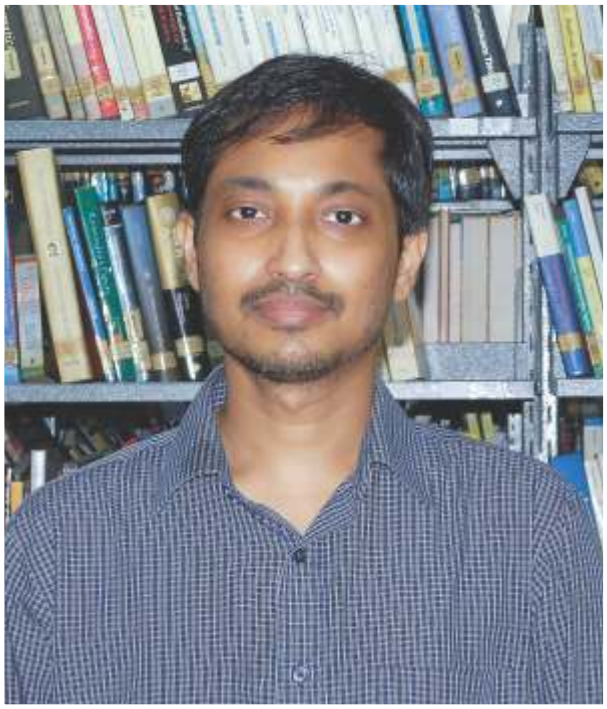

Atindra Nath Pal

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Guidance of Students/Post-Docs/Scientists

a) Ph.D. Students

1. Shubhadip Moulick; Charge and spin transport in hybrid two dimensional nanodevices; Under progress
2. Biswajit Pabi; An investigation of mechanical tunability in single molecular junction; Under progress
3. Shubhrasish Mukherjee; An investigation of electronic and optical properties in 2D semiconductors and their heterostructures; Under progress; S. K. Ray (Supervisor), Atindra Nath Pal (Co-supervisor)
4. Rafiqul Alam; An investigation of transport phenomena in topological materials; Under progress
5. Riju Pal; Charge and spin transport in hybrid two dimensional nanodevices; Under progress

b) Post-Docs

1. Buddhadeb Pal; Spintronics with 2d materials and superconductor

c) External Project Students / Summer Training

1. Tausif; On chip gas sensor based on 2d materials; TRC, SNBNCBS
2. Taniya Basu; Technical Assistant of the clean room; TRC, SNBNCBS
3. Soumili Dutta; Research Assistant for clean room device fabrication; TRC, SNBNCBS

Teaching

1. Autumn semester; PHY 501- Research Methodology; PhD; 38 students; with 1 (Prof. Rajib Kumar Mitra) co-teacher

Talks / Seminars Delivered in reputed conference / institutions

1. Invited talk at QMAT 2020 (September 7-11, 2020); Sep 8, 2020; SNBNCBS (online mode); 30 min

Administrative duties

1. Joint in-charge of clean room and Helios-FIB system
2. In charge of Helium plant
3. In charge of 3K measurement system
4. In charge of Ellipsometry system
5. Member of Project & Patent Cell
6. Member of purchase sub committee

Extramural Projects (DST, CSIR, DAE, UNDP, etc.)

1. CRG/2020/004208 - Project Title - Probing orbital hybridization and structural asymmetry in atomic and molecular nano-contact via inelastic electron spectroscopy and shot noise; SERB-DST; 3 years; PI

Conference / Symposia / Schools organized

1. Q-MAT : 2020: 3RD ANNUAL CONFERENCE OF QUANTUM CONDENSED MATTER; Sep 7, 2020; SNBNCBS (online mode); 4 days

Areas of Research

Experimental condensed matter physics

Ferrocene based highly conducting single molecular molecular junction at ambient temperature:

We have investigated the conductance property of ferrocene and ferrocene based single molecular junction. For all the studied molecule (ferrocene, 1,1' bis(aminomethyl)ferrocene and 1,1' dicyanoferrocene), a high conductance region is observed (0.2-0.5 G_0). Apart from that, we observed a low conductance region in the molecules with anchoring group, which may be related to the junction forming due to the connection with the anchoring groups like CN or NH_2. The high conductance is rather surprising and promising in this metallocene based molecular junction. Initial speculation could be that the gold is directly binding with the Fe atom and high conductance may originate due to spin dependent quantum interference effect similar to our former work on vanadocene molecular junction at low temperature. We are collaborating with Dr. Richard Korytar, Charles University, for transport calculations.

Gate tunable Broadband photodetector with graphene-WS_2 hybrid:

One of our major research directions is hybrid optoelectronic devices from TMDC and other 2D materials. In this work, we demonstrate a lithography free cost-effective hybrid phototransistor based on CVD graphene and chemically exfoliated WS2 quantum dots (QDs). In this 2D-0D configuration, WS2 QDs act as light absorber, while the CVD grown single layered graphene is the conductive channel for photocurrent flow. This experimental results demonstrate a highly stable low cost graphene based UV-visible (365-633 nm) broadband phototransistor. Adding with the simple solution process for the preparation of WS2 QDs, these results are very promising for scaling up to make photodetector devices for future optoelectronic applications.

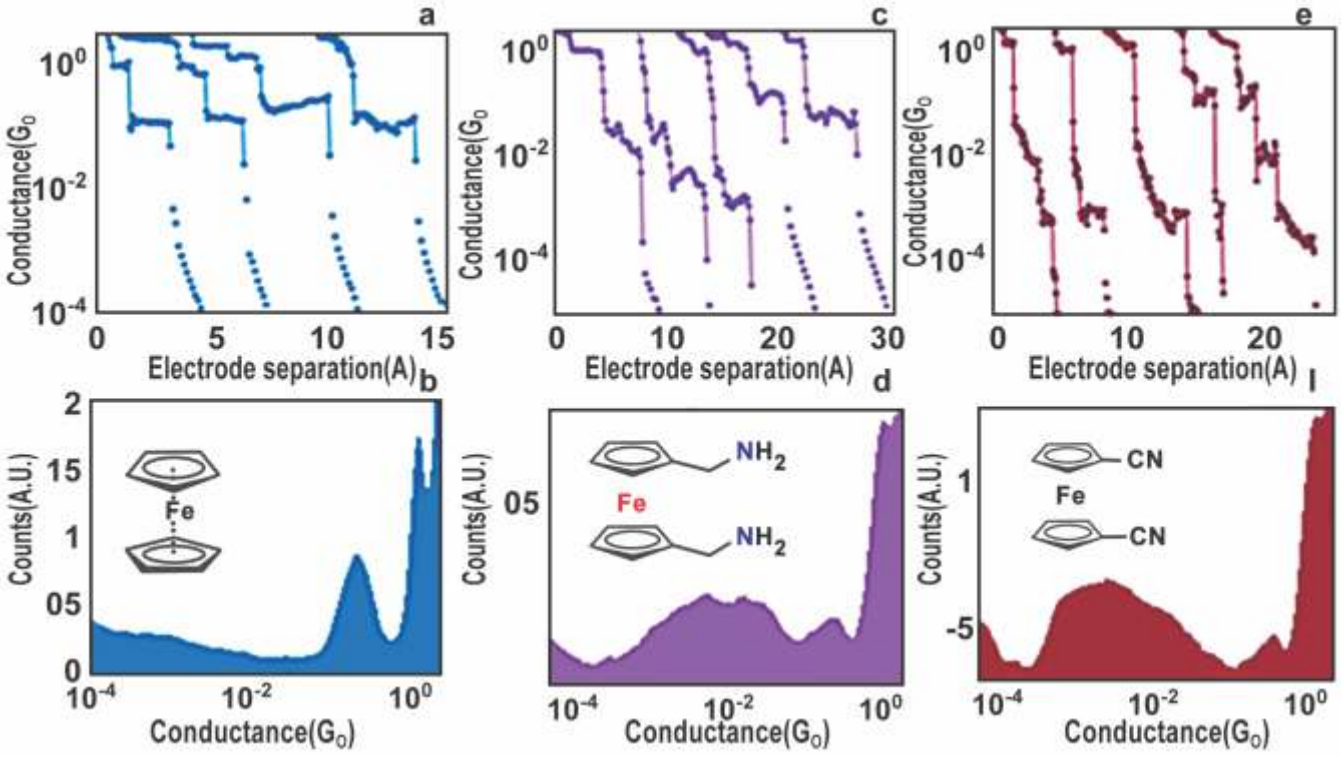

Figure 1 : Typical conductance traces for Mol A (Ferrocene), (a), Mol B (1.1 'bis(aminomethyl)ferrocene)(c) & Mol C (1.1' dicyanoferrocene) (e) respectively, (b), (d) & (f) conductance histogram for Mol A, B & C and histogram is constructed from 1500, 5000 & 5000 traces with 40 bins per decode.

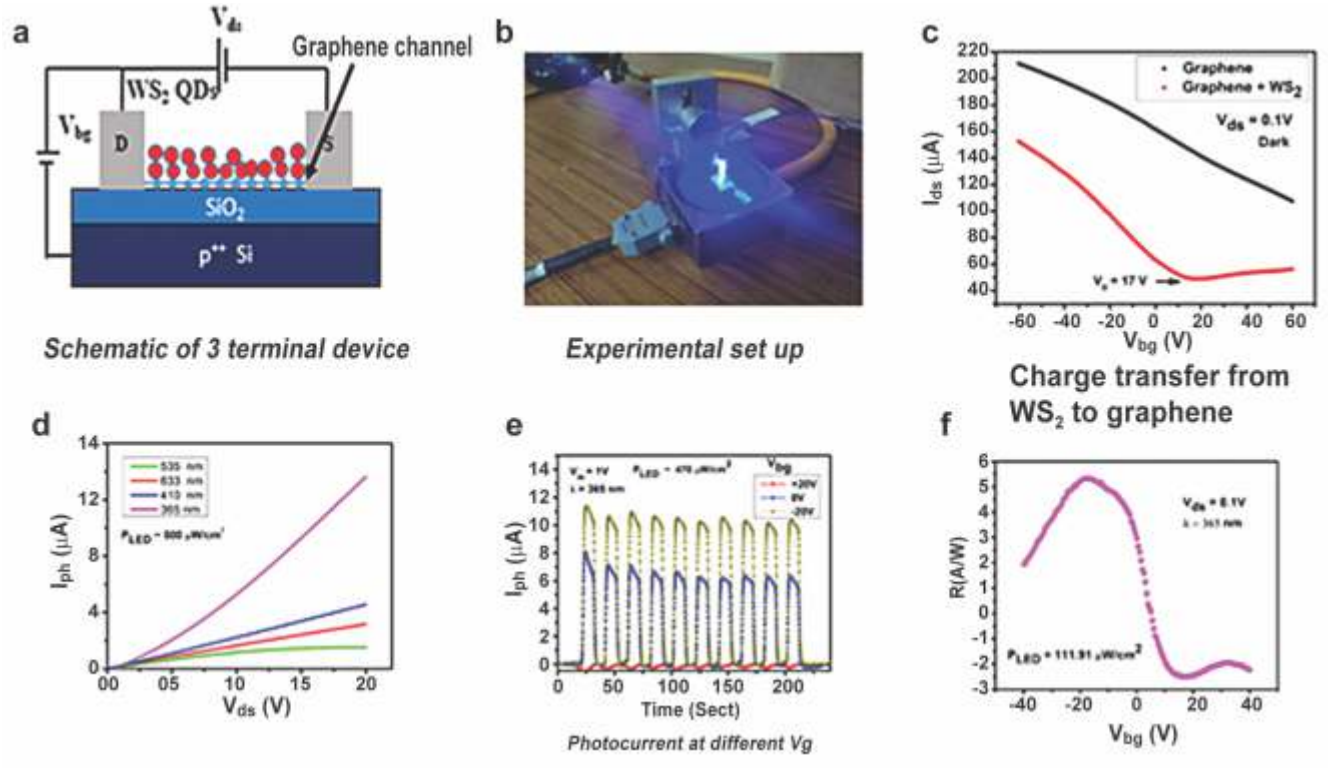

Figure 2 : (a) Optoelectronic transport measurement set up, (b) I–V characteristics at different gate voltages for a two terminal few layer Mo52 transistor, inset shows the device image, (c) IDS-Vbg characteristics in dark and, in presence of red light, showing signal.

Unconventional superconductivity coexisting with Charge density wave in non-Centro symmetric $(TaSe_4)_3I$

The following work focuses on the electronic and magnetic transport through a non-Centro symmetric $(TaSe_4)_3I$ nanowires, grown in Dr. Mintu Mondal's group, IACS. This work is part of joint collaboration with IACS, IISER Mohali, SINP and IISc. We are focusing on the electrical transport in few wire to single wire devices. We observe CDW like transition at 146K, followed by a superconducting transition below 2.2K. The magnetic property of the sample is indeed interesting and shows a field dependent magnetism below 10K. Our initial measurements indicate the coexistence of CDW, Superconductivity and magnetism at temperature below 10K. We have carried out differential conductance measurement at different temperature, showing two different energy scale, one of them corresponding to the superconductivity and the other one may be related to the CDW.

Noise spectroscopy in understanding transport phenomena in topological semimetal

Low frequency noise measurement, an important in solid state devices, used before to understand various scattering phenomena, phase transitions and even quantum transport in two-dimensional devices. Our basic motivation is to understand the transport mechanism of various topological materials where average resistance measurement is not enough to provide detail information about the underline physics. We focus on transport measurement in topological semimetals ($LaAgSb_2$ and Ta_3SiTe_6), which also exhibit CDW transition. Initial data indicate a sudden rise in noise near the transition, however, measurements need to be repeated for further conclusion.

Plan of Future Work Including Project

1. Single molecular transport: During the last three years we have been able to create mechanical

break junction set up to study single molecular junction at room temperature as well as at cryogenic temperature. We have recently got a project to investigate the relation between the orbital structure and electron transport via electronic transport and shot noise. We would like to pursue the metallocene based organic molecules which show exceptionally high conductance at room temperature. Studying these molecules with different electrodes will help us to understand the orbital hybridization effect on these molecules.

2. Van der Waal hybrids: The isolation of graphene by a simple scotch-tape based technique has created a huge playground for exploring various two-dimensional (2d) layered materials due to their excellent electronic, optical, mechanical and thermal properties. After graphene, lot of new 2D materials were discovered including insulators, semiconductors, superconductors, topological insulator, topological semimetals and two dimensional magnets. Superlattices and heterostructures have already been widely explored to tailor the electronic properties of two-dimensional electron systems. With today's nanofabrication scheme it is possible align different 2D materials almost perfectly on top of each other to form heterostructures. Proximity effect is being emerged as a radically different path to transform a given material through its adjacent regions to become superconducting, magnetic, or topologically nontrivial. Such proximity effects not only is a ubiquitous approach compared to the conventional methods of doping or functionalization but also can overcome their various limitations. Our current research focusses on the following:

   - Fabricating high quality two-dimensional devices (graphene, transition metal dichalcognides (TMDCs) etc.) in combination with various functional molecules. Our immediate attention is to create hybrid devices in combination with spin crossover molecules and understand the transport mechanism.
   - Optoelectronics with TMDC based hybrids. In particular, we intend to create large area broadband photodetector using 2D-0D hybrids (e.g., CVD graphene with MoS2 or WS2 quantum dots).
   - We intend to explore spintronics and other emerging phenomena with 2d magnetic heterostructure in future.

3. Transport in emerging materials: Our aim is to investigate some of the key issues in solid-state physics and materials science by studying new topological materials, semimetals, unconventional superconductivity, charge density wave physics. etc. in various emerging materials. Our recent experiment on layered Ta(Se4)3I, has opened possibilities to study them at lower dimension. Moreover, we aim to focus on tuning the CDW transition, studying the possible coexistence of competing orders like superconductivity and magnetism in this materials through electrical magnetostransport measurements.