At IIT Delhi, we are committed to creating an ecosystem for generation of new ideas and advancement of scientific knowledge for the benefit of mankind. In order to address the societal problems and to push the frontiers of knowledge, we have taken several steps and launched various programmes to strengthen the multi-disciplinary research culture on the campus. Some of these initiatives include setting up of a School of Interdisciplinary Research (SIRe), launching a Faculty Interdisciplinary Research Programme (FIRP), creation of a Nano-scale Research Facility (NRF), establishing strong linkages with the All India Institute of Medical Sciences (AIIMS), various DRDO and Indian Council for Agricultural Research (ICAR) laboratories, All India Institute of Ayurveda etc. A Joint Advanced Technology Center (JATC) in collaboration with DRDO has been recently set up at IIT Delhi with a goal to carryout interdisciplinary research with well-defined goals of developing advanced technologies and products. IITD has also provided institutional support to about 60 interdisciplinary projects and 40 student Start-ups under the Discovery & Learn 1-2-3-4 projects. We have also recently enhanced the central pool of experimental research facilities for nano-research through creation of a Nanoscale Research Facility with funding from MeitY, DST, MHRD and from our own internal sources. Currently, Nanoscience and Nanotechnology are among the strong areas of research focus at IIT Delhi in terms of number of faculty engaged in these areas and the external sponsored projects. The research in the institute encompasses both basic as well as applied technology areas of national importance. The research activities in the area of Nanoscience and Nanotechnology at IIT Delhi were seeded with support from the Nano Mission Programme of DST in the form of a Unit on Nano Science and a number of research projects.

On the occasion of the decennial edition of the Bengaluru INDIA NANO 2018, IIT Delhi is pleased to bring out this booklet summarizing the research activities in the area of Nanoscience and Nanotechnology being carried out at IIT Delhi. We hope this encourages researchers in India as well as in the rest of the world to collaborate with our researchers and advance the frontiers of this very interesting field.

With Best Wishes,
Prof. V. Ramgopal Rao
(Fellow IEEE, FNA, FNAE, FASc, FNASC)
Director,
Indian Institute of Technology Delhi
### Physics of Nanoscale Systems

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### Applications of Nanoscale Systems

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Research

The central theme of our research work is the science and technology of thin films and nanostructured materials for solar cell, photoelectrochemical, thermoelectric and gas sensing applications. The main highlight of our work has been implementing a new methodology for the large scale and continuous synthesis of size selected nanoparticles having monosized distributions. Metal (Pd, Ag, Cu), alloy (Pd-Cu, Pd-Ag, Si-5n) and Pd-graphene core shell nanoparticles prepared by this method have been used for sensor, solar cell and plasmonic applications. Two dimensional MoS₂ layers grown by CVD technique have been integrated into thin films for fabricating intermediate band gap semiconductors for next generation solar cell devices. Effect of semiconductor-2D layer interfaces on electron transport and phonon scattering has been utilized to improve the thermoelectric figure of merit in semiconductor-Graphene and semiconductor-MoS₂ composite nanostructures. KPFM technique has been used to study 2D layer interfaces in Si-Graphene and CZTS:Se-Cds solar cells. Inorganic-organic hybrid Interfaces of copper oxide with hexa-peri-hexabenzocoronene based monolayer materials have been studied. Electronic properties of these interfaces can be tuned by controlling structural and electronic properties of inorganic (CuO, Cu₂O) and organic counterparts (HBC, HBC-6F), modifying the device characteristics of resulting resistive memory devices.

Representative Publications

i. Large surface charge accumulation in 2D MoS₂/Sb₂Te₃ junction and its effect on junction properties: KPFM based study.


KPFM based study in surface and junction modes of MoS₂/ZnS heterojunctions having monolayer [MS(M)/ZnS], few layer [MS(F)/ZnS] and bulk [MS(B)/ZnS] thickness of MoS₂ layers.
The research group led by Prof. B.D. Gupta (Physics Department, IIT Delhi) is involved in the research and development activities on optical fiber plasmonic sensors for the detection of various chemicals, biological analytes and gases. He has entrenched the field for real time analysis using the techniques of SPR (Surface Plasmon Resonance), LSPR (Localized Surface Plasmon Resonance) and LMR (Lossy Mode Resonance). He has reported sensors for the monitoring of H2S, Cl2, NH3, H2 and methane gases, food quality control, pesticides and heavy metal ions in water, and for the sensing of biologically crucial analytes such as cortisol, glucose, erythromycin, urea, pH, vitamins and many more. The application of nanostructures of metals and metal oxides such as ITO and ZnO has ascertained simple and low cost sensors with direct immobilization of ligands for sensing. Molecular imprinting technique has been incorporated for the sensing of melamine in milk, tetracycline in water and pesticides in waste water.

Representative Publications

Research
We develop and use first-principles computational models to probe the exciting physics and corresponding technological application in condensed matter systems in bulk and nanostructure forms. The condensed matter systems we study include (anti)ferroelectrics, (anti)ferromagnetics, multiferroics, and relaxor ferroelectrics. The unprecedented functional properties of these materials are key to several technological applications. Some examples include energy and charge storage devices, electrocaloric refrigerators, high strain actuators and transducers, magnetic field sensors, spin filters, four logical states devices, and ferroelectric random access memory. The computational methods we employ include the density functional theory and based methods, effective Hamiltonian based atomistic models, molecular dynamics and Monte Carlo simulations, and genetic algorithm based optimization methods.

Representative Publications
Research

The Nanophotonics group is focused on the research of nano and microphotonic materials, optically-active and novel photonic bandgap structures. Our research interests focus on a wide range of device-oriented activities, including passive/active optoelectronics devices, Superlattices, Semiconductor multilayers, MOS devices, silicon based heterostructures, Inorganic-Organic semiconductor heterostructures, and rare-earth-based broad band sources for telecommunication applications and ultrafast-laser matter interactions.

Representative Publications


Research

One of the objectives of our lab has been towards development of nanostructures in diamond like carbon films for their strange hardness. However, by introducing foreign elements in these films we could also reduce the stress and lowered the threshold voltage for their better electronic applications. We also work on ZnO films, where anisotropy / inhomogeneity is introduced at nanoscale for achieving higher magnetic properties by maintaining the smoothness, contrary to the normal approaches. This is done with the application of accelerated heavy ion beams. On the other hand, we have been working on the growth of nanowires using molecular beam epitaxy approach. In addition, growth parameters have been optimized for GaBi Quantum Dots on GaAs substrate using this approach. We also aim at producing silver nanoparticles for their sensing applications.

Representative Publications


Figure 1. ZnO, DLC Films showing the application of nanostructures discussed above.
Research

We use a novel growth technique glancing angle deposition (GLAD) to fabricate different morphology such as zig-zag, nanosprings, cantilevers and vertically standing of metal and metal oxide nanostructures. The grown nanostructures have been utilized in various applications like gas sensing, superhydrophobic/superhydrophilic surface preparation, water filtration and surface enhanced Raman spectroscopy (SERS) based chemical and biological sensing.

Representative Publications


Research
We focus on large area and single step fabrication approaches based on phase SLM assisted and Lloyd mirror interference lithography techniques, for realization of sub-micron linear grating, 2D periodic & quasi-periodic and chiral photonic structures on photoresist. Lasers at wavelengths of 325nm, 355nm, 405nm and 442nm are used for fabrication of nano-photonic structures of dimensions ranging from 300nm to 2 microns covering 5 to 20mm area. This approach opens up the flexibility of interference lithography to fabricate more complex sub-micron photonic structures for applications in sensors, metamaterials, micro-resonators, light trapping, light guiding and many future applications.

Representative Publications


Research

Prof. Neeraj Khare research interest is in the synthesis of semiconducting, magnetic, ferroelectric, superconducting nanostructure/nano-composites and explore its potential for novel applications such as for enhanced photodegradation of organic dyes in industrial waste water, photoelectrochemical water splitting for H₂ production, nanogenerator for harnessing mechanical energy, thermoelectric devices, solar cells, microwave tunable filters, resistive switching memories, superhydrophobic surfaces, higher critical current of superconductor etc. He has demonstrated a correlation in the presence of intrinsic strain/defects in the CFO nanostructures and its effect on tunning the magnetic and optical properties. The core/shell nanostructures/nanocomposites combining semiconducting/magnetic and ferroelectric exhibited enhanced photocatalytic properties and electrical/magnetic tunning of the performance.

Representative Publications


ii. Low field magneto-tunable photocurrent in CoFe₂O₄ nanostructure films for enhanced photoelectrochemical properties, S. Singh, Neeraj Khare, Scientific reports 8, 6522 (2018)

Our group is working on nanomagnetism and spintronics with emphasis on spin torque induced magnetization dynamics. We are interested in study of magnetization dynamics at nanoscale, with focus on spin torque nano-oscillators (SNTO) and spin Hall nano-oscillators. We are also working on spin Hall effect, spin pumping, nanoscale tiny objects called magnetic skyrmions which are very recent developments in the field of spintronics.

Representative Publications


Research

We are interested in the understanding of switching processes and the dynamics in nanoscale magnetic elements or arrays - which can be substantially controlled via the size, shape or density of elements in an array. One of our main interests is in the investigation of the switching processes in individual magnetic nanoelements, novel magnetic nanostructures, etc. where entire magnetic signal, without any loss due to averaging process, can be captured. For measurements of such low-signal samples, we employ state of the art two-dimensional electron gas (2-DEG) based micro-Hall magnetometry method. Hall devices from such high mobility materials are fabricated using lithography techniques at the nano research facility of IIT Delhi. The figure below shows the stray field measurements of hysteresis loop of an α-Fe nanorod filled in a single carbon nanotube using such 2-DEG based Hall sensors.

Representative Publications


Pintu Das
ASSISTANT PROFESSOR
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Research

We are interested in the understanding of switching processes and the dynamics in nanoscale magnetic elements or arrays - which can be substantially controlled via the size, shape or density of elements in an array. One of our main interests is in the investigation of the switching processes in individual magnetic nanoelements, novel magnetic nanostructures, etc. where entire magnetic signal, without any loss due to averaging process, can be captured. For measurements of such low-signal samples, we employ state of the art two-dimensional electron gas (2-DEG) based micro-Hall magnetometry method. Hall devices from such high mobility materials are fabricated using lithography techniques at the nano research facility of IIT Delhi. The figure below shows the stray field measurements of hysteresis loop of an α-Fe nanorod filled in a single carbon nanotube using such 2-DEG based Hall sensors.

Representative Publications

Research

In the area of nanoscience/nanotechnology, we are interested in studying the growth and properties of semiconductor nanowires and 2D materials and also nanoscale devices based on these nanomaterials. The semiconductor nanowires such as GaN and Ga2O3 are grown using hot-wall CVD technique. The 2D materials are grown/fabricated using CVD/exfoliation technique. The nanoscale devices such as Schottky diodes and UV photodetectors are fabricated using electron-beam lithography (EBL) and maskless lithography techniques. We have fabricated high quality/performance nanodevices on semiconductor wires and 2D materials. In the recent times our interest has also been on understanding the current transport process in few layer and monolayer 2D materials based few nanodevices and heterojunctions.

Representative Publications


Rajendra S. Dhaka

Assistant Professor
Department of Physics
Novel Materials and Interface Physics Laboratory
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Lab: MS 402
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Research
Experimental Condensed Matter Physics, Cathode materials for Na-ion batteries (nanostructures and thin-films), Half-metallic Heusler alloys (polycrystalline and thin-films), Single crystal growth (Fe-based superconductors, Topological insulators, etc.), Complex oxides including double perovskites (bulk and heterostructures), Energy storage applications, Spintronic and thermoelectric applications, Solar-cell applications, Solid oxide fuel cells, Strongly correlated physics.

Representative Publications:
Research
In our lab, we work on materials that fall under the broad category of “smart magnetic multifunctional materials”. In this context, some of the materials that are of current interest and are being investigated using magnetic & ferroic tools are: (i) Topological insulators of BTS family- the ideal “spintronics” materials, (ii) Multiferroic thin-films for multiferroic tunnel junctions (MFTJ) & (iii) Multifunctional Huesler Alloys for spintronics.

Recent works in this direction include: magneto-transport properties of BTS and doped BTS nano-flakes, growth of oriented single crystal like half-Heusler films and heterostructures of magnetic & ferroelectric oxides for MFTJ applications. In the area of MFTJs, we are interested in exploiting the magnetostatic effect of the magnetic layer to improve the 4-state non-volatile memory.

Representative Publications

ii. Experimental evidence of surface states in Bi$_x$Te$_{1-x}$Se topological insulators, Bushra Irfan and Ratnamala Chatterjee, AIP Advances 6, 095215 (2016).

iii. Observation of strong magnetoelectric coupling and ferromagnetism at room temperature in Fe substituted ferroelectric BaZr$_{0.05}$Ti$_{0.95}$O$_3$ thin films, Mukesl Kumari, Danilo G. Barrionuevo Diestra, Ram Katyar, Jyoti Shah, R. K. Kotnala, and Ratnamala Chatterjee, Journal of Applied Physics 121, 034101 (2017).


BTS Family of Topological Insulators

Research
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Representative Publications

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Research

I am interested in studying the effect of enhanced electric field near metal nanoparticle surface on molecules. We prepare metal nanoparticles and nanopatterned substrates by nanosecond and femtosecond laser ablation. We have developed laser based methods for shape controlled growth of anisotropic nanostructures and one-step bioconjugation of protein molecules for understanding charge transfer. We are also interested in developing nanomaterials for UV and deep UV plasmonics for refractive index sensing, metal enhanced fluorescence and molecular sensing using surface enhanced Raman spectroscopy.

Representative Publications

Research
An undergraduate from IIT Delhi and PhD from University of Florence, Italy. Trained as biophysicist, now I am learning optics to visualize micro-nano-cosmos of biological world and applying them to develop in vitro diagnostics technologies. My lab is broadly working in two themes:

- Studying the mechanical nature of molecular motors
- Developing automated sample processing methods and optical detection methods for infectious diseases.

Representative Publications


ii. “Maximum limit to the number of myosin II motors participating in processive sliding of actin” Rastogi Khushboo, Pullyakodan Mohammed Shabeel, Pandey Vikas, Nath Sunil and Elangovan Ravikrishnan. Scientific Reports. 2016. DOI: 10.1038/srep32043

Santanu Ghosh

PROFESSOR
Department of Physics
NanoStech Laboratory
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Research

We are actively working in the following areas:

(i) Metal nanoparticles embedded in thin dielectric matrix for field emission, magnetic storage and Extraordinary Hall effect.
(ii) Growth of vertically aligned CNTs and their field emission characteristics

Representative Publications

i. Evidence of local structural influence on the shape driven magnetic anisotropy in electronically excited Ni nanoparticles embedded in SiO2 matrix, D. Sarker, S. Bhattacharya, H. Kumar, P. Srivastava and S. Ghosh, Scientific REPORTS | (2018) 8:1040, DOI:10.1038/s41598-017-18731-x


Research
I work in inter-disciplinary areas of condensed matter physics with broad research interest in first principles based simulation of designing new materials preferably at nano-scale and understanding their properties using state-of-the-art density functional theory (DFT) and beyond methods. We predict properties of materials by integrating different level of theories and validate our prediction using the highest level of theoretical approaches beyond DFT framework or by comparing with experimental data (if available).

Representative Publications
Sujeet Chaudhary

PROFESSOR
Department of Physics
PVD Thin Films - Magnetism and Spintronics

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Research

Employing several variants of sputtering, we fabricate multilayers comprising of interface between ultrathin films of ferromagnetic (e.g., NiFe, CoFe2Al, CoFeB, Co, Fe, etc.) with either non—magnetic metals (e.g., Ta, W, Al, Mo, Cu, etc.) or antiferromagnetic alloys/oxides (e.g., FeMn, IrMn, NiMn, BaFeO3, etc.) or non-magnetic oxides (MgO, Al2O3, bilayers), for number of interesting physical phenomenon involving surface magnetism, viz. shifting of magnetization loops (Exchange bias), Spin polarized tunnelling (Tunnel Magnetoresistance), Spin pumping leading to magnetization (anti) damping, etc. These find applications in information processing and new generation data storage technologies such as MRAMs, magnetization switching, logic, etc. We are also interested in growing nanomagnetic stacks having ultra low spin-damping, perpendicular magnetic anisotropy, complex magnetic structures e.g., Skyrmions, etc.

Research Publications


ii. Observation of Skyrmions at Room Temperature in CoFeAl Heusler Alloy Ultrathin Film Heterostructures: Sajid Husain, Naveen Sisodia, Avinash Kumar Chaurasiya, Ankik Kumar, Jitendra Pal Singh, Brajesh S. Yadav, Serkan Akansel, Keun Hwa Chae, Anjan Barman, P.


Research

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Research Publications


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Research

His primary interest is in optical properties of nanostructured materials, and implementation of nanophotonics concepts for enhancing solar cell performance. He also interested in hetero-junction based silicon solar cells.

Representative Publications


iii. Fabrication of perovskite films using an electrostatic assisted spray technique; the effect of electric field on morphology, crystallinity and solar cell performance, P S Chandrasekhar, N Kumar, S K Swami, V Dutta and V K Komarala, Nanoscale 8 (2016) 6792.

Research

I am interested in understanding of electronic defects and interface states in silicon, III-V and II-VI semiconductors as well as organic semiconductors. I have also been involved in the development of MMIC technology based on GaAs MESFET and HEMT. I have studied carrier transport in organic semiconductors. Currently I am involved in GaN and Ga2O3 nanowires, as also photovoltaics technology. I am also member or chair for several committees of DST, MHRD, DIT and other agencies.

Representative Publications

i. Effect of ammonification temperature on the formation of coaxial GaN/Ga2O3 nanowires; Mukesh Kumar, George Sarau, Martin Heilmann, Silke Christiansen, Vikram Kumar and R Singh, J Phys D: Appl Phys, 50(3), 05302, 2017

ii. Barrier inhomogeneities limited current and 1/f noise transport in GaN based nanoscale Schottky barrier diodes; Ashutosh Kumar, Martin Heilmann, Michael Latzel, Raman Kapoor, Intu Sharma, Manuela Goebelt, Silke Christiansen, Vikram Kumar, and Rajendra Singh; Nature Scientific Reports 6, 27555, 2016.

iii. Designing variable height carbon nanotube bundle for enhanced electron field emission; Manta Khaneja, Santanu Ghosh, P.K. Chaudhury, V. D. Vankar, Vikram Kumar; Physica E 69, 17-176 2015


v. Schematic of GaN NRs fabrication process using Ni nanomasking and reactive ion etching: a top-down approach. (b) FESEM image of Ni NPs formed after rapid thermal annealing Ni film at 850 °C for 1 min. (c) FESEM image of vertically standing GaN NRs after selective RIE of SiO2 and GaN. Size distributions of NPs and NRs are shown in (d, e), respectively. The NRs are about 1.2 μm in length and 210 nm (standard deviation of 35 nm) in diameter. Insets of (b, c) show magnified view of NPs and NRs, respectively.
Fig. 1: TEM image of a gate-all-around nanorod device with sub-10 nm dimensions. The gate stack wrapping the nanorod from all sides can be clearly seen. The devices were fabricated by collaborating industry.

Research

Ultra-high transistor density in logic and memory applications has enabled realization of high-end, multi-billion transistor chips. Such high layout densities have been achieved by aggressively scaling the transistor dimensions, primarily so in the case of the gate length. However, it is critical to control short-channel effects for low static power, hence industry moved from planar transistors to fin type devices. Currently, production nodes have gate lengths in the range of 15-20 nm, and fins or wires down to 5 nm width or diameter are required to achieve the power-performance matrix. At such nano-scale dimensions, electronic properties of materials, such as bandgap and carrier mobility in silicon, are very different from their bulk properties. In the device and wafer level characterization lab, we are focused on modeling and characterization of Si and alternate material devices at such advanced technology nodes, namely 14 to 7 nm CMOS.

Representative Publications


Ankur Gupta

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Research
My research focus is to improve radio-frequency (RF) behaviour of various electronic devices such as MOSFET, HEMT etc. We developed multiple device optimization strategy based on various device parameters. We are looking at novel nano-materials to further improve the RF performance of these devices. We also develop complete circuits and systems using these improved devices which involve analog/mixed-signal circuit design as well as their hardware implementation.

Representative Publications

Research
I and my research group are interested in designing and developing sensitive optical sensors for detecting gases as well as chemical and biological agents. My research group primarily works on the modelling and development of novel nanophotonic and plasmonic sensors for detecting biological molecules, gases, and chemical agents. Some of the sensors being designed and developed in my research group are based on phenomena such as surface plasmon resonance and surface enhanced Raman scattering. My research group is also interested in developing novel nanofabrication technologies to fabricate nano-scale materials.

Representative Publications
iii. Rahul Trivedi, Yashna Sharma, Anuj Dhawan, “Plane wave scattering from a plasmonic nanowire-film system with the inclusion of non-local effects,” Optics Express, 23 (20), 26062-26079, 2015.
iv. Yashna Sharma and Anuj Dhawan, “SERS substrates with gap-controlled enhancements and resonances,” Nanotechnology, 25,
Research
We are working on developing novel intelligent, smart and functional materials for textile applications using various nanomaterials. The research group is involved in modification/functionalization of polymeric/textile substrates using atmospheric pressure plasma or by incorporating nanomaterials in the form of nanocomposites or nanofinishes. Nanomaterials, such as ZnO nanorods have been used to fabricate reinforced micro and nanofibers. Various nanomaterials such as silver, TiO₂ nanoparticles and nanoemulsions have been used to impart different activities such as antimicrobial, self-cleaning and hydrophobicity on the textile surface. Besides, the research group is also active in the area of synthesis of nanomaterials of different size and shape such as nanoparticles, nanorods, nanobelts and nanowires.

Representative Publications


Bhaskar Mitra

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Research

My research group works on a diverse group of projects related to MEMS and microfabrication. We are currently working on Piezoelectric energy harvesters, G-switches, Bistable actuators and switches and ISFET’s for chemical sensing. Additionally, I am interested in the scaling of microplasmas and their applications particularly to chemical sensing.

Representative Publications

i. B. Mitra and Y.B. Gianchandani, The detection of chemical vapors in air using optical emission spectroscopy of pulsed microdischarges from two and three electrode microstructures IEEE Sensors Journal, vol 8 (8), pp. 1445- 1454, Aug 2008

Research

Spintronics has rapidly emerged as a highly pursued research area in solid-state physics and devices owing to its potential application in low power memory and logic as well as the rich physics associated with it. Traditionally in spintronics, spin transfer torque in magnetic tunnel junctions and spin valves has been used to manipulate ferromagnets. Spin orbit torque has recently emerged as an alternative mechanism for manipulating ferromagnets, which offers advantages of lower energy consumption, simpler device structure, etc. In my doctoral thesis, I have shown various applications of spin orbit torque like low power memory and logic, and I have also explored fundamental physics of domain wall motion driven by spin orbit torque. As a faculty at IITD, I want to continue working on spin orbit torque and other aspects of spintronics keeping low power computing applications in mind, particularly non Boolean computing. I am also interested in studying topological effects in magnetic nanostructures like skyrmion formation and motion.

Research Publications


Research

I am interested in developing a greater understanding of solution-processed nanomaterials for low cost fabrication of solar cells, LEDs, sensors, photodetectors, TFTs, etc. We develop methods of depositing functional thin films with nanoscale uniformity from solution-based precursors while exploiting and tuning material chemistry and surface interactions to reduce the thermal budget. We are also carrying out studies of nanoscale transport in disordered materials like organic and inorganic semiconductors to develop better models relevant for device designers for scaled devices. We use both bottom up and top down fabrication methods to produce various devices on mechanically flexible substrates to develop new functionalities not possible with conventional microelectronic fabrication methods.

Representative Publications


ii. Ferroelectric random access memory based on one-transistor-one-capacitor structure for flexible electronics, D Mao, I Mejia, AL Salas-Villasenor, M Singh, H Steiger, BE Gnade, MA Quevedo-Lopez, Organic Electronics, 14(2), 505-510 (2013)


Research

I am interested in building low-power next generation non-volatile memory nanodevices. In our on-going research we investigate different families of emerging resistive memory technology such as OxRAM, PCM, CBRAM and STT-MRAM. We are building a diverse application ecosystem around such nanodevices. We use them for applications beyond conventional storage. We are among the few first and leading groups in the world to exploit NVM nanodevices for machine-learning, neuromorphic computing, and imaging applications. In our group we look at all stages from material stacks, device fabrication, characterization, Nano architectures to final end application.

Representative Publications


Research

The group is engaged in the synthesis of isotropic and anisotropic nanostructures based on silver, TiO$_2$, ZnO, MoO$_3$ as well as Janus particles. The application of these nanostructures for functional finishing, coating of textile/polymeric surfaces has been demonstrated. Understanding the role of aspect ratio of nanostructures in governing the physical and mechanical properties of polymer composite fibres has also been the focus of our research. The fundamental concepts of electrospinning to obtain uniform nanofibres of desired morphology for applications ranging from tissue engineering to filtration have also been investigated.

Representative Publications


iv. R. Nain, K. Yadav, M. Jassal, A. K. Agrawal, Aligned ZnO nanorods as effective reinforcing material for obtaining high performance...
Research

My research is focused on investigation of mechanical and tribological properties of materials in nanoscale contacts. Using novel atomic force microscopy based methods, my group is investigating molecular level force interactions at the liquid-solid interfaces which are relevant for understanding adhesion, friction, lubrication and wear at the single-asperity level. Most recently, I am exploring interactions of industrial lubricant additives with the surfaces of lightweight alloys for automotive applications which will help understand molecular level functionality of such additives. The figure below shows in situ imaging of growth of a tribochemical film derived from zinc dialkyldithiophosphate (ZDDP), an industrial antiwear additive, in a nanoscale single-asperity sliding contact. The study demonstrates that the growth of such films is governed by the contact stresses and temperature which protects the sliding components of automotive engines against wear.

Representative Publications


Research

I am interested in developing MEMS/NEMS sensor system for recording important physical quantities for various applications such as environmental monitoring, biomedical and harsh environments. The deformation of the MEMS actuators is recorded via piezoresistive, capacitive, magnetostrictive and piezoelectric principles. Nano-dimension structures are recently emerged due to their quantum physics phenomenon's and it has potential to significantly improve the measurement limits of conventional macro/micro scale sensing materials. These nano-dimension structures can be integrated with the MEMS structures to sense various physical quantities such as pressure, force, air flow, temperature, humidity etc. Enormous application areas can be targeted after developing these tiny sensors and then integrating many sensors onto a small scale chip.

Representative Publications


ii. Vaibhav Rana, Kshitij Saxena, Saakshi Dhanekar, Pushpapraj Singh, "Robust Piezoresistive Cantilever MEMS Switch for Extremely High Air/Gas Flow Sensing" ICMAT, 18-23 June 2017, Singapore. [Accepted]

iii. Sushil Kumar, Saakshi Dhanekar, Pushpapraj Singh, “Molybdenum Based RF MEMS Switch for Harsh Environment Applications”, IC-MAT, 18-23 Jun 2017, Singapore. [Accepted]


S. Aravindan
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Research
Interested in surface structure fabrication at micro and nano scale for inducing special functionality/artificial properties to substrates. Dual Beam (FIB-FESEM) System is used to generate the moulds, tools etc. Moulds and tools are integrated through multiple processes for the fabrication of large area structures. Surfaces having low reflectance (Optical functionality), induced hydrophobicity (Wettability) and increased cell adhesion properties (Bio function) are fabricated through these approaches. We work on a wide range of substrates which includes pure metals, alloys, composites, dielectrics, layered structures etc. Interested in study of conventional manufacturing processes like welding, casting, friction stir processing for the development of nano composites and ultra fine grained metals.

Representative Publications
Research
Prof. S.K. Khare has been actively involved in the wide research arena of nanotechnology by working on different aspects of interactions of nanomaterials with biological entities like microbes and enzymes. His candidature covers broad areas of research like nanobiocatalysis and nanotoxicity. He is actively engaged in developing efficient biocatalysts by immobilising industrially relevant enzymes on different nanomaterials. His group has contributed significantly to understanding about the potential impact of nanoparticles on the environment and their interactions with biological systems. His research findings on the microbial system mediated mechanisms involved in nanotoxicity have led to many publications and book chapters to his credit.

Representative Publications


Research

My research area focuses on development of permanent solutions for societal issues. We implement wafer scalable processes for development of devices for detection of alcohol, diabetes and E. coli bacteria. These devices comprise of nanomaterials which includes porous silicon, silicon nanowires, metal oxides (TiO2, MoO3, In2O3 etc.), 2D materials (MoS2) and in some cases heterostructures. The figures below show the microscope images of nanomaterials and devices developed and packaged. Few devices are being tested for detection of E. coli bacteria in water using two detection techniques: (1) Impedance Spectroscopy, (2) PL spectroscopy. The main motive of the research is to develop low cost, robust, handheld sensors to be used by the common man.

Representative Publications


Research

My research area focuses on development of permanent solutions for societal issues. We implement wafer scalable processes for development of devices for detection of alcohol, diabetes and E. coli bacteria. These devices comprise of nanomaterials which includes porous silicon, silicon nanowires, metal oxides (TiO2, MoO3, In2O3 etc.), 2D materials (MoS2) and in some cases heterostructures. The figures below show the microscope images of nanomaterials and devices developed and packaged. Few devices are being tested for detection of E. coli bacteria in water using two detection techniques: (1) Impedance Spectroscopy, (2) PL spectroscopy. The main motive of the research is to develop low cost, robust, handheld sensors to be used by the common man.

Representative Publications


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Research
Dr. Samaresh Das is fascinated to carry research in Nanoelectronics and Optoelectronics. He has worked on quantum dot based memory devices, light emitters and photo-detectors on silicon substrate. He worked on the fabrication and characterization of Junction less Nanowire Tri-gate MOSFET. Currently, his group is working on highly efficient Photodetectors, Gas and Bio-Sensor and Quantum electronic devices. Research Students: Bhagaban, Veerendra, Priyanka, Wasi and Akshay

Representative Publications


High sensitivity Junction less Phototransistor
MoS2/Si heterojunction high speed photodetector
Room Temperature Gas Sensor: Metal Oxide (TiO2 or MoO3) Nanostructures on Porous-Si
Multi dopant resonance conduction in Nanowire @ 25K

76
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Research

Dr. Sandeep K. Jha is a joint faculty at the Centre for Biomedical Engineering (CBME), Indian Institute of Technology Delhi and All India Institute of Medical Sciences New Delhi. His areas of interest include Lab-on-a-chip and Microfluidics devices for biomedical applications; electrochemical and optical chemical and biosensor; bioinstrumentation & nanomaterials, conducting and synthetic polymers based immobilization techniques. Previously he served under various capacities at Banasthali University, India; Korea University, South Korea; KIIT University, Bhubaneswar, India; Myongji University, South Korea; Indian Institute of Technology, Mumbai, India and Bhabha Atomic Research Center, Mumbai, India. His teaching interests include diversified subjects such as biosensor technology, point-of-care medical diagnostic devices; bionanotechnology; bio-electrochemistry; Industrial biotechnology & topics related to microfabrication and microfluidics.

Representative Publications

i. Appan Roychoudhury, Sudhanshau Baru, Sandeep K. Jha, (2016) Dopamine biosensor based on surface functionalized nanostructured nickel oxide platform. Biosensors & Bioelectronics. 84: 72–81 (IF 7.5)


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Research

My group consisting of nine Ph.D. students and five post-doctoral fellows and three Master students primarily working on development of nano-materials as electrochemical, photochemical and photo-electrochemical catalysts and catalyst supports and their application in electrochemical storage devices, sensor development. Under Nano Mission Project, micro glucose fuel cell and, DeITy sponsored NRF projects, microfluidic fuel cell based on CNx nano-fibre as cathode have been developed and demonstrated. We are also working on in-situ water splitting in micro reactor and use of hydrogen and oxygen in micro fuel cell and CO₂ conversion to chemical fuel (artificial photosynthesis) through photocatalytic route assisted by water splitting. Another major thrust in our lab is to develop direct hydrocarbon proton exchange fuel cell and solid oxide fuel cell. For this purpose we are developing various co-doped perovskites material as anode and cathode, which provides both ionic and electronic conductivity and active towards redox reaction.

Research Publications


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Suddhasatwa Basu, F.N.A.Sc.

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Research

My research interests focus on Nanoscale devices for electronics and sensor applications addressing the real world problems. My current projects include development of highly sensitive and selective nano-electro-mechanical-sensing platforms for healthcare, agriculture and environmental applications, use of bottom up approaches for solving the CMOS technology scaling issues and flexible electronics. Some of these projects involve complete system development integrating the sensors with electronics, power source and a sample preparation stage meeting the requirements of Internet of Things applications. Many of these projects are undertaken in close collaboration with industry, with commercialization as a target.

Representative Publications


Ashok K. Ganguli

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Research
Current research of our group is focused on 2D materials, metal oxides, metal chalcogenides and alloy nanostructures for photoelectrochemical water splitting, photocatalytic organic pollutant (dye) degradation, photocatalytic fuel generation and water purification. Various transition metal based inorganic solids like based binary and ternary alloy nanostructures, metal oxides, carbide, nitride, sulphide and phosphide nanostructures were rationally designed by our group for their electrocatalytic activity in water splitting and CO₂ conversions. We are also working on the fabrication of microfluidic chip for surfactant-free synthesis of metal oxides nanostructures for online photocatalytic devices. Water purification cartridge development using novel nanoadsorbents is another area of research of our group.

Representative Publications

Representative Publications
Research

My research group focuses on design and manipulation of one-dimensional nanostructures such as nanofibers using polymer self-assembly and electrospinning as fabrication tools. We have used these fabrication tools to fabricate functional and multifunctional one-dimensional nanomaterials. The below shown figure shows polymer nanorods with helically assembled silver nanoparticles in the core ascertaining TEM tomography. These novel nanostructures were obtained using the hierarchically self-assembled structures from block copolymer/nanoparticle mixtures. Furthermore, our research group also works on understanding the polymer properties confined in nanoshaped materials. For example, we are currently investigating the crystallization of polymers confined in nanodomains formed either via self-assembly or electrospinning techniques.

Representative Publications


ii. Hairy Core-Shell Polymer Nanoobjects from Self-assembled Block Copolymer Structures, B. Nandan, A. Horechyy, ACS Applied Materi-
Jayati Sarkar
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Research
I am interested in studying instabilities at soft interfaces. Pattern formation through self organization method of elastic thin films, which involves reorganization of surface morphology due to application of an internal or external force field to attain minimum energy state, has been found to be an excellent cheaper alternative route compared to conventional lithographic techniques for meso/nano scale fabrications at such soft interfaces. The patterns formed are found to be short-wave and independent of the nature of interactions present. To impart enhanced functional properties it is essential to achieve smaller and smaller length scales. We have found that remarkably smaller length scales are achieved with contact proximity configuration of elastic films cast on patterned substrates than those obtained with films cast on flat substrates. When van der Waals contact interactions are present, the patterns are uniformly formed throughout the film but are not regularly ordered whereas both uniformity and order of patterns is attained with electrostatic interactions. Such patterns are very useful in various applications like micro fluids; they are formed with great ease and can be morphologically tuned by tuning the externally applied electric field. We have also shown that miniaturization of patterns can also be achieved in thin wetting liquid films if the viscosity of the film is found to vary with the thickness.

Representative Publications

Top Panel: Left to right display progressively smaller wavelength features seen on soft film surfaces cast over patterned substrates created in lab with help of commercially available CDs or naturally available water lily leaf replicas. Length scales obtained are all less than 3h seen over planar substrates.

Middle Panel: The first figure shows a contactor substrate assembly that when connected to an external e-field leads to an uniform field across the film and engenders progressively miniaturized columnar surface patterns from left to right in higher rough-substrate films as found from non-linear simulations. Length scales obtained are all less than 3h seen over planar substrates.

Bottom Panel: Non-linear simulations reveal satellite hole formation by deepening of satellite depressions between the rims of growing holes in liquid thin films undergoing dewetting with higher base mobility as opposed to the rising for normal films.
M. Ali Haider

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Renewable Energy and Chemicals Research Group

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Research
The Renewable Energy and Chemicals (REC) group is focused on the study of molecular heterogeneous catalysis to provide sustainable solutions for the demand of energy and chemicals. Whether it is required to convert biomass into fuels and chemicals, or to convert fuels into electrical energy, advancement in catalyst materials forms the core of development. The group is interested in an integrated approach in which material synthesis is guided by a molecular level understanding of the reaction. Both experiments and ab-initio level (DFT) theory are applied in solving a problem at hand. The group has recently developed a novel bio-milling synthesis method to fabricate layered perovskite structured materials to be used as the cathode in solid oxide fuel cells with high electrocatalytic activity (Figure a). In another successful effort, facet dependent selectivity control for phenol hydrogenation was elucidated on defined Pd nanostructures (cubes, spheres, octahedral particles) of size ranging from 6 to 25 nm as shown in Figure (b).

Representative Publications

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Research

Our research focuses on the electrochemical investigations on advanced functional materials for renewable energy harvesting and its storage so that the use of traditional fossil fuels can be minimized. The main goal of the research is to design and develop the nano-electrocatalysts based on nanoparticles anchored to a suitable support. Metal nanoparticles and semiconductor quantum dots are being studied in this regard. Carbon based materials such as CNTs, graphene, and reduced graphene oxide as well as semiconductor oxides such as TiO₂, ZnO are used as a support material. Our group concentrates mainly on the following aspects,

(i) fabricating nano-electrocatalysts for the electrochemical conversion of organic pollutants such as CO₂ into fuels and/or useful chemical feedstock, (ii) Electrochemical and spectro-electrochemical studies on the advanced functional materials in order to characterize and tune their electronic band structure, and (iii) developing photo-electrocatalysts based on semiconductor quantum dots for photovoltaic solar cell applications.

Representative Publications


Research
I am interested in studying the changes that can be brought about in nanomaterials as a function of various synthesis parameters. We develop a number of new nano-heterostructures and study the basic principles governing their charge dynamics. The figure below shows such a system with Type-I and Type-II junctions both exhibiting fluorescence. Through the links on my webpage, you will also find a number of bio-applications being developed based on these materials. We are also interested in developing materials for photovoltaics and photocatalysis including hydrogen evolution reactions. In recent times we have also been interested in perovskite nanomaterials for light emitting properties.

Representative Publications
iii. Probing the Mechanism of Fluorescence Quenching of QDs by Co(III)-Complexes: Size of QD and Nature of the Complex, Both Dictate

Research

The current research utilizes technological skills for the development of sustainable green solutions. Recently, attempts have been made to develop botanical-based nanoparticles for the effective control of indoor pests (housefly and mosquitoes) and food microbes. Nanoparticles of PEG-Mentha oil were prepared by melt-dispersion method (Figure 1). The developed nanoparticles were characterized using various analytical (Zeta potential, DLS, FTIR, UV-vis) and microscopic techniques (SEM). The developed PEG-Mentha nanoparticles showed considerable mortality against housefly larvae in lab (100%) as well as simulated field condition after first week (93%) and 6th week (57%) of application (Kumar et al., 2014).

Research Publications


Research

Research at our lab focuses at exploring the potential of cell penetrating peptides as effective nanocarriers for macromolecule delivery including therapeutic molecules. We are investigating the versatility of CPPs as cargo delivery vehicle, organelle targeting peptide, and application in peptide based therapeutics. One of the areas is ocular disease management by CPP-drug complex. Conjugation of an antifungal drug with CPP resulted into enhanced cell penetration as well as antifungal activity (Figure 1 and 2). We are in the process of developing nanoparticle based drug delivery systems for ocular disease management. Another area focuses on antimicrobial aspects of existing CPPs.

Representative Publications


Arun Kumar

ASSOCIATE PROFESSOR

Effects of nanomaterials on biodegradation; Reuse of nanomaterials-contaminated water; Risk due to exposures to nanomaterials

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Research:

My research group studies on (1) improving understanding on effects of nanomaterials toxicity to bacteria and its implications on biodegradation in wastewater treatment, (2) exploring reuse potential of nanomaterials-contaminated water as irrigation water, and (3) identifying knowledge gaps in estimating risks due to exposures of nanomaterials from environment. We specifically focus on effects of mixtures of nanomaterials in environmental samples. The figure below details different aspects of our research focus and its interconnectedness.

The group is actively collaborating with related groups in India (IIT Delhi (Chemistry, Kusuma School of Biological Sciences, and Centre of Biomedical Engineering), INST Mohali, IIT Bombay (Centre for Environment Science and Engineering)); USA (Michigan State University East Lansing); Germany (Leibniz University, Hannover).

Representative Publications

i. Srivastava, S. and Kumar, A. Comparative Cytotoxicity of Nanoparticles and Ions to E.coli in Binary Mixtures. J. Env. Sci. [accepted]


iii. Piplai, T., Kumar, A. and Alappat, B.J. 2017. Removal of mixture of ZnO and CuO nanoparticles (NPs) from water using Activated Carbon
Our research is focused on the development of functional polymeric systems at nanoscale for diverse healthcare applications in tissue engineering, wound care systems, implants, catheters and infection resistant materials.

(i) Tissue Engineering: Design and development of biodegradable nanofibrous electrospun mats for tissue engineering for human organ reconstruction with precise inputs in skin, urinary bladder and cardiac systems. (ii) Bioactive nanogels: Enormous potential lies towards the preparation of the nanohydrogels where nanosilver may be generated in-situ in the gel matrix to develop nano coatings on implants. The recent focus of the group lies in the development of functional nanogels with herbal therapeutics such as curcumin and aloe vera and essential oils. (iii) Woundcare Systems: Natural polymers reinforced with nanoparticles and functional moieties have been employed for the development of membranes and infection resistant biomaterials.

Representative Publications


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Research

Nanoplatforms for therapy and diagnostics, drug delivery systems, antimicrobial polymers for water disinfection, polymer synthesis and modification for biomedical and Industrial application. Major focus is on the development of biodegradable nano vehicles for targeted delivery of anticancer agents, particularly small molecules/peptides/DNAs, for prolonged period of time with an aim to increase the efficacy and reduce toxicity. These interdisciplinary research activities are in collaboration with Dana Farber Cancer Institute, Boston, USA; All India Medical Sciences Delhi and Institute of Nuclear Medicine & Allied Sciences Delhi (INMAS). Biodegradable polymeric nanoparticles and process of preparation thereof for delivery of chemio, peptide and DNA based anticancer agents has been patented and technology has been transferred to Nanoproteagen, Boston, USA.

Representative Publications

i. Sruti Chattopadhyay, Ameet Kaur, Swati Jain and Harpal Singh, "Sensitive detection of food-borne pathogen Salmonella by modified PAN fibers-immunosassay" Biosensors and Bioelectronics, 2013, 45, 274-280. (IF 5.4)

Research

Our research interest is the development of bio-inspired and bio-derived nano-materials to meet unmet needs in treating and diagnosing disease. We strive to use chemistry and engineering approaches to iteratively design, synthesize, characterize, evaluate and validate next generation biomaterials which can self-assemble to form nanoparticle with the goal of making a translational impact on improving human health. A major research focus is developing bio-inspired materials that will allow better therapeutic outcome for cancer therapy.

In my post-doctoral studies, I demonstrated that conjugation of multiple copies of hydrophobic chemotherapeutic to recombinant chimeric polypeptide spontaneously self-assemble into sub-100-nm-sized, near-monodisperse nanoparticles which improve plasma half-life, tumor accumulation and therapeutic efficacy of the chemotherapeutic. To encapsulate hydrophilic chemotherapeutics into the core of polymeric nanoparticles, I designed a recombinant asymmetric triblock polypeptide (ATBBP) that self-assembles into rod-shaped nanoparticles, and which can be used to conjugate diverse hydrophilic molecules, including chemotherapeutics into their core.

Representative Publications


Cell cycle arrest at the G2/M phase by CP-PTX*
Research:
Nanostructures, due to their similar size scale as bio-macromolecules and cellular components, provide an unprecedented opportunity to target and potentially modulate important biological processes. My research group strives to characterize the interactions of these materials with the biosystem of interest, and to optimize them for specific biomedical applications such as tissue engineering, drug delivery and bio-imaging. My lab harnesses and integrates concepts of from chemistry, materials science, and biology for the systematic design and synthesis of high-fidelity biomedically-relevant nanomaterials. We believe that such a rational approach is necessary for advancing nano-materials and biomedical technologies of the future.

Representative Publications


Prashant Mishra

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Research

The current interest of our group is nanoparticle based drug delivery and protein based nanodevices. We are synthesizing hybrid metal-bioactive nanoparticles for their antimicrobial and anticancer properties. Our group is synthesizing drug loaded biodegradable nanoparticles for targeted and enhanced drug delivery. We are using rational protein design for self assembly based nanopatterning and for applications in nanodevices.

Representative Publications


Sitikantha Roy

Research

Atomic force microscopy based single cell based force spectroscopy can be used to extract the cell's elastic, viscoelastic and adhesion properties. These biomechanical properties of live biological cells play important role in cell-matrix adhesion, morphology, and migration. They can be used as potential biomechanical markers in understanding the health state of cells in tissues and in understanding the effects of drugs on cells. We are developing uncertainty-free experimental methods to characterize the cell material and working on developing mathematical contact models for a reliable estimate of the biological cell material properties.

Representative Publications


Nanoscale Research Facility @IIT Delhi

Nanoscale Research Facility (NRF) at IIT Delhi has been established in August 2010 with the support from Ministry of Electronics and Information Technology (MeitY) and IIT Delhi for implementing the MeitY funded project on Research Initiative on “Non-Silicon Based Technologies for Nanofabrication and Nanoscale Devices”. The facility consists of class 100/1000 clean rooms with several state of the art fabrication/thin film deposition equipments and characterization facilities. Online booking system is maintained for the use of the equipments at NRF (http://nrf.iitd.ac.in/slotbooking/). These facilities are also open to other academic institutes and industry. Details of the research facilities are given at NRF website (http://nano.iitd.ac.in/).

The research programme of NRF has been focused on both thematic areas of national importance and basic research with importance to the development of nanoscience and nanotechnology. More than 50 faculty members from different Departments/Centres of IIT Delhi are participating in cutting edge research at Nanoscale Research Facility. Using the facilities at NRF, several deliverables related with Nanophotonics, Nanomagnetics, Nanomechanics, Nanophotovoltaics, Nanoelectronics and Biosensing have been successfully demonstrated. Currently a new mega project NNetRA (Nanoelectronics Network for Research and Application) is being implemented which has been jointly funded by MeitY, DST and IITD. This project focuses on developing Nanoscale Devices for Health, Agriculture, Safety and Energy Sectors. In this NNetRA project there will be networking with IIT Bombay, IIT Madras, IIT Kharagpur and IISc Bangalore. With the grant of NNetRA project we are now moving forward from a capacity building to develop micro/nanoscale working prototype devices which can be given to users.

Neeraj Khare
Coordinator, NRF

Selected Nano Facilities

- Brucker AFM
- E-beam lithography
- Ellipsometer
- Ebeam evaporation
Inductively Coupled Plasma Reactive Ion Etching

Plasma Enhanced Chemical Vapour Deposition System