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PROGRAMME

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Microfluidics for Ultra-High-Throughput Chemistry & Biology

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Recent years have seen considerable developments in the use of microfabricated systems for chemical/biological experimentation. Interest in microfluidics has been driven by concomitant advances in genomics, proteomics, drug discovery and diagnostics, with a clearly defined need to perform rapid measurements in small volumes. Put simply, microfluidic activities have been stimulated by the fact that physical processes can be more easily controlled when instrumental dimensions are reduced to the micron scale. I will discuss how the spontaneous formation of droplets in microchannels can be exploited to perform a variety of experiments and why the marriage of such systems with optical spectroscopies provides a direct route to high-throughput experimentation. I will show how droplets can be used in nanomaterial synthesis, cell-based assays and DNA amplification. I will also describe studies focused on the development of an imaging flow cytometry platform that allows high-resolution imaging of cells at throughputs approaching 105 cells/second.

Tailoring properties of magnetic metamaterials

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Analogous to optical metamaterials, magnetic metamaterials can be fabricated with properties determined by the texture at the nanoscale. Such systems can be realized by arranging ferromagnetic nanodisks in a lattice (e.g. figure 1), each disk of such small size that it is in a monodomain state.[1,2] The magnetic spins in each disk act in unison as a single superspin, and the coupling between the disks is governed by the dipolar field emanating from each disk. The ground state arrangement of the magnetic superspins is predicted to be governed by the symmetry of the nanodisk array.[3] However, few experimental realizations exist, possibly due to the strict nanofabrication and characterization requirements.[4] In this work we have fabricated arrays of ferromagnetic permalloy nanodisks by electron beam lithography and lift off. Characterization of nanomagnet arrays by photoemission electron microscopy reveal, as predicted, antiferromagnetic order in the square lattice and ferromagnetic order in the hexagonal lattice.

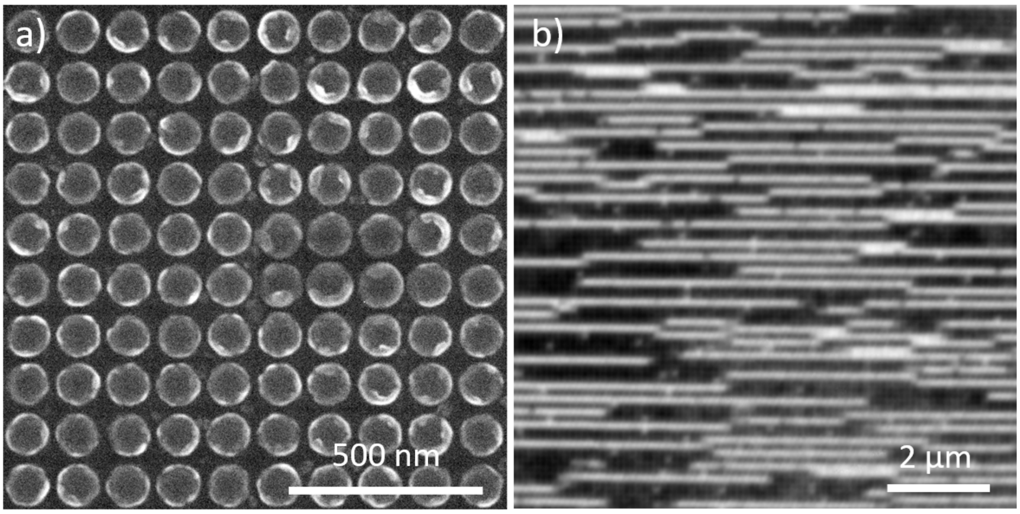

Figure 1 a) Scanning electron micrograph of permalloy nanodisks on a square lattice. b) Magnetic stripe pattern revealed by XMCD PEEM on the square lattice.

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Writing wires by nanoscale control of defect structure

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Controlling conductivity is of critical importance for any electronic device. This control of conductivity is used in computers for processing, e.g. logic gates, and as a way of storing information, e.g. the giant magnetoresistive effect. In this work, we demonstrate a new way of controlling conductivity, using the electrically biased probe-tip of an atomic force microscope. We write conducting features with nanoscale precision, enhancing conductivity locally by a factor of 4000. This is done on the inherently functional ferroelectric semiconducting. By combining electron-energy loss spectroscopy (EELS) and density functional theory (DFT) calculations, we attribute the conductivity enhancement to the electric-field driven formation of anti-Frenkel defects (movement of oxygen from a lattice site to an interstitial site).

Bacterial surface adhesion studied and manipulated at the nanoscale

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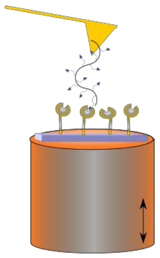
Simple and complex carbohydrates (glycans) have long been known to play major metabolic, structural and physical roles in biological systems. Recently an additional function of glycans; the targeted microbial binding to host glycans has received increased attention. In a recent review, we provided an overview of the role of glycans in bacterial adhesion to mucosal surfaces, and also argue that the single-molecule techniques are powerful tools to advance our understanding of the mechanisms underlying bacterial adhesion. [1] In the talk, I will present examples of studies in which we have used AFM and optical tweezers [2,3] to provide new insight into the functions of glycans in living systems. In addition, I will present our work related to the preparation of bacterial microarrays using soft lithography techniques available in NTNU Nanolab [4] and their potential use in investigations of bacteria, including but not limited to their surface adhesive properties.



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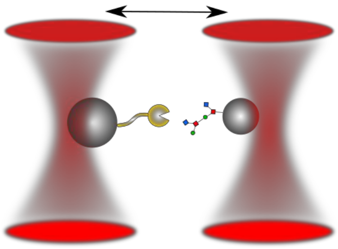
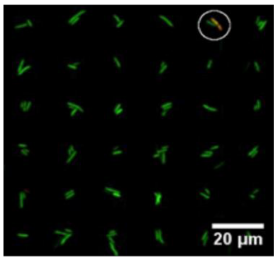


Optical tweezers



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Dry Submicron Porous Elastomeric Coatings for Durable Icephobicity

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Ice accretion is a severe challenge for both production and livelihood in cold regions. Previously reported high-performance icephobic surfaces by infusing lubricants are either temporarily icephobic, chemically unstable or mechanically weak. Herein, we report the design and fabrication of dry submicron porous polydimethylsiloxane (PDMS with weight ratio 10:1) elastomer based chemically stable and mechanically robust icephobic materials. The relationship between the ice adhesion strength and porosity is revealed. Without any surface additives and lubricants as well as sacrificing the crosslinking density of elastomer, the stable ice adhesion strength of the dry submicron porous coating reaches ca. 16.8 ± 5.8 kPa after 50 icing/deicing cycles. In addition, the icephobic coatings show excellent chemical stability and mechanical robustness, and the ice adhesion strengths are all less than 30.0 kPa after acid/base/salt/organic solvent corrosion and 1000 abrasion cycles. The dry submicron porous elastomeric strategy opens up a new avenue for high-performance durable icephobic materials with excellent stability and robustness.

Bias-dependent Scanning Photocurrent Microscopy on a Single GaAs Nanowire Graphene Hybrid Device

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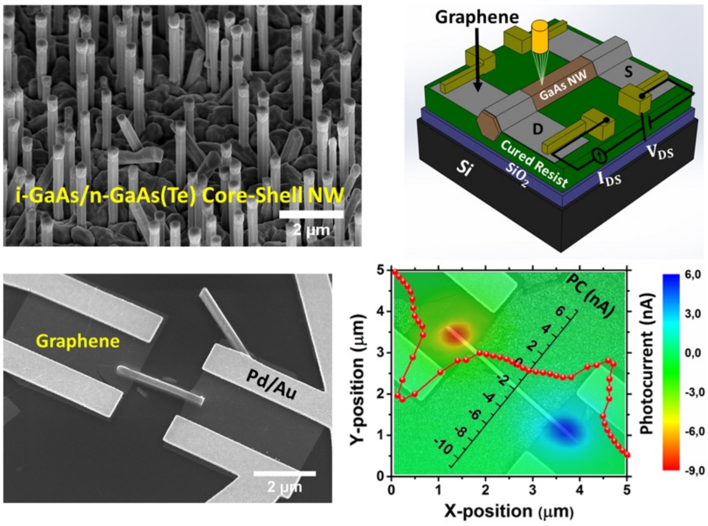
Scanning Photocurrent Microscopy (SPCM) is a valuable spectroscopy technique to investigate the junction properties between semiconductor nanowires (NWs) and its contact electrodes which can provide critical insight into local transport mechanisms with a high spatial resolution.[1-2] Many NW-based optoelectronic devices like solar cells, LEDs and photo-detectors could benefit from using a transparent and flexible electrode for the improvement of their performance through enhanced light absorption or better light extraction. In this context, graphene is a very appealing candidate which could also serve as a substrate for the NW growth [3] and at the same as a transparent and flexible electrode to the NWs. However, to the best of our knowledge, a detailed study of NW/graphene junctions has not been explored yet. In this work we present an in-depth investigation of such hybrid junction by using SPCM through local photoexcitation. In order to make reliable contacts between the NW and graphene we have employed a position-controlled micro-transfer and imprinting technique to embed the NW in a curable photo-resist layer.

We present a quantitative analysis of single GaAs NW/graphene hybrid junction from bias-dependent SPCM measurements. The measurements have been compared with conventional GaAs NW/metal junctions to better understand the benefits of using graphene as a replacement of metal electrodes for NW applications. An amplified photocurrent polarization anisotropy was observed at the NW/graphene junction compared to at the bare NW position suggesting an enhanced anisotropic electron-photon interaction at the NW/graphene junction. [4]



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Gold over nano-spheres for fiber based Surface-Enhanced Raman Scattering sensing

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Raman scattering is an inelastic scattering of light by molecular vibrations that provides fingerprints of specific molecules without the need for labelling elements. Moreover, surface-enhanced Raman scattering (SERS) is a technique that can increase the Raman signal by a factor on the order of 10^6 – 10^{10}, making single molecule detection possible. The signal enhancement relies on the excitation of the surface plasmon resonances of nanoscale metal features that generate strong electromagnetic fields and enhance both the incident excitation and the resulting Raman scattered fields.

We present the fabrication and analysis of SERS substrates by using a nano-sphere lithography method, where a single layer of polystyrene microspheres is self-assembled on an air-water interface, transferred to a substrate and coated with 100-200 nm gold layer, composing a Au film over nano-spheres (AuFON, Fig.1). The application of an AuFON structures in fiber based sensing devices will be presented.

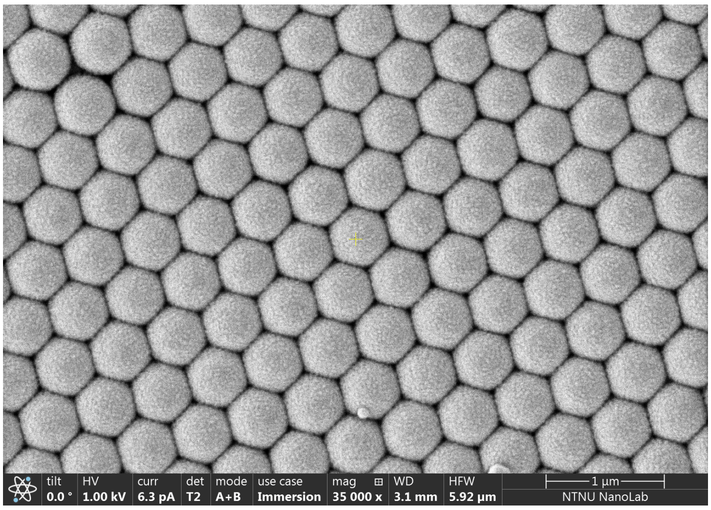

Fig.1 SEM image of fabricated gold over nano-spheres structure.

Micro- and Nanoencapsulation and Controlled Release of Active Ingredients

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Micro- or nanoencapsulation is a process whereby an active ingredient – gas, liquid or solid – is wrapped within e.g. a polymeric coating, forming small particles, typically in the micrometer or nanometer range. The polymer acts as a barrier, isolating and protecting the active ingredient from the external environment, and can dissolve or disintegrate through specific stimulus, releasing the capsule content under specified conditions. Depending on the active ingredient and the intended application, micro/nanoencapsulation is used to protect sensitive ingredients such as vitamins from oxidation, increase solubility/compatibility, mask unwanted taste and smell, increase bioavailability, transport nonpolar drug molecules via the bloodstream, promote gradual or triggered release and more. In this talk, requirements for matching wall materials, micro/nanoencapsulation method and release profile will be discussed for several active ingredients used in food, personal care products and nanomedicine.

A hidden correlation between peaks in absorption spectra of zigzag graphene nanoribbons and armchair carbon nanotubes

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Graphene nanoribbons and carbon nanotubes are both quasi-one-dimenstional structures based on graphene. Depending on the geometry of their edges (for ribbons) or terminations (for tubes) they are classified on two major types – zigzag and armchair. Such classification ensures that an armchair carbon nanotube (ACNT) unrolls into a zigzag graphene nanoribbon (ZGNR). This transformation preserves the number of atoms in the unit cells of both structures but alters their optical properties properties. We show that matching transverse momenta of the electrons in armchair carbon nanotubes and zigzag graphene nanoribbons allows one to "decompose" the tube onto two zigzag ribbons of equal width maintaining positions of the optical absorption peaks of the initial tube (see Fig. 1). The correlation between peak positions of thus related structures is important in optoelectronics applications for enhanced resonance interaction between the structures and for avoiding a crosstalk in complicated carbon-based nanodevices.

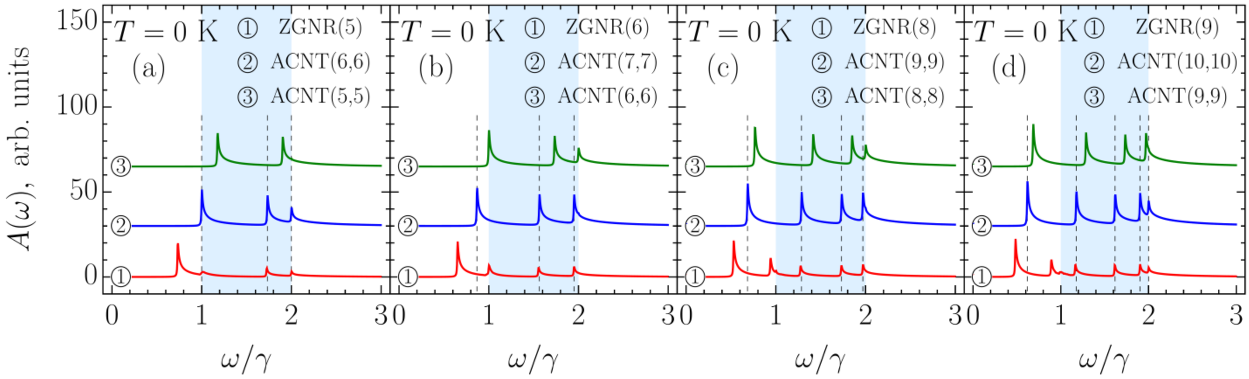

Fig. 1: The optical absorption spectra of zigzag graphene nanoribbons and armchair carbon nanotubes.

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KNN Thin Films on Flexible Substrates

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$K_{0.5}Na_{0.5}NbO_3$ (KNN) thin films hold great potential for lead-free ferroelectric components in electronic devices. Synthesis of flexible ferroelectric thin films on polymeric substrates is advantageous for maximizing the functionality of the films, as the ferroelectric loss is reduced with the lower clamping effect from the substrate. Liu et al. [1] have reported on synthesis of $PbZr_xTi_{1-x}O_3$ (PZT) thin films on flexible polyimide substrates using high temperature crystallization and a transfer technique of the prepared ceramic film onto the polymer. Here we report on the synthesis of lead-free KNN thin films on polydimethylsiloxane (PDMS) substrate, based on the technique reported by Liu et al. [1] and an aqueous solution for KNN thin films [2].

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Research on Tungsten oxide Electrochromic Thin Films

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Tungsten oxide (WO_3) is probably the most studied EC material for smart window applications. In this work, we developed a radio frequency sputtering method for WO_3 film preparation. This method can accurately control the thickness of WO_3 films at nano scale. WO3 thin films with different film thicknesses, namely, 36, 72, 108, and 144 nm, were prepared. The role of film thickness on the structural and physical properties of WO_3 films was studied. The microstructure of as-prepared WO_3 thin films were characterized by using x-ray diffraction (XRD), scanning electron microscope (SEM), and Fourier transform infrared (FTIR) spectroscopy. Electrochemical properties of the as-prepared WO_3 films were also characterized. UV-VIS-NIR spectroscopy was used to analyze the optical properties of WO_3 films during the electrochemical cycles.

Silicon-on-insulator photonic biosensor

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Our goal is to develop a lab-on-a-chip label-free photonic biosensor platform for highly sensitive and selective multiplexed quantitative diagnostic tests. Microfluidic channels transport fluids containing target biomarkers to multiplexed sensing elements. By modifying the surface functionalization of these, different biomarkers are detected in parallel enabling numerous biomedical applications.

The proof-of-concept sensor is designed for simultaneous detection of three distinct antigens: C-reactive protein, lipocalin 2 and tumor necrosis factor. The main challenge lies within their respective concentrations, limit-of-detection (LOD) and dynamic ranges for each analyte (mg/ml-pg/ml).

Waveguide, ring resonator and photonic crystal sensing elements are being investigated. Individual resonator designs facilitate different LOD's and dynamic ranges for each analyte. Processing using PECVD, ICP-RIE and EBL is optimized on an SOI platform. Characterization is performed using SEM and a specially designed transmission setup.

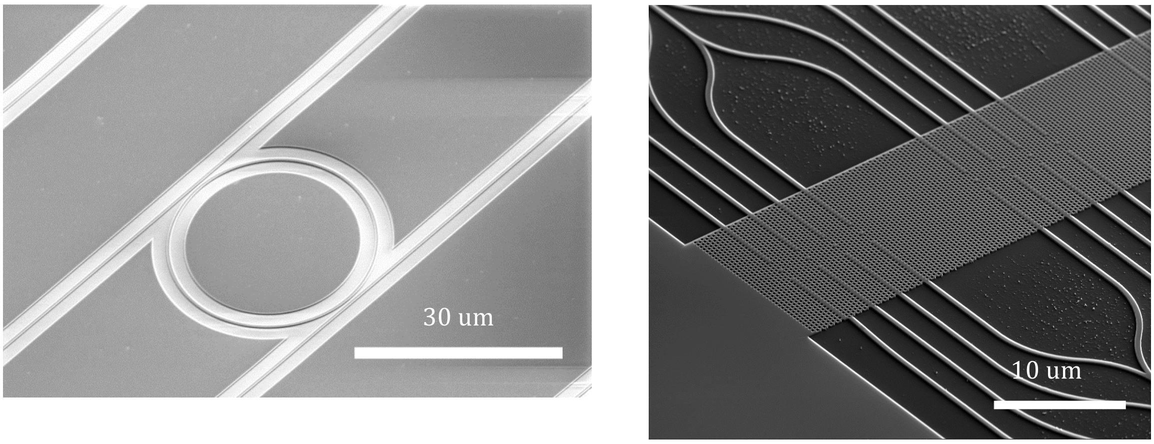

Figure 1 Ring resonator (left) and multiplexed photonic crystal ring resonators (right) on silicon-on-insulator (SOI) platform.

The Swing Adsorption Reactor Cluster (SARC) for Post Combustion CO_2 Capture using Polyethyleneimine (PEI) sorbent

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The SARC concept is an adsorption-based technology that aims at minimizing the energy penalty of CO_2 capture and has a huge potential to mitigate the global problem of climate change. It consists of a cluster of reactors running simultaneously and alternating sorbent carbonation and regeneration steps to ensure steady state processing of a flue gas stream. Heat is transferred from carbonation to regeneration using a heat pump that can work very efficiently if the temperature difference between the two stages is minimized by applying a partial vacuum in the regeneration step (*Figure 1*).

This concept was demonstrated in 2 cm diameter lab reactor using polyethyleneimine (PEI) sorbent developed at KRICT at real SARC conditions. The results indicate that vacuum reduces the temperature difference between the carbonation and regeneration step (can results in high heat pump efficiency). A sorbent working capacity of 0.55 mol/kg was achieved over the SARC cycle [1], which is in line with previous modelling work of the SARC concept integrated with a coal-fired power plant [2].

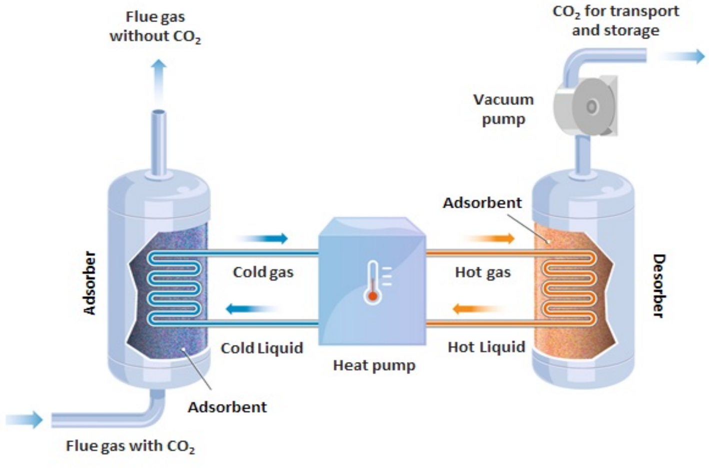

Figure 1: SARC process configuration

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III-V semiconductor nanowire/graphene hybrid structures and devices

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Heterostructured III-V semiconductor nanowires have attracted considerable attention in recent years due to their potential in future nano-electronic and nano-photonic device applications. The III-V nanowire project at NTNU today involves the epitaxial growth (MBE), structural (HRTEM), nano-optoelectrical characterization, as well as processing (NanoLab) of devices. In this talk, I will give some highlights of our work since the first GaAs nanowires were grown in our lab in 2006.

I will then focus on our most recent work on epitaxial growth of GaAs nanowires on graphene [1-2]. In 2012 we described a generic atomic model, which describes the epitaxial growth of semiconductor nanostructures on graphene that is applicable to all conventional semiconductor materials. The model was first verified by cross-sectional transmission electron microscopy studies of GaAs nanowires that grow epitaxially and dislocation-free on graphene. Recently we have also shown the vertical growth of dislocation-free GaN nanowires on graphene [3]. The epitaxial growth of semiconductor nanostructures on graphene is very appealing for device applications since graphene can function not only as a replacement of the semiconductor substrate but in addition as a transparent and flexible electrode for e.g. solar cells and LEDs.

For deep ultraviolet AlGaN based LEDs, in need for various disinfection and sterilization purposes, the concept offers a real advantage over present thin film-based technology. Such UV LEDs are today very expensive and inefficient due to the lack of a good transparent electrode (ITO is absorbing in deep UV), the high dislocation density in the active thin film layers, low light extraction efficiency, and the use of very expensive semiconductor substrates or buffer layers of AlN. Both NTNU (using MBE) and our spin-off CrayoNano (using MOCVD) are now developing UV LEDs based on the growth of AlGaN nanostructures on graphene as will be further discussed in my talk.

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Controlling Growth - from Spherical Seeds to Anisotropic Au Nanoparticles (NPs).

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Recent years have seen unparalleled efforts in synthesizing different sizes and shapes of anisotropic Au nanoparticles (NPs) using binary surfactant mixtures via seed-mediated growth approaches. Such anisotropic NPs find wide applications ranging from sensing, spectroscopy, catalysis to drug delivery. However, controlling the growth depends on the interplay among several factors – pH, reducing agents, co-surfactants, ratio of surfactant to co-surfactant, presence of silver nitrate and so on. Further, how these factors influence the shape of the resulting NPs still remains to be elucidated.

Here, we report the shape-controlled synthesis of Au NPs using a binary surfactant mixture of cetyltrimethylammonium bromide and oleic acid via a Ag-assisted seed-mediated growth approach. We report for the first time a ternary plot that shows how by controlling synthetic parameters of interest, different shapes and sizes may be obtained. Using statistical analysis, significant parameters have been identified, leading to insights into the growth mechanism.

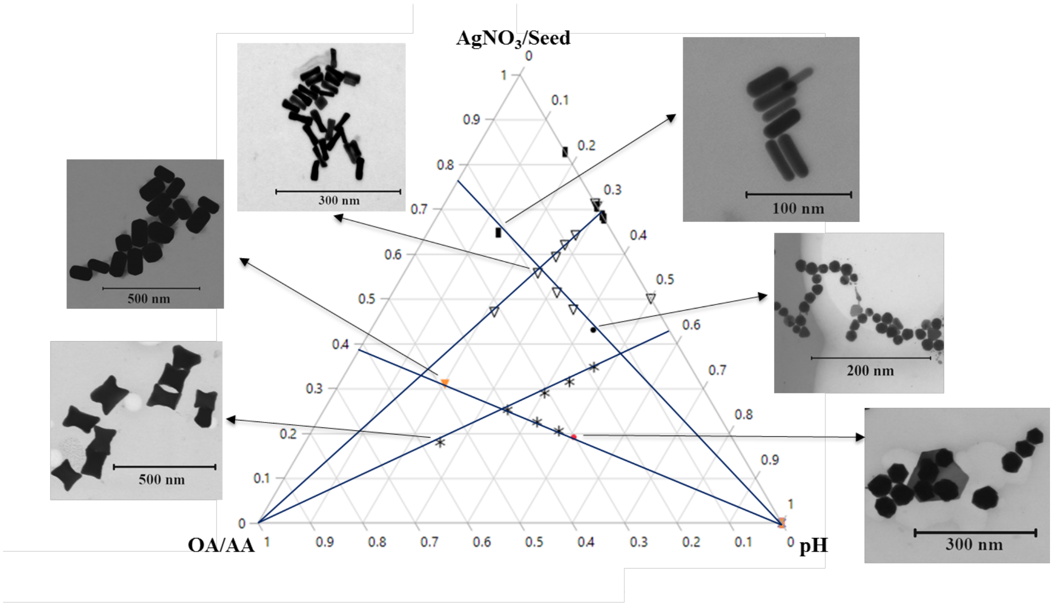

Figure: Ternary plot showing the different shapes of Au NPs obtained by varying synthetic parameters. (OA – Oleic acid, AA – Ascorbic acid)

Large-area nanogap electronics enabled by spontaneous adhesion lithography

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Adhesion lithography is a simple method for forming nanoscale gaps between dissimilar metals. In its usual form, a metal is patterned on a substrate, and conformally coated with an alkyl-functionalised self-assembled monolayer, rendering it non-adhesive to other metals; a second metal is then deposited uniformly over the full area of the substrate; next, an adhesive film is pressed against the top surface of the second metal; and, finally, the adhesive film is peeled away from the substrate under an applied force, taking with it those parts of the second metal that lie directly above the first metal. We show here that, by selecting an adhesive layer with high internal strain, it is possible to induce spontaneous delamination of the peeling layer without the need for any applied force. We show that functional devices including photodetectors and plasmonics, can be fabricated in a facile manner with minimum process complexity on a range of substrates.

Designing Dirac states by Molecular Beam Epitaxy

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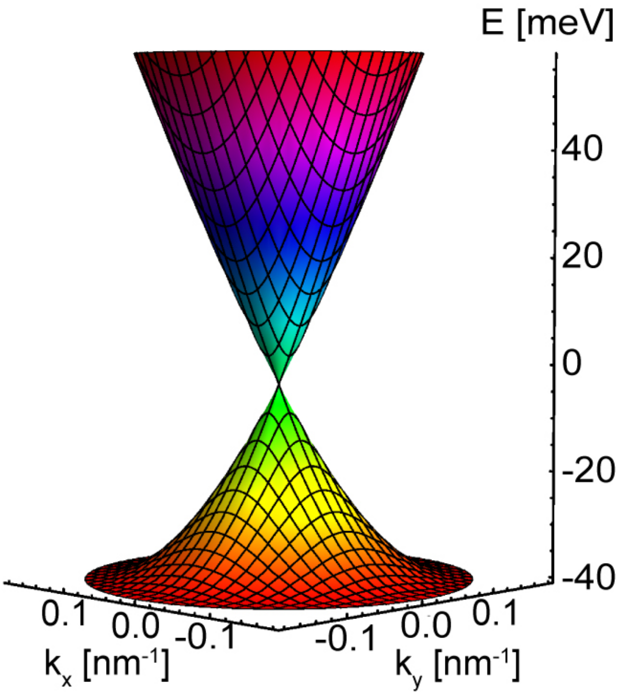
HgTe in its bulk state is a semimetal with an unconventional electronic band structure. The heavy elements together with spin orbit interaction lead to an inversion of two energy bands in the material. This band inversion is the basis for a new state of mater in HgTe: the topological insulator state. Topological insulators are characterized by conducting edge or surface states while the bulk of the material remains insulating. A key feature of topological surface states is a linear band dispersion resulting in so-called Dirac states.

I will discuss how one can experimentally realize and design Dirac states in HgTe. For this purpose, we synthesize high quality, single-crystalline samples using molecular beam epitaxy - a method that allows control on the level of single atomic layers.



Beam-steering lens arrays for solar tracking

Håkon Jarand Dugstad Johnsen[1], Jan Torgersen[1], Astrid Aksnes[2].

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The efficiency and flexibility of solar energy utilization can be significantly improved by introducing optical concentration to sunlight, enabling applications such as highly efficient multi-junction photovoltaic (PV) cells, or high-temperature thermal energy. In existing implementations, this optical concentration introduces significant mechanical bulk and complexity by requiring the optical system to rotate to follow the sun's movement across the sky. Beam-steering lens arrays can be used to eliminate the need to rotate the solar concentrator. It consists of a set of lens arrays stacked in an afocal configuration, and tracking is implemented by relative translation between these lens arrays. In this way, the system is able to redirect sunlight into a fixed direction towards a fixed concentrator. Using ray-tracing and optimization, we design a beam-steering lens array capable of redirecting sunlight across a two-axis ±60° tracking range, with a simulated ≈75% efficiency and a divergence of the outgoing beam of less than ±1°. The beam-steering lens array will be manufactured using grayscale lithography in the NanoLab. We also present a previously manufactured physical proof-of-concept in order to demonstrate the idea.

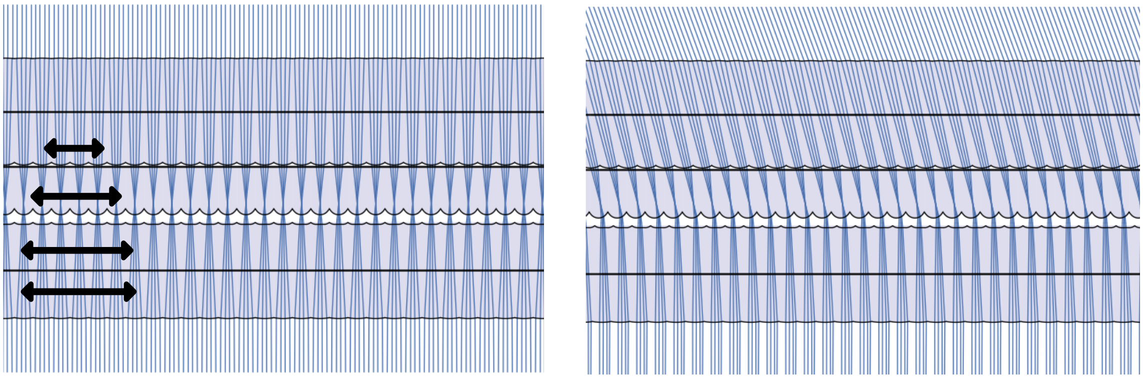

Figure 1: Example beam-steering lens array design at 0° configuration and 40° configuration. Tracking using lateral translation is indicated by black arrows.

Unconventional Computing with Artificial Spin Ice

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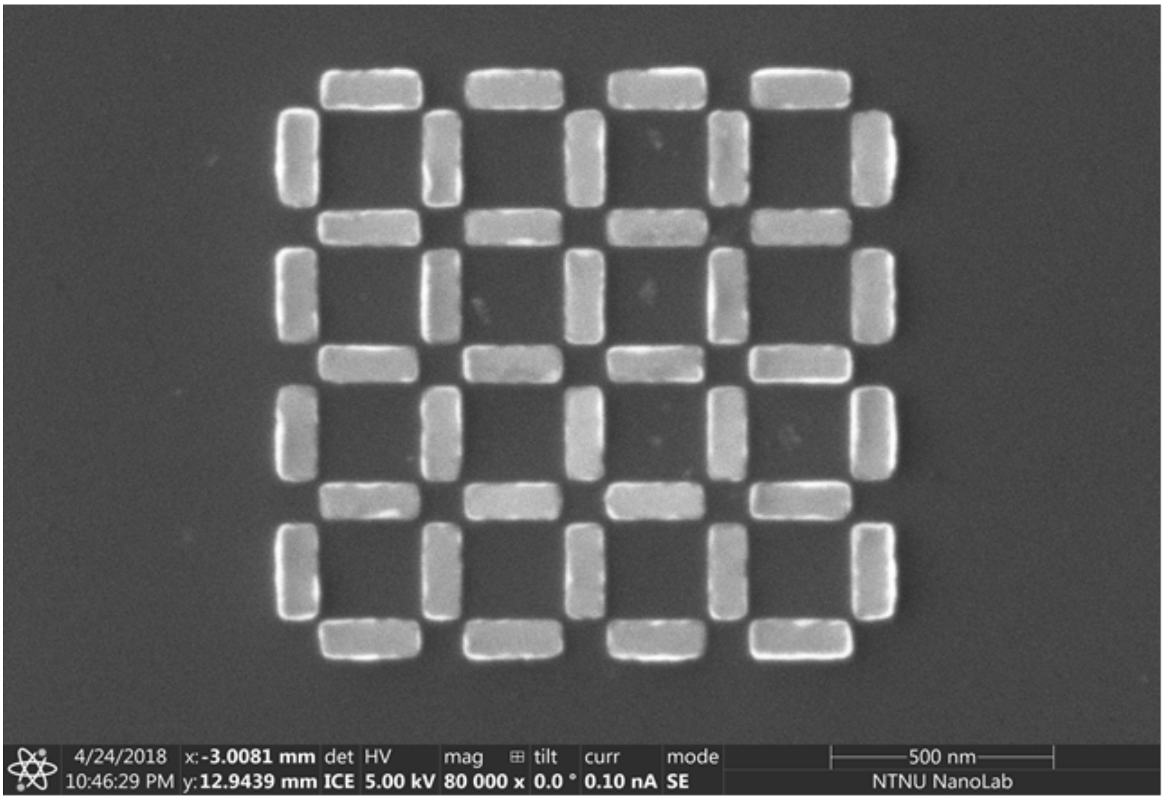
With a rapidly increasing rate of global data production, high-performance and low-power computing is an inevitable necessity. The SOCRATES (**S**elf-**O**rganizing **C**omputational subst**RATES**) project aims at radical breakthroughs toward efficient and powerful data analysis. Square artificial spin ice, comprised of a square array of vertical and horizontal bistable nanomagnets, provides a candidate system for computation *in-materio*. These systems exhibit emergent behavior that is typical in networks of nonlinear nodes, similar in many ways to the neural networks of the brain. The specific collective behavior is highly tunable through parameters such as magnet geometry, stacking geometry and thickness. Nanoscale spin ice structures are fabricated through a single layer electron beam lithography with pattern transfer to permalloy by lift-off. Magnetization states are investigated using magnetic force microscopy and manipulated through externally applied fields. Preliminary findings suggest that carefully engineered artificial spin ice presents a promising solution towards efficient and powerful data analysis.



Tuning nanoscale properties of nanocellulose fibrils for application in hybrid membranes for CO_2 capture

*Saravanan Janakiram, Xinyi Yu, Zhongde Dai, Luca Ansaloni, Liyuan Deng**

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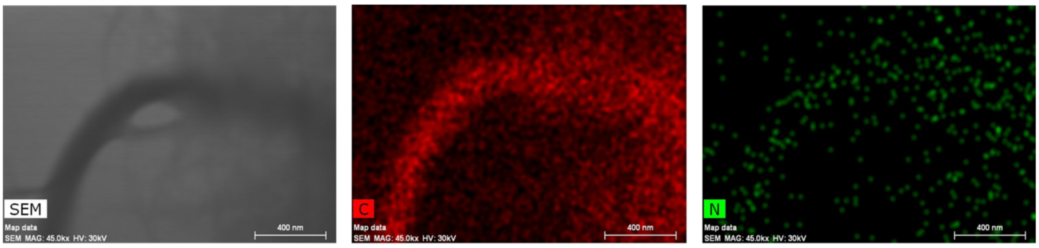
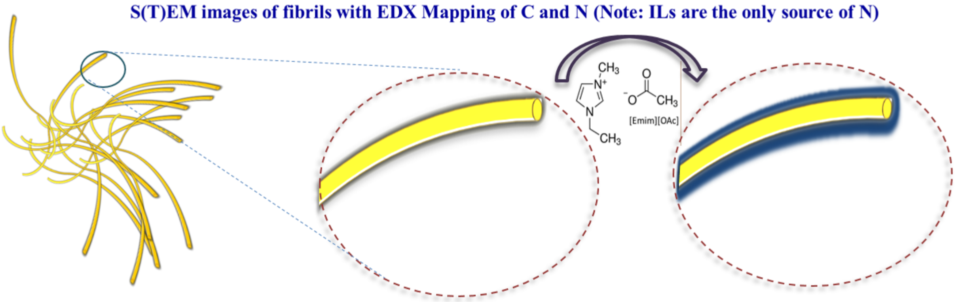
Bio-based materials represent sustainable alternative to synthetic plastics. Nanocellulose fibrils (NFCs) represent a renewable bio nanomaterial, obtained from mechanical/chemical treatment of cellulosic sources. In an attempt to increase the CO_2 permeability of NFCs, novel hybrid membranes have been fabricated by adding CO_2-philic ionic liquid (IL) (Figure). High compatibility of IL and nanocellulose resulted in the achievement of homogeneous blends, most of which conveniently outstripped the Robeson upper bound. The study demonstrates one of the highest CO_2 selectivities obtained in physical and chemical sorption room temperature ionic liquid-based membranes. Whilst using NFCs as composite in polymer matrices, high aspect ratio, good mechanical properties and ability to form hydrogen bonding are accompanying benefits. To study the effect of varying interfaces, NFC fibrils have been grafted with different small polymeric moieties and the resulting sub-500nm thin hybrid selective layers have been found to be endowed with varying gas permeation capabilities based on surface chemistries.



S(T)EM images of fibrils with EDX Mapping of C and N (Note: ILs are the only source of N)



Nanocellulose fibrils – Reservoirs of CO_2-philic Ionic Liquids

Enriching the Properties of Carbon Nanostructures Through Chemical Functionalization

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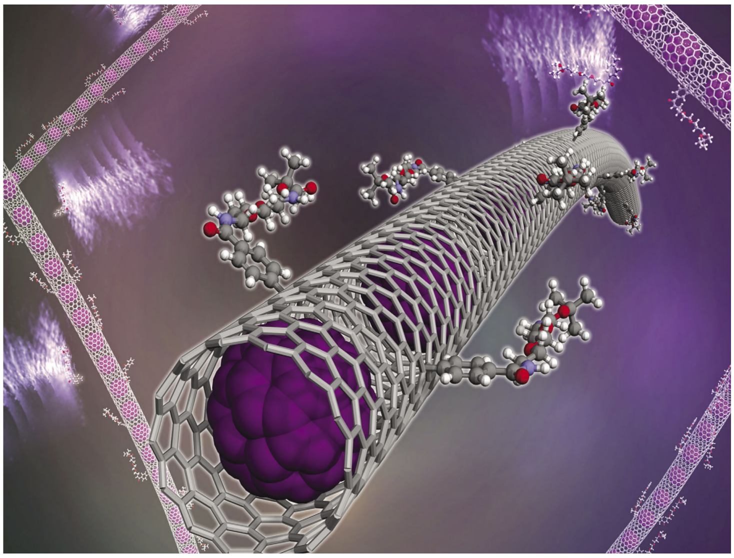
The family of carbon nanostructures includes fullerenes, carbon nanotubes and graphene and have the potential to cater to a variety of nanotechnological applications ranging from optoelectronics, to biomedical as well as, industrial. However, several shortcomings need to be addressed on the way to commercial applications. We present efficient approaches to decorate these materials with organic addends, or even with multichromophore systems, to promote individualization and solubilization as well as enrich the properties of the resulting hybrid materials and nanoensembles. These functionalization techniques open up ways to obtain materials with tailored solubilities. (aqueous/organic solvents) There are two main functionalization routes followed: covalent attachment yields stable carbon-based hybrids, while non-covalent functionalization techniques take advantage of π-π stacking interactions to produce nanoensembles with no additional defects onto the graphitic backbone, retaining the electronic properties of the carbon nanomaterial.



X-ray Absorption Spectroscopy on ALD Platinum catalysts for Oxygen Reduction Reaction

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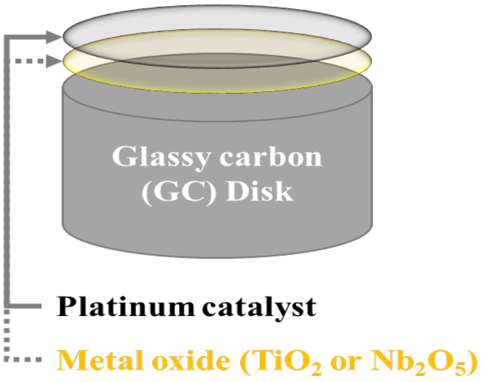
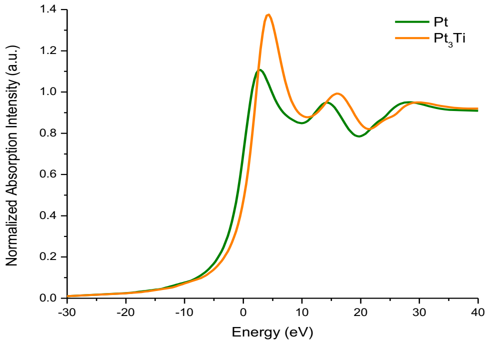
Polymer electrolyte membrane fuel cells (PEMFCs), regarded as the most promising implementation of fuel cells in the automotive sector, still require the development of more efficient electrocatalysts. One of the necessary strategies for increasing the techno-economic outlook of PEMFCs is through increasing the intrinsic per-atom activity of the expensive platinum-based cathode electrocatalysts. We demonstrate the facile fabrication of Pt based catalysts by atomic layer deposition (ALD). This catalyst shows an enhanced mass activity (electrochemical activity normalized by platinum loading) toward the cathodic oxygen reduction reaction (ORR). By the use of X-ray absorption spectroscopy we unravel the underlying reasons for this enhanced reactivity.





Shape Effects of Dipolar-Coupled Magnetic Nanodot Arrays Below the Blocking Temperature

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2D hexagonal arrays of ferromagnetic nanodots give rise to emergent 'superferromagnetic' order when the spacing between the dots becomes sufficiently small. In this study, we define nanodot arrays in micron-sized shapes such as hexagons and rectangles to investigate the finite size effects of such configurations, and compare these results to regular continuous patterned magnets. We use electron beam lithography to fabricate the dot arrays (disc diameter 100 nm, spacing 50 nm) and the resulting superferromagnetic configurations were examined using photoemission electron microscopy (XPEEM). At room temperature (T = 295 K), we find that the arrays are below the blocking temperature (i.e. they are not thermally active), and clear differences are observed between switching characteristics of horizontally and vertically oriented rectangular arrays ($2\times 5\ \mu\mathrm{m}^2$). The results are in good qualitative agreement with micromagnetic simulations, in which the blocking behaviour is modelled as biaxial anisotropy that varies in direction.

Nanotechnology brings batteries to the next level

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Li-ion batteries (LIBs) is currently dominating the battery market for rechargeable batteries, and will most likely continue to do so for many years to come. Still, there are new and evolving technologies being developed, including multivalent battery chemistries such as Mg-ion batteries (MIB). Although MIBs are still in their infancy, they hold promise for the future and may with time provide new solutions for specific battery markets. Materials and chemistries for LIBs and MIBs are in many aspects very different. However, one common denominator is the tailoring of materials composition, structure and morphology. In this regard, it has become increasingly more evident that nanostructuring and upscaling of methods for production of nanostructured materials play a vital role in both improving current LIB technology as well as developing new materials for evolving technologies. The work presented here will show how nanostructured electrodes can make large impacts on battery properties.

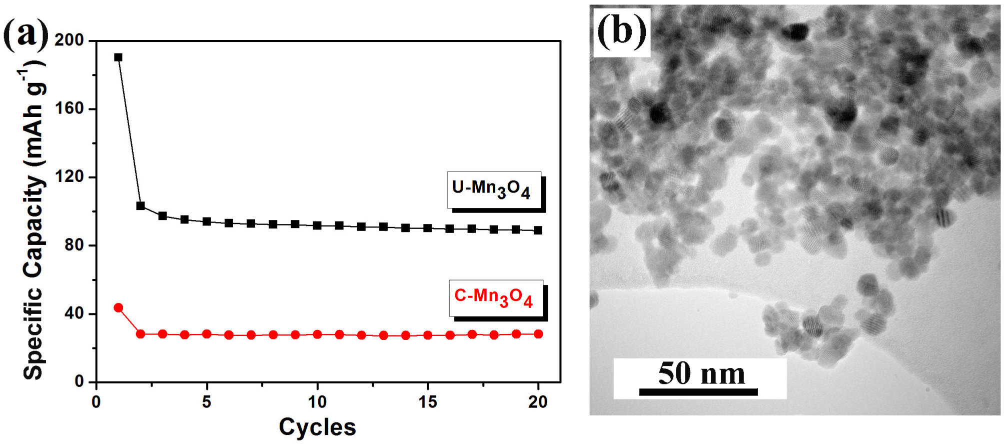

Figure 1: Nanoparticles of Mn_3O_4 as cathode material in Mg-battery.

MetaFluidics: A platform for rapid and cost-effective functional metagenomic screening.

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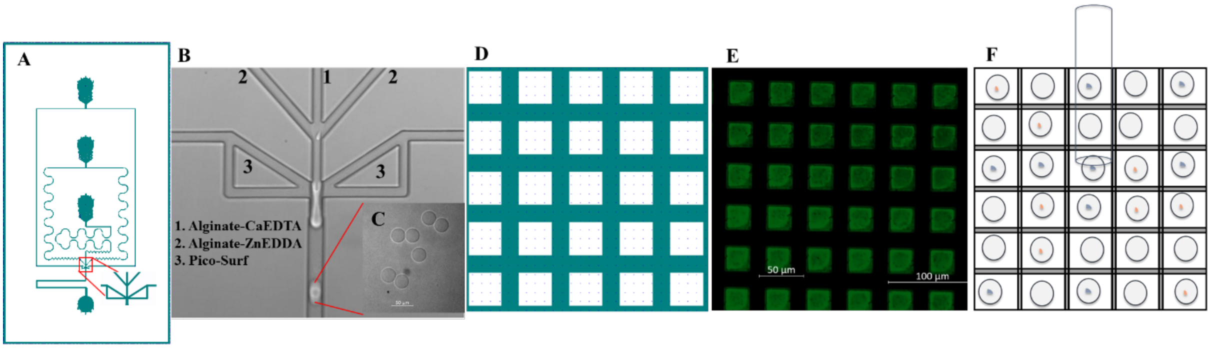
Metagenomics and single-cell genomics have enabled genome discovery from unknown branches of life. However, extracting novel genomes from complex mixtures of metagenomic data is still challenging and represents an ill-posed problem which is generally approached with ad hoc methods. Here we present microfluidics and micro contact printing based approaches to extract novel microbial genomes while preserving single-cell resolution, with increased throughput and sensitivity while at the same time reducing the cost.

Methods: Microfluidics chip (3 inlet, 1 outlet) (fig1A) and bead array (30 µm square with 45 µm spacing, array size 20x20 spots) (fig1D) were designed in a layout editor software CleWin. The microfluidic devices were fabricated by standard soft lithography using a 4-inch silicon wafer, negative photoresist (mrdwl 40, mr600 developer), Maskless Aligner 150 (wavelength 405 nm, exposure energy of 500 mJ cm^{-2}) to obtain the desired thickness of the microfluidic device (30 µm). The wafers were then treated with fluorosilane for 1 hr. 10:1 polydimethylsiloxane (PDMS) and initiator was casted onto the wafer and baked (65 °C, 3 hours) and subsequently peeled off. Inlet and outlet plastic tubing were inserted into 1 mm diameter punched holes of the PDMS microfluidics chip bonded to a glass slide (after plasma treatment). The PDMS microfluidic chip were baked for 24 hr after bonding and treated with 1% (v/v) of fluorosilane in hydrofluoroether (HFE7500, 3M) for 5 min. Alginate gel beads were produced from microfluidics chip using competitive ligand exchange crosslinking (CLEX) method. The flow rates were set to 650 µL h^{-1} for the continuous phase (Pico-Surf, Spherefluidics) and 50 µL h^{-1} for both dispersed phases by controlled injection using BD plastic syringes mounted on syringe pumps. The collected alginate bead emulsions were treated with Pico-Break to separate the gel beads from the emulsion and transfer them to an aqueous phase. For the bead array, one of the array on PDMS was cut and plasma cleaned and later used for microcontact printing to visualize the pattern using PLL-FITC (0.5 mg/ml) using standard protocol. Alginate beads and pattern were visualized employing a Axio Observer Zeiss inverted microscope.

Results and Discussion: Monodisperse alginate beads of size 30±2 µm were obtained (fig1B and C). Uniform bead array PLL-FITC pattern was obtained (fig1D). This combined platform will be further exploited to encapsulate single bacterial cells in alginate beads and immobilize the alginate beads on the microcontact printed array. The immobilized beads combined with micromanipulator will then serve as platform for metagenomics screening (bacteria/enzyme/drug) of interest (fig1F).



In situ and *ex situ* study on the hydrothermal synthesis of hexagonal $YMnO_3$

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The study of the hydrothermal synthesis of hexagonal yttrium manganite (hex-$YMnO_3$) for producing anisotropic grains using a combination of *in situ* and *ex situ* studies is shown. The synthesis procedure is performed in a high temperature autoclave at over 300 °C from Y_2O_3 and Mn_2O_3 starting materials, and the products have been analysed with X-ray diffraction and scanning electron microscopy, which showed the formation of large cross-section and thin hexagonal grains. This was followed up with *in situ* synchrotron studies which showed the that the reaction occurs in three stages; the initial stage which contains the starting materials, an intermediate stage which shows the rapid conversion of Y_2O_3 to $Y(OH)_3$, and a final stage in which the product are formed (Figure 1). However, there are still a number of challenges to be addressed with the formation of a number of secondary phases.

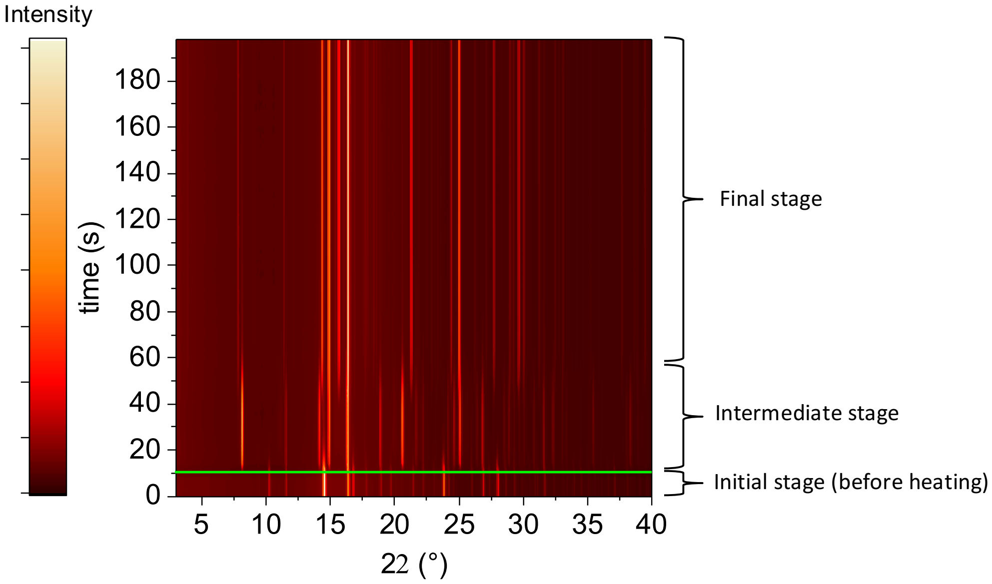

Figure 1: Contour plot of an *in situ* reaction monitored by X-ray diffraction from a synchrotron source

Surface treatment of 316L stainless steel by ZrO_2/SiO_2 nanocomposite coating

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Surface treatment of metallic implants in order to improvement of surface biocompatibility and inhibiting the release of poisonous ions into the blood has attracted significantly increasing interest. In this work, ZrO_2-SiO_2 nanocomposite particles were prepared using alkoxide based sole gel and coated on electrochemically treated stainless steel 316L using electrophoretic deposition technique. In order to increase the adhesion strength, the deposited layer was sintered at 1100oC for 2h. Studying the effect of surface treatment demonstrated that porous structure decreased the corrosion resistance of substrate, while the electropolished substrate reduced the corrosion current density (i_{corr}) and shifted the corrosion potential (E_{corr}) toward nobler potential. ZrO_2-SiO_2 coated on porous 316L metallic implant can serves as good barrier against metallic ion release into the body fluid along with improvement in biocompatibility due to presence of amorphous silica particles.

Atomistic modeling of polymer friction

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The theoretical understanding of the friction and wear of polymers is still lacking and therefore, development of novel low friction material of solid polymers can only be achieved by trial and error procedures including expensive testing. In this work, the focus is put on the influence of structural properties of solid polymers on the friction and wear. Molecular dynamic simulation is used to capture the crystallization process of PolyVinyl Alcohol (PVA). The coarse grain potential for PVA (CG-PVA) developed by Meyer and Muller-Plathe has been used in order to drastically speed up the simulation. Depending on the cooling rate and the number of monomers per chain, the crystalline domains will have different structural properties. We create samples of polymers with different crystalline structure and investigate numerically by simulating the effect of rubbing the surface with an AFM tip the relation between friction, wear, and crystallinity.

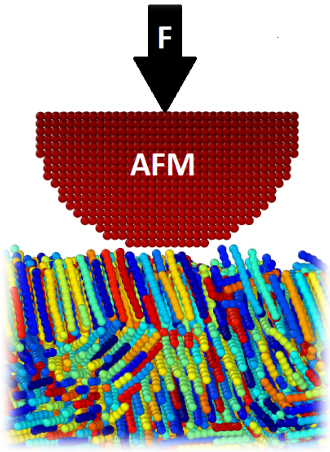

Figure 1 Atomistic simulation : sliding of a virtual AFM tip over a solid polymer substrate

Novel Topological Spin Textures in Helimagnetic FeGe

E. Lysne[1]*, M. Stepanova*[1]*, P. Schoenherr*[2] *and D. Meier*[1]

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In non-centrosymmetric ferromagnets, the so-called Dzyaloshinskii-Moriya interaction is symmetry-allowed and can lead to a canting of the spins, introducing complex spin spiral structures. Examples are transition-metal silicides and germanides, which crystalize in the non-centrosymmetric B20 structure and which display a helimagnetic ground state. Such helimagnetic order is at the center of our microscopy studies, motivated by both the unusual physical properties and the potential for novel device applications.

We use magnetic force microscopy (MFM) to investigate magnetic long-range order in the near room-temperature helimagnet FeGe. Completely new types of helimagnetic domain walls are observed, connecting regions with different orientation of the helical structure. Analogous to the much-studied Skyrmions, the walls can exhibit a nonzero topological winding number and, hence, possibly give rise to emergent electrodynamics. Our goal is to control the domain wall formation and positioning, demonstrating new opportunities for future applications in spintronics.

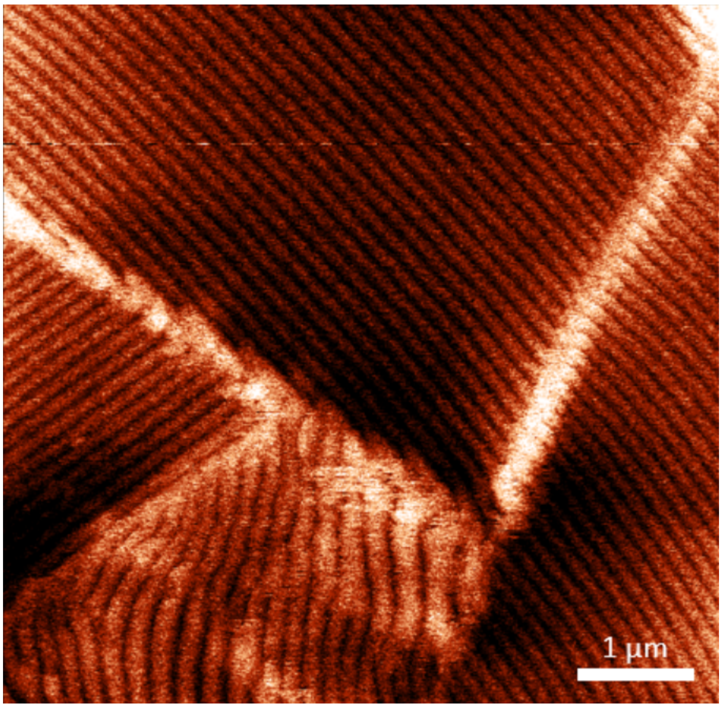

Figure 2 Magnetic force microscopy (MFM) image showing the magnetic structure of FeGe. Dark and bright stripes correspond to magnetization pointing in and out of the plane, revealing a helical spin structure. Helimagnetic domain walls can be observed at interfaces between regions of different orientation of the helical structure.

Gold-Bismutite Hybrid Catalysts for Photosynthesis of Ammonia

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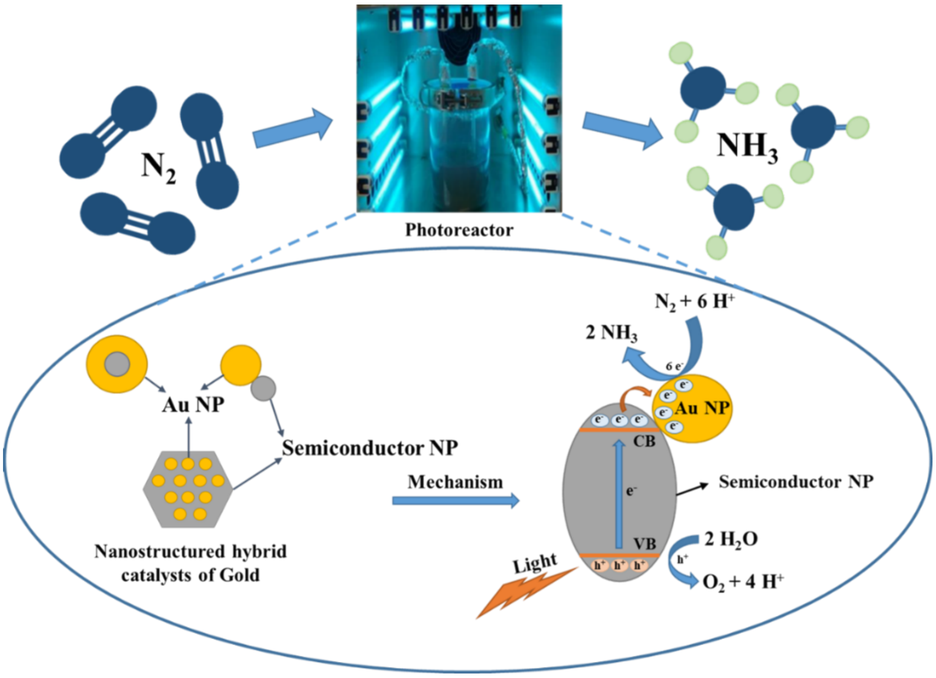
Ammonia is one of the most important chemicals for the industrial production of fertilizers, pharmaceuticals, and many other nitrogenous compounds.[1] The extreme energy demand required for the industrial production of ammonia along with depleting fossil fuels calls for the pressing need for an alternative greener synthesis route. Bismutite ($Bi_2O_2CO_3$) has recently emerged as an important candidate in photocatalysis.[1] Controlling the size and shape of bismutite nanoparticles (NPs) has been reported to have significant effects on its activity.[2] On the other hand, gold (Au) nanoparticles due to their excellent optical properties and localized surface plasmon resonance (LSPR) effect have been reported to significantly enhance solar energy collection efficiency of semiconductors.[1, 3] In this project, nanostructured hybrids of Au NPs with bismutite and other semiconductors of interest will be synthesized, which when coupled with their morphological properties, is anticipated to pave way for energy efficient photosynthesis of ammonia.



Synthesis of ammonia using a photoreactor setup

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Understanding Nucleation phenomenon of ALD Deposited Ultra -Thin Functional Films

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Atomic layer deposition (ALD) is indispensable for the deposition of conformal layers on high aspect ratio structures. The deposition mechanism works on the principal of self-saturation, thus giving ultimate control over the process. It has been extensively used for the deposition of dielectric layers of semi-conducting devices and DRAM capacitors. In recent years great focus has been directed towards miniaturization of devices which requires atomic level control of the deposited layer for which ALD has been the preferred choice. On the path towards miniaturization, it has been observed that for layers below 10nm there is island formation, thus breaking the myth of atomic layer by layer deposition. Now it becomes crucial to determine the thin film evolution in the sub 10 nm thickness regime using in-situ characterization and simultaneously conducting quantum mechanical simulation using density functional theory (DFT) to get insight into atomic structure at every stage of deposition.

FunNano – Functional Nanomaterials for Diverse Applications

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FunNano (Functional Nanomaterials Group) is a collaborative group that works with inorganic and polymeric nanomaterials. Our group focusses on synthesis, characterization, functionalization and applications of these NPs. Although, our investigations scale over a huge library of NPs, primary focus of the group is on (i) metallic NPs of different sizes, shapes, surface functionalities, active components and (ii) stimuli-responsive polymeric NPs.

Ongoing research focusses on synthesizing and tailoring NPs for drug delivery, photocatalysis, water management and clean energy. Growth and properties of NPs are being studied using both experimental and computational methods. Owing to their excellent optical and surface properties, Au based bimetallic NPs are being investigated as catalysts for photosynthesis of ammonia. Fe NPs, synthesized using thermal decomposition and thereafter functionalized with DNA are being tested as potential hydrological tracers. Fe NPs, silica NPs and their hybrids are being tested for use in drilling fluids, enhanced oil recovery and cementing.

Nanostructured surfaces with controlled surface chemistry for cell studies

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In this work we present a versatile and quick approach to fabricate nanostructured surfaces for cell studies and manipulation using electron beam lithography. The structures are fabricated directly in SU-8, a photo- and electro-sensitive epoxy-based resist. We are able to make large arrays of freestanding nanopillars as well as semi-3D surfaces by exposing structures of various height. The structures have different chemistry compared to the substrate and we have tested various approaches for functionalising the resist, for example by attaching biologically relevant molecules. To test the surface chemistry, several reaction routes and corresponding analysis techniques have been tested and compared.

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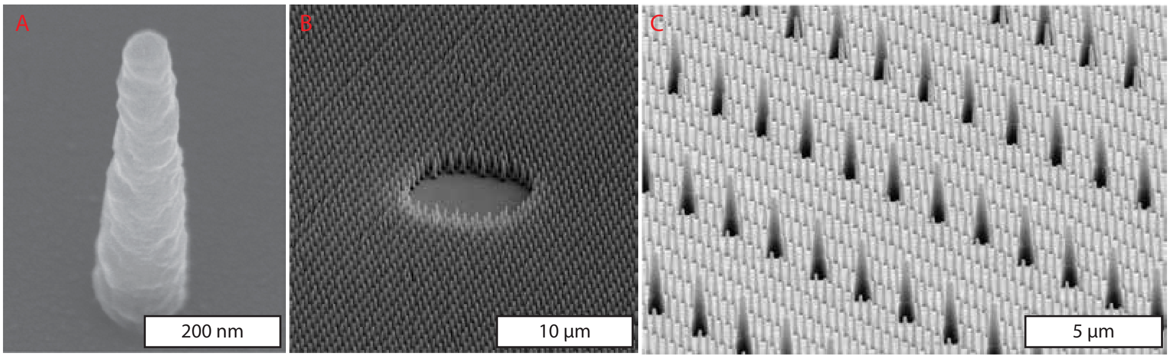

Enabling high resolution in-situ studies of self-limiting deposition processes in a TEM

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In recent years the topic of in-situ analyses of materials on an atomic scale has increased significantly. As the trend of downsizing in the Micro-Electro-Mechanical Systems (MEMS) related industries continues it is an imperative need to deposit thinner layers and have control over the resulting properties. The most promising deposition techniques in order to enable thinner layers with satisfying properties are self-limiting deposition techniques such as atomic layer deposition (ALD). Here the films grow on an atomic scale and therefore allow an outstanding control over the thickness and conformity of the layer. Nevertheless, the first 10 nm of the growth are still poorly understood and bear a lot of questions concerning the atomic growth, structure and conformity of the layers. To gain control over the nucleation phase, in-situ studies of self-limiting deposition processes using a closed gas-cell holder system in a transmission electron microscope (TEM) are striven.

Conformal high aspect ratio fill using RF sputtering

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RF sputtering is a common deposition technique used in fabrication of optical waveguide-based devices. This technique is predominantly used to deposit thin film of high index dielectric oxide/nitride for waveguides. RF sputtering provides uniform deposition of film on a planar substrate. Challenges arise while depositing film on a high aspect ratio structure, e.g. depositing top cladding on a strip waveguide. Uniform and conformal deposition on a high aspect ratio structure requires higher substrate temperature and annealing. High temperature processing inhibits lift-off processing. It also affects the material property, e.g., amorphous silicon starts converting into polysilicon at 300 °C. We present here an RF sputtering process, which can be used to deposit a conformal layer on a high aspect ratio structure without introducing heating. We introduce a DC bias to the substrate in addition to RF, which allows deposition and etching to happen simultaneously. DC bias to wafer/substrate results in re-deposition.

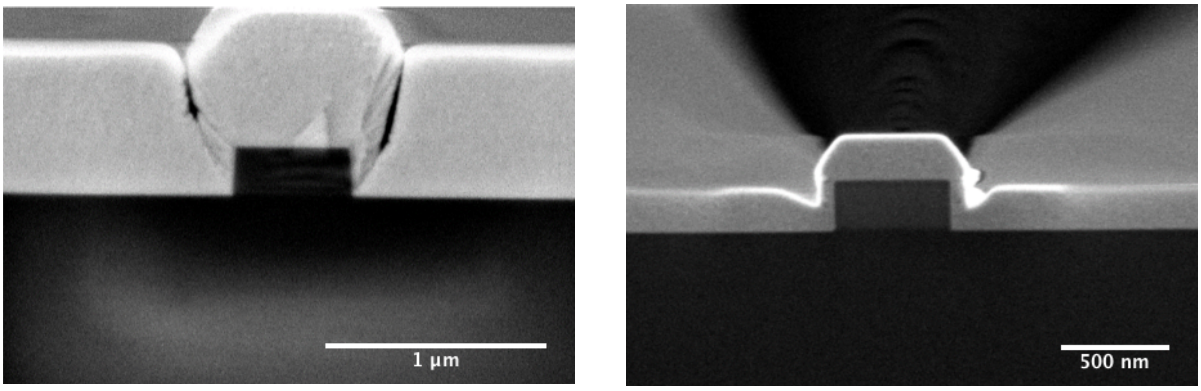

Fig. 1 Sputtered Tantalum pentoxide on Silicon waveguide by using 300 W RF power and 0 bias (Left), sputtered layer using 300 W RF power and 25 W bias (Right).

Fabrication of antifouling surface based on PDMS/GO-ZnO nanocomposites

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This study investigated a series of polydimethyl-siloxane/graphene oxide-zinc oxide (PDMS/GO-ZnO) composites with different amounts of nanofiller for the application of antifouling coating. With tetrahydrofuran (THF) as solvent, the coating was fabricated by spin coating the PDMS/GO-ZnO/THF suspension on the surface of glass slides. The synthesized composites were characterized by UV-visible spectroscopy (UV), X-ray powder diffraction (XRD), fourier transform infrared spectroscopy (FTIR), and transmission emission microscopy (TEM). In addition, the PDMS/GO-ZnO suspension was characterized by Raman microscopy (Raman) and scanning transmission microscopy (SEM). A comparable study was performed between the pristine PDMS coating and the PDMS/GO-ZnO coating. Typical bacteria (Synechoccocus sp 7002 and H. pacifica Dobson) and algae (Phaeodactylum tricornutum and chlamydomonas reinhardtii 5155) from fresh water and seawater, respectively, were selected for antifouling test.

Structural investigation of lead-free ferroelectric materials during aqueous chemical solution processing

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There is an extensive research effort to develop new environment friendly lead-free piezoelectric materials due to the lead toxicity concern of the most widely used ferroelectrics. Among various fabrication methods of ferroelectric thin films, aqueous wet chemical solution deposition (CSD) offers serval advantages, such as simple procedures, low cost, and possible to be scaled up for industrial production. However, the development of CSD in lead-free ferroelectrics suffers from the general lack of knowledge of the nucleation and growth mechanisms. The processing parameters that are of utmost importance for the control of the growth of the specific ferroelectric thin films are still remain unclear. Here, we used *in situ* total scattering technique during the full thermal annealing process, in order to reveal the structural evolution as a function of temperature, both at local and long-range scale. Important lead-free ferroelectric material systems e.g. $BaTiO_3$ (BT) and $K_{0.5}Na_{0.5}NbO_3$ (KNN) were investigated.

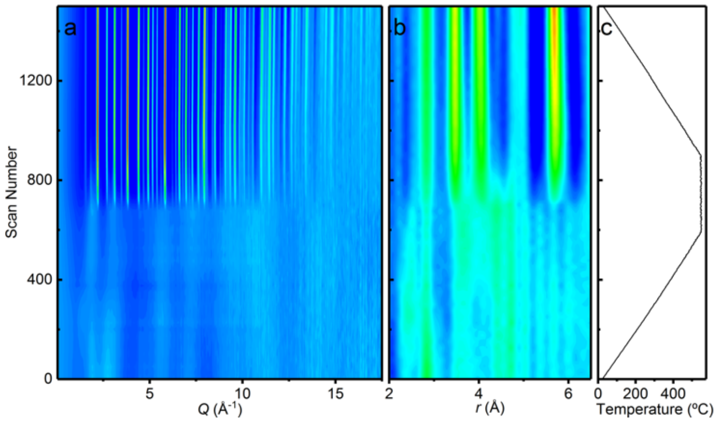

Figure 1 *In situ* total scattering patterns (a), pair distribution functions (b), and monitored temperature profile (c) during the full thermal treatment of BT precursors.

Molecular Dynamics Simulations of Polymeric Fibre Bundles under Tensile Load

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Bundles of polymeric materials play essential and ubiquitous roles in biological systems, and often display remarkable mechanical properties [1]. By utilizing non-equilibrium molecular dynamics simulations to preform force controlled and length controlled virtual stretching experiments of polymeric fibre bundles one may get valuable insight into the mechanical properties of nanofibrous materials. The supra-molecular structure of fibrils in nanometric bundles is studied, which have been shown experimentally to have a great impact on e.g. the Young's modulus of the bundles [2]. A minimalistic reactive force field is applied to allow for the breaking of bundles. The material investigated here is Polyethylene Oxide, a polyether compound with applications ranging from industrial manufacturing to medicine.

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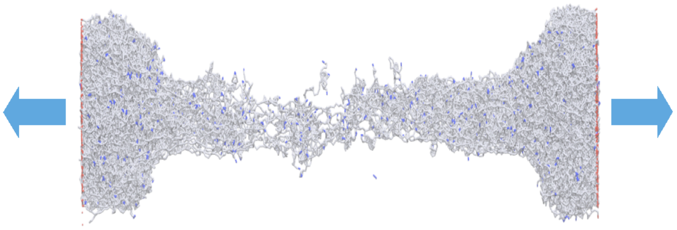

Figure: Illustration of a fibre bundle rupturing by an external force.

In situ Preparation of Epoxy-SiO_2 nanocomposites for High Voltage Insulation

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Epoxy-based nanocomposites, containing inorganic oxide nanoparticles as filler, display novel properties making them suitable for application in nanodielectrics, such as in high voltage insulation. SiO_2 nanoparticles, surface functionalized using a silane coupling agent, have been synthesized directly in the epoxy monomer during the fabrication of epoxy-SiO_2 nanocomposites via the sol-gel route. The formation of the SiO_2 is followed using FTIR, and confirmed with thermogravimetric analysis. Dielectric spectroscopy characterization (Figure 1) showed that for small concentrations of SiO_2 (between 0 and 5 wt%), the complex permittivity of epoxy-SiO_2 hybrids can be decreased from that of pure epoxy. Differential scanning calorimetry revealed that the glass transition temperature of the nanocomposites is increased compared to that of pure epoxy. The use of an *in situ* approach therefore appears to be a promising alternative in fabricating epoxy-SiO_2 nanocomposites with enhancements in both the thermal and dielectric properties.

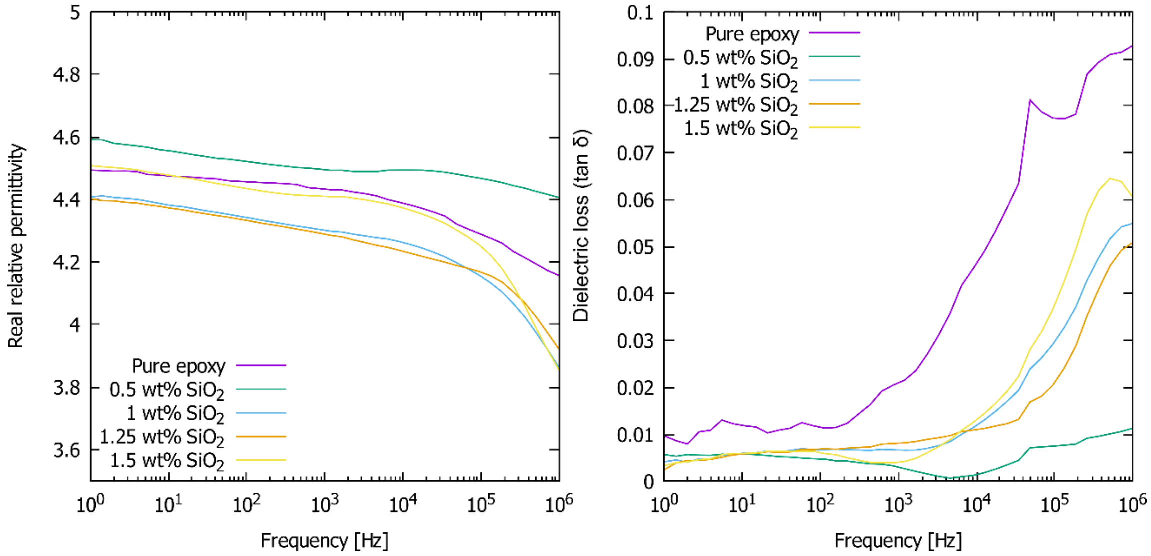

Figure 1. Comparison of the real relative permittivity (left) and dielectric losses (right) of epoxy nanocomposites with varying content of SiO_2.

Nanofriction of atomically thin layered materials

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Recent experiments and computer simulations have shown that layered materials do not quite exhibit ordinary stick-slip dynamics as prescribed by the Prantl-Tomlinson model [1][2][3]. Rather, these materials show stick-slip motion with the addition of an initial period of friction strengthening. In this project, we propose a novel one degree of freedom extension to the Prantl-Tomlinson model which successfully captures this strengthening. We also investigate the nature of the strengthening and conclude that previous results largely depend not only on the layered material itself, but also on the substrate which it deposited on.

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Deconvoluting conductance contributions at charged ferroelectric domain walls

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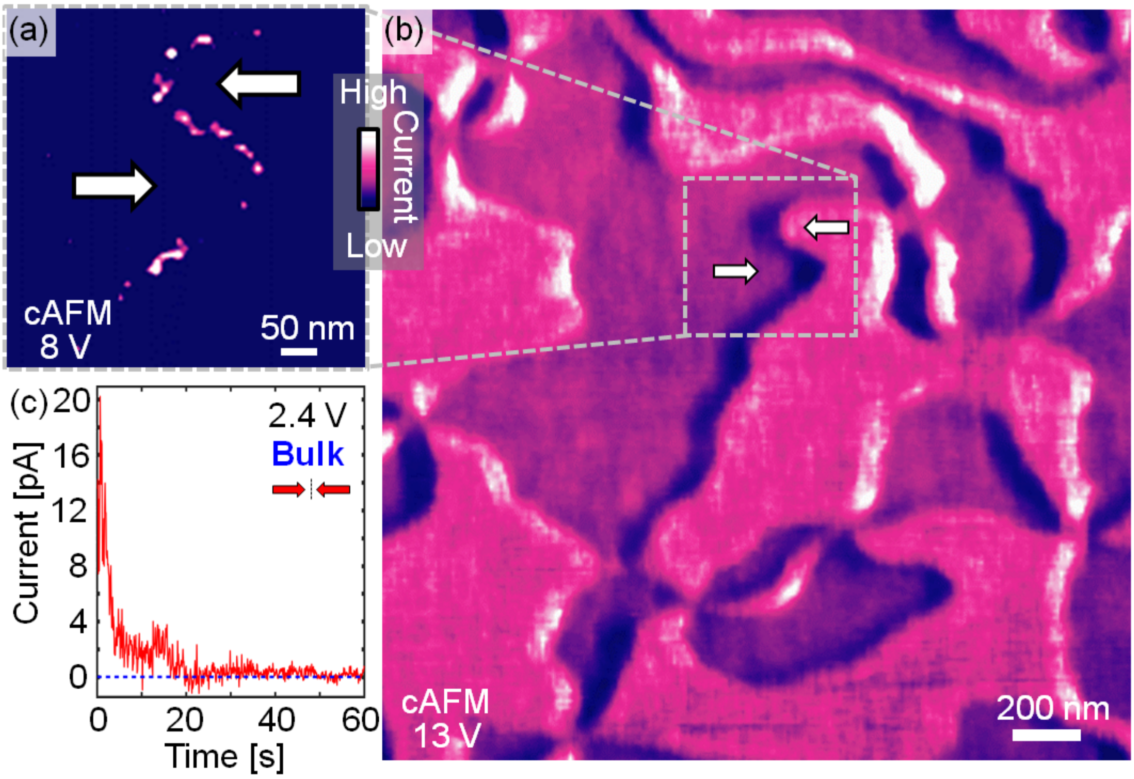
Ferroelectric domain walls are spatially mobile interfaces that naturally occur in materials that develop a spontaneous electric polarization. Because of their unique electronic properties, such walls hold great promise as functional 2D systems, but the characterization of their intrinsic transport properties remains a challenging task.

Here, we combine scanning probe microscopy (SPM) with machine learning to gain new insight into the local electronic domain wall properties and to enhance the informational value of local conductance measurements. As a model case, we study the transport at ferroelectric domain walls in $(Er_{0.99}, Zr_{0.01})MnO_3$: At low voltages, head-to-head domain walls appear to be conducting (a). At higher voltages, however, the same domain walls are insulating (b). Using machine learning, we disentangle different conduction contributions and explain these seemingly contradictory results, highlighting how machine detection enhances the SPM output.



Focused ion beam lift-out enabling scanning probe microscopy on individual $ErMnO_3$ domain walls

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Multiferroic erbium manganite ($ErMnO_3$) has over the past years become increasingly popular as a model system for the study of functional ferroelectric domain walls. Quantitative study of domain walls in bulk crystals is challenging since they form a complex 3D network with varying electronic properties. This makes it desirable to create smaller specimens where individual walls can be studied. In this contribution we present the selective isolation of a small volume of $ErMnO_3$ using focused ion beam (FIB). This procedure enables us to study quasi-2D domain structures and investigate individual domain walls with a well-defined charge state.

We will present the preparation of a thin $ErMnO_3$ 10 x 15 μm^2 slab lifted out from a bulk sample with out-of-plane polarization P (Fig. 1(a)). The milling out and in-situ lift-out were done in a dual beam FIB-SEM system where a lift-out needle with motorized rotation was used to orient the sample in plan-view. The slab was attached to a Pt/Pd-coated MnO substrate and fixed with local C-deposition (Fig. 1(b)) before thinning to ~500 nm thickness and polishing (Fig. 1(c) with the ion beam. The domain structure, now with P in-plane, can be identified in SEM (Fig.1 (c)). Piezoresponse force microscopy (PFM) confirms the ferroelectric nature of the domain structure seen in SEM, opening the door for correlative studies using various electron beam and surface probe techniques on isolated domain wall configurations. The ability to identify, lift out and study individual domain walls represents an important step on the path to realizing prototype device structures using single $ErMnO_3$ domain walls.

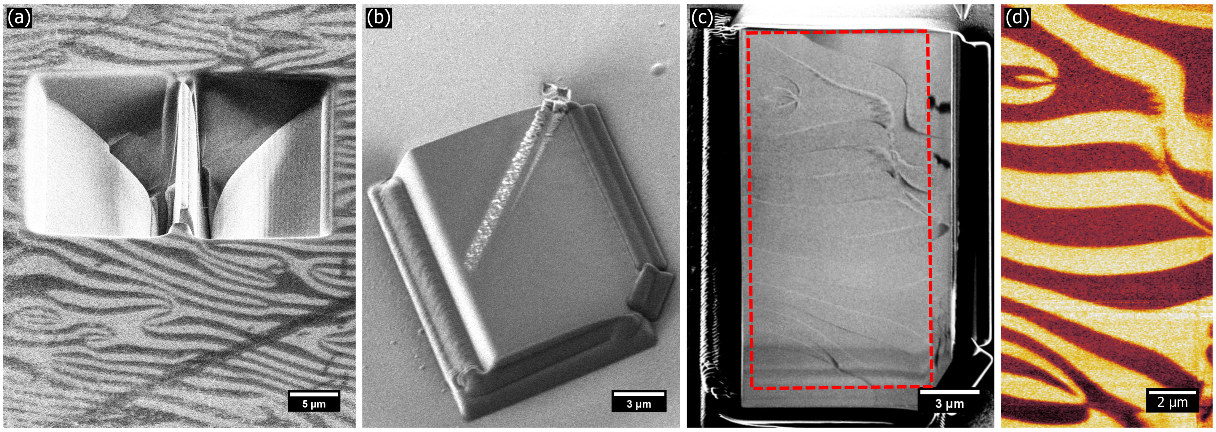

Fig. 1: (a) Lift-out location with FIB-milled trenches and domain contrast (out-of-plane P) on the original sample surface. (b) Specimen transferred to substrate. (c) SEM domain wall contrast (in-plane P) after 5 kV polish. (d) PFM domain contrast from indicated area in (c).

Facile synthesis approach for core-shell TiO_2–CdS nanoparticles for enhanced photocatalytic H_2 generation from water

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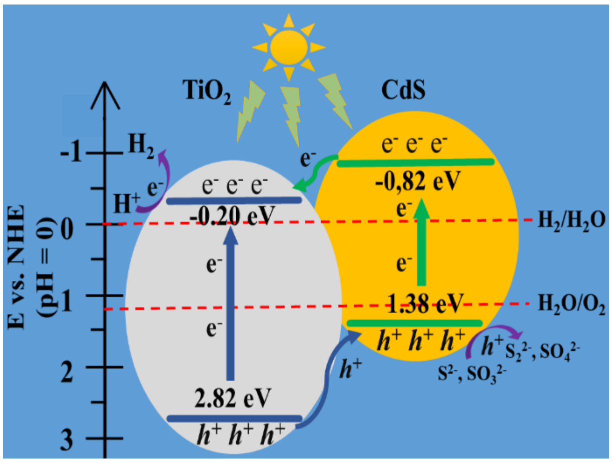
Cost-effective and highly stable photocatalyst with improved photocatalytic activity towards H_2 generation by water splitting, core-shell structure of TiO_2-CdS is reported which was synthesize by facile two-step hydrothermal process. The photocatalytic activity is evaluated by measuring the ability of TiO_2-CdS to generate H_2 gas by water splitting in the presence of hole scavengers under simulated solar light at AM 1.5G conditions. Our optimized sample TiO_2-CdS (3:2) exhibited an enhanced photocatalytic activity by generating 954 µmol g^{-1} h^{-1} of hydrogen which is ~1.4 and ~1.7 times higher than pure CdS nanoparticles and pure TiO_2, respectively. The optimized sample achieved an apparent quantum efficiency of 3.53% along with good stability by generating a similar amount of H_2 for 40 consecutive hours. The enhanced photocatalytic activity and stability of the core-shell TiO_2-CdS nanocomposite is attributed to the broader solar spectrum absorption, efficient photo-induced charge separation and high surface area with a large fraction of mesopores.



Monitoring Axial and Radial Junction GaAs Nanowire Solar Cells Through a New Approach: Towards Efficient Performance

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Vertical GaAs nanowires (NW) in regular arrays are one of the most promising designs to outperform and replace conventional thin film planar geometry solar cells, and achieving high-efficiency & low-cost future solar cells due to its unique intrinsic light trapping with exceptionally low optical reflection in addition to low material consumption. A solar energy conversion efficiency of 15.3 % under AM1.5G solar illumination at 1-sun intensity in an axial junction GaAs NW array device has already been reported [1]. On the other hand, the radial junction GaAs/Al_x Ga_(1-x)As core-shell NW geometry can enhance this efficiency beyond the Shockley-Queisser theoretical limit as this structure allows extracting carriers radially through a much shorter dimension, resulting in a much higher carrier collection efficiency [2]. However, to practically achieve high solar conversion efficiency either from an axial or radial junction NW array device is challenging as it requires a strong enough rectifying junction (axial or radial) inside the NW, transparent and low-resistive electrical contacts, proper insulation between p- & n- segment or shell, an effective passivation shell for the reduction of surface recombination etc.

In this contribution, we are presenting a new approach to monitor both axial and radial junction GaAs NW solar cell devices from the analysis of its dark current-voltage characteristics through three different probing schemes: a) single NW device, b) NW array device and c) direct probing of individual as-grown NWs using tungsten nano-probes in a focused ion beam (FIB) system. Each of these schemes will help us to eliminate one or more possible major issues in the device individually, and together they allow us to understand and monitor the NW solar cell in order to systematically improve the design and maximize the photovoltaic efficiency.

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Characterization of model biomarkers in microfluidic Y-channels.

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Microfluidic flow channels are combined with biosensors to enhance performance related to detection limit, and detection in small volumes. However, the laminar flow in microfluidics reduces the probability of the biomarker reaching the sensing area since this flow regime limits the biomarker to diffusive transport. Therefore, the fraction of biomarkers in the sample reaching the specific recognition moieties at the sensing area is limited.

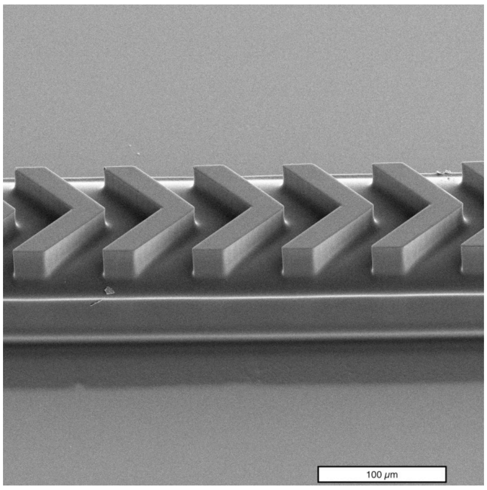

Fig1. Microfluidic Si-mold with a passive mixing structure.

Through the addition of passive mixing structures in the microfluidic channels the probability of contact between the biomarker and immobilized capture molecules can be increased. The effects of minimizing sample volume and efficient mass transfer to the sensing area are expected to reduce readout time. In the present contribution, we address the optimization of core microfluidic device parameters related to enhancing biosensor performance, using computational and experimental methods.