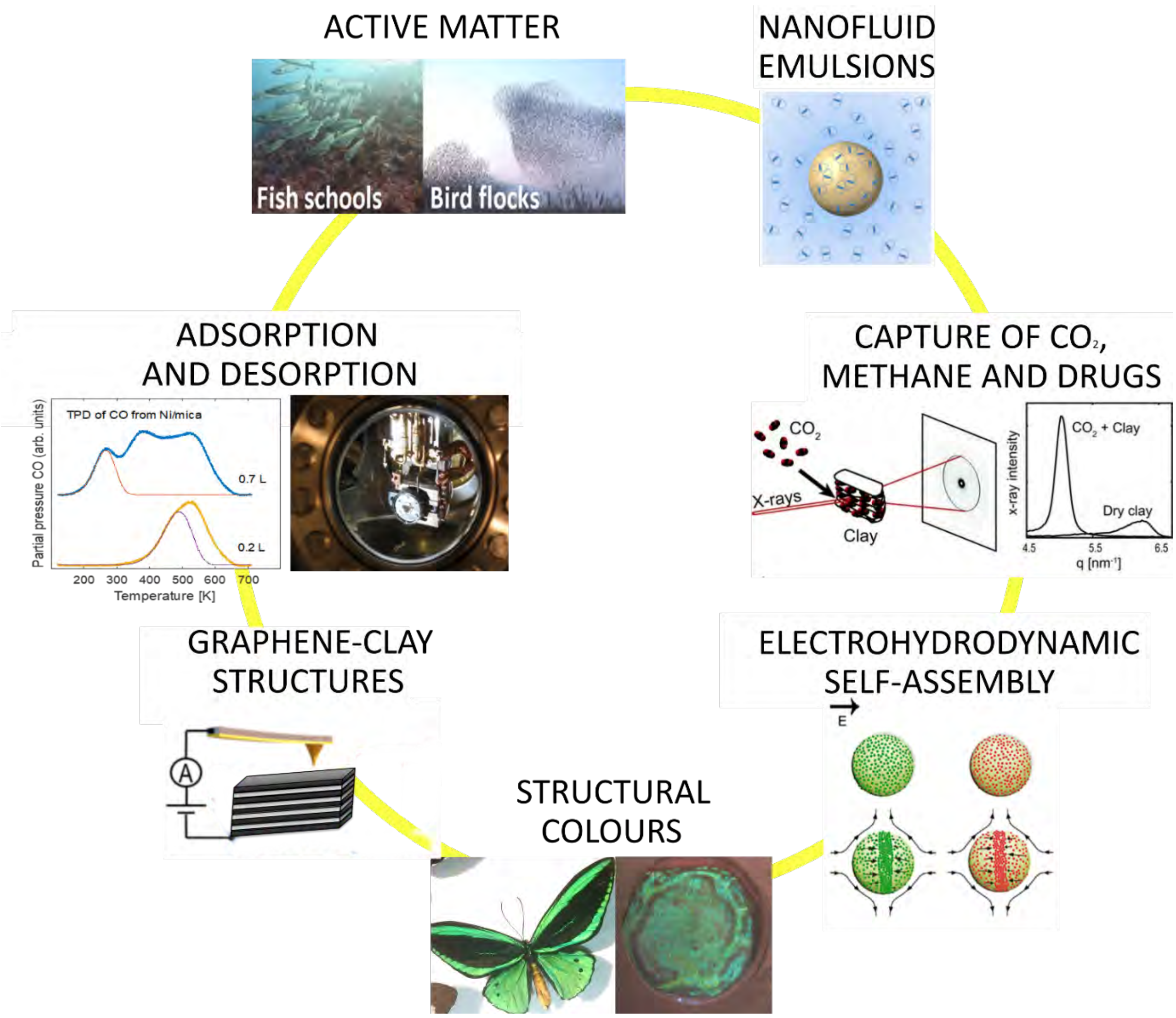
PROJECT/MASTER PROJECTS 2019 IN LABORATORY FOR SOFT AND COMPLEX MATTER STUDIES

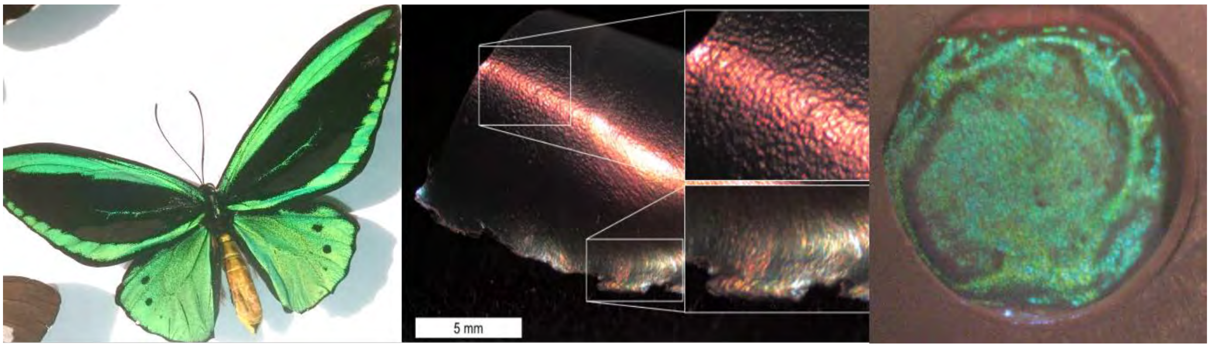
The Laboratory of Soft and Complex Matter Studies has a focus on natural materials (clay, cellulose, carbon, iron-oxide etc.), their properties and functionalities (like structural, optical, electronic), the fundamentals of soft matter (colloids and particle-particle interactions), active matter, and cross disciplinary topics (such as medical drug release, CO_2 capture). Depending on the studied problem, our work includes everything from hands-on work with simple experiments using in-house equipment to top-end experiments at international synchrotron radiation facilities. The project descriptions below are aimed at both 5-year and 2-year Master students, of physics, chemistry, materials science, nano-technology, or bio-physics.



PROJECT 1:
STRUCTURAL COLOURS – MAKING PHYSICAL COLOUR WITHOUT CHEMICAL PIGMENTS

Motivation

Nature can produce various wonderful physical colours without use of chemical pigments, as we can see when looking at butterflies, birds, beetles, reptiles or bacteria. How is it possible that no dye is needed to make such a nice effect? Periodic structures on the surface can cause constructive or destructive interference of incoming light and as a result, colour perception with no dye included is observed. One motivation of the current project is to go beyond the traditional ways of making colours, and use structure of surface itself to reflect light with desired wavelength.



Left: *Butterfly. Middle: Mesoporous SiO_2 film reflecting in red.* ***Right:*** *Polystyrene-clay layer reflecting in green.*

Role of the student in the project

The Master student will focus on preparation of the structural colour samples. The actual work will depend on the student's interest and preferences. Materials used for sample preparation can be polystyrene and glass nanobeads, single layer clay sheets, cellulose, carbon black particles and their combination. Projects involve making the extended colour palette using monodispersed polystyrene or glass nanobeads and clay, preparing mesoporous glass films combined with cellulose and/or clay, changing colour tone selected structural colour sample, preparation of multilayered structures combining effect of structural colour and multi-layer reflectivity or others. The Master students will work on their own specific projects in the NTNU home lab and in case of interest, participate on experimental work performed on synchrotron facilities and laboratories of collaborating partners.

Requirements

Interest in science and experimental work. Background in the soft matter, condensed matter, material physics or chemistry is of high advantage. Ability to work independently under the supervision and in the larger experimental group.

Other aspects

There are several ongoing projects in the lab. Students can participate in the experiments carried at the synchrotron/neutron facilities and experiments in external collaborating laboratories (NOVA University Lisboa, Portugal or Univ. Cambridge, UK).

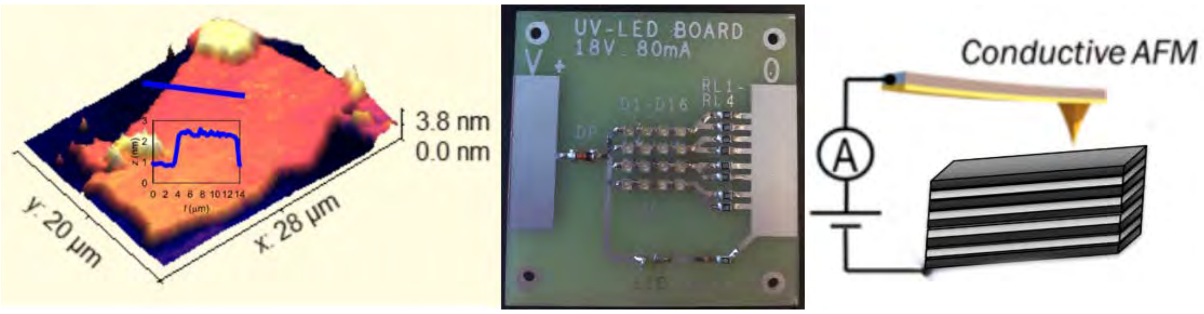
Contact person(s)

For further details, please contact Ana Trindade (ana.c.trindade@ntnu.no), Ville Liljeström (ville.v.liljestrom@gmail.com) or Jon Otto Fossum (jon.fossum@ntnu.no).

PROJECT 2: GRAPHENE-CLAY HETEROSTRUCTURES

Motivation

Two dimensional (2D) structures belong to the new class of materials exhibiting completely new and exciting physical properties. With this class of materials, we have the experimental access to phenomena that were either just predicted theoretically or their existence was even not postulated before. Inspired by the variety of studied 2D (semi)-conductors and insulators, we work on 2D systems based on layered silicates and graphene, with the focus on their potential use in electronics.



Left: *3D AFM image of the single layer Na-fluorohectorite. Middle: UV LED-array for illumination of graphene oxide.* ***Right****: Sketch of the C-AFM experiment on heterostructure of clay (gray layers)-intercalated layers (black layers).*

Role of the student in the project

The Master student will study different types of 2D materials and heterostructures, with focus on preparation and selected characterizations. The actual work will depend on the student's interest and preferences. Possible projects involve preparation and characterization of mechanically exfoliated single sheets of natural or synthetic clays; development of various methods for conversion of graphene oxide to graphene and/or investigation of its structure and electrical transport properties; preparation and selected characterizations of multi-layered structures of graphene and clay; development of methods for preparation of macroscopic layers with desired functionality, combining clay and graphene and others. Master student will work on its own specific project in the home NTNU lab and in case of interest, participate on experimental work performed on synchrotron facilities and laboratories of collaborating partners. Master work is related to the project Graphene-Clay systems.

Requirements

Interest in science and experimental work. Background in the condensed matter physics is of high advantage. Ability to work independently under the supervision and in the larger experimental group.

Other aspects

There are several ongoing projects in the lab. Students can participate in the experiments carried at the synchrotron/neutron facilities and experiments in external collaborating laboratories (Univ. Manchester, UK; Chalmers University, Sweden; Univ. Bayreuth, Germany).

Contact person(s)

For further details, please contact Barbara Pacakova (barbara.pacakova@ntnu.no), Paulo Brito (paulo.h.m.brito@ntnu.no) or Jon Otto Fossum (jon.fossum@ntnu.no).

PROJECT 3:
NANOFLUID EMULSIONS

Motivation

Nanofluids are fluids that contain one or multiple nanosized components such as metal, polymer, or mineral nanoparticles. Colloidal nanoparticles can be used to modulate the carrier fluid properties. Typical examples include improving the thermal or flow properties. Nanoparticles can also be used to stabilize emulsion drops (Pickering emulsions). In a complex material such as the three-phase system of water-oil-clay particles, the water-oil interface will additionally take part in the governing of the self-assembly, since the particles will be trapped by capillary forces and confined in a film at the liquid-liquid interface, as illustrated below). We focus on environmentally friendly nanoparticles. Such can be applied for example in medical applications, food industry, cosmetics, and improved oil recovery. The properties, distribution, and diffusion of nanoparticles within emulsions are studied in this project. The research utilizes microfluidics to produce uniform emulsions with controlled composition.

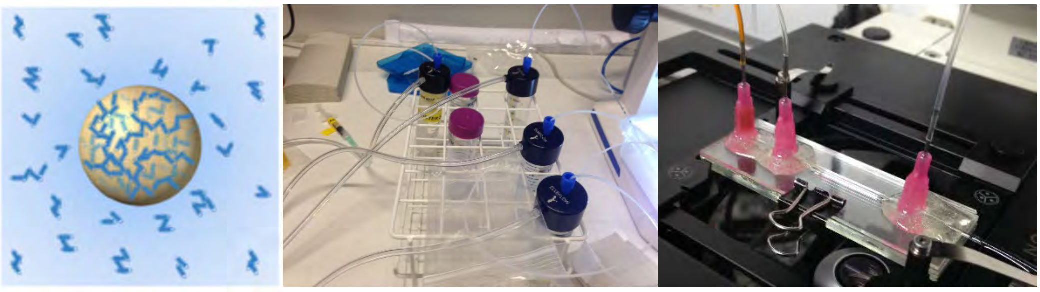


Figure: *Schematic (not to scale) representation of clay particle structure on an oil drop in water, without salt (left). For the system without salt, a repulsive "Wigner" colloidal glass is formed at the interface. From A. Gholamipour-Shirazi, M. S. Carvalho, M. Huila, K. Araki, P. Dommersnes & J. O. Fossum SCIENTIFIC REPORTS BY NATURE 6, 37239 (2016). (Middel, right): currect microfluidic laboratory setup.*

Role of the student in the project

The student will carry out microfluidic experiments, which will be initially monitored using optical microscopy. The student will take part in the planning and design of the experiments. Further characterization of nanofluid emulsions can be carried out using X-ray scattering or rheometry. The student will work together and be instructed by a post-doctoral researcher or a doctoral candidate.

The project is in collaboration with international partners and the planned research allows for a shorter or longer stay (one week to several weeks) at a partner organization. The partner organizations in this project are the École supérieure de physique et de chimie industrielles (Paris), Pontifical Catholic University of Rio de Janeiro (Brazil), Chalmers (Sweden).

Requirements

Enthusiasm and curiosity about materials science and soft materials. Any knowledge in chemistry and experience in micro- or nanofabrication is considered a plus.

Other aspects/ or Supplementary specifications

The project can include travelling to international synchrotron facilities (voluntary).

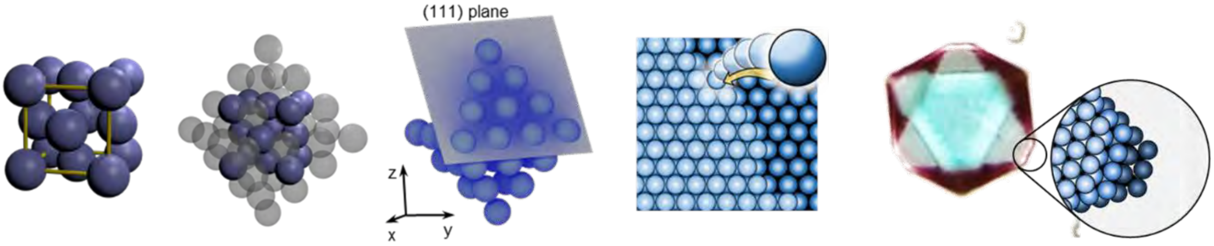
Contact person(s)

For further details, please contact Osvaldo Trigueiro (osvaldo.t.neto@ntnu.no), Ville Liljeström (ville.v.liljestrom@gmail.com) or Jon Otto Fossum (jon.fossum@ntnu.no).

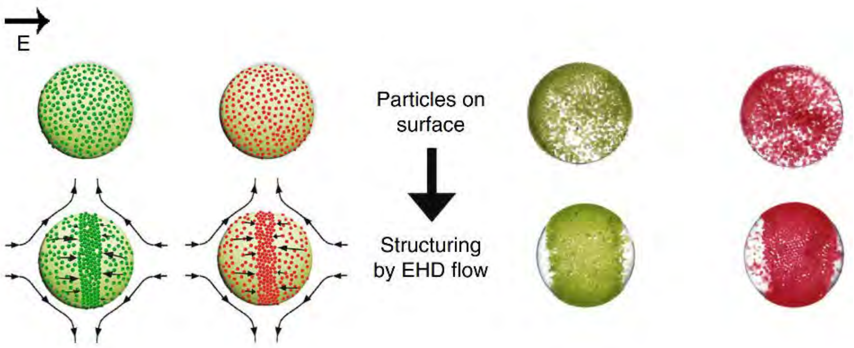
PROJECT 4:
SELF-ASSEMBLY OF NANOPARTICLE STRUCTURES

Motivation

Nanoparticles, both synthetic and biological (e.g. proteins) can be viewed as functional building units. Recent studies show that such nanoparticles can be self-assembled into functional aggregates with a well-ordered structure. Also the macroscopic shape (submillimetre range) of such assemblies can be controlled. For practical application such materials need to be further manipulated, processed, and integrated into a device. This project focuses on understanding and controlling the electrostatic self-assembly of facetted multicomponent nanoparticle crystals, which can in a later stage be assembled into larger structures using external fields i.e. electrohydrodynamic self-assembly (EHD).



The relationship between the observed face centred cubic structure and the macroscopic crystal habit.



Example of self-assembly by EHD flow, as presented by Rozynek Z., Mikkelsen A., Dommersnes P. and Fossum J. O. in NATURE COMMUNICATIONS, 5, 3945 (2014).

Role of the student in the project

The student will work hands-on with in-house equipment. The student will participate in most of the experiments included in the project. The project includes microfluidic experiments that will be initially observed with optical microscopy and eventually small-angle X-ray scattering (SAXS) will be used to analyze the resulting structures.
The project is in collaboration with international partners and the planned research allows for a shorter or longer stay (one week to several weeks) at a partner organization. The partner organizations in this project are Aalto University (Finland), the École supérieure de physique et de chimie industrielles (Paris), Pontifical Catholic University of Rio de Janeiro (Brazil), Chalmers (Sweden).

Requirements

Enthusiasm and curiosity about materials science and soft materials. Any knowledge in chemistry and experience in micro- or nanofabrication is considered a plus.

Other aspects/ or Supplementary specifications

The project can include travelling to international synchrotron facilities (voluntary).

Contact person(s)

For further details, please contact Ville Liljeström (ville.v.liljestrom@gmail.com), Kenneth Knudsen (kenneth.knudsen@ife.no), Paulo Brito (paulo.h.m.brito@ntnu.no) or Jon Otto Fossum (jon.fossum@ntnu.no).

PROJECT 5:
ACTIVE MATTER

Motivation

The objective is to investigate and model experimentally and theoretically how dynamic activated colloidal (such as clay) particle assemblies can be used to mimic common structures found in nature, such as bird, fish or insect flocking, or even human or traffic crowding behaviors. Active matter (https://en.wikipedia.org/wiki/Active_matter) is currently itself a very active area in soft matter statistical physics, and we will initiate student projects looking at active processing of novel soft materials structures based on natural materials such as clay, zeolite, cellulose, graphite, etc.

Role of the student in the project

The Master student will work together with a PhD candidate or a postdoc, and will study cooperative behaviors of activated particles, and aid in modeling the cooperative mechanisms. The experimental techniques involved are optical microscopy and subsequently image analysis. At a later stage we will study such phenomena using nano-particles and employ (synchrotron or NTNU home-laboratory based) X-ray scattering, neutron scattering (at Institute for Energy Technology) at Kjeller, or at international neutron facilities. International collaboration is integrated in the activities, and the Master project can be designed to contain from weeks to months stays with external partners. The main international partners in these activities are: Aalto Univ. Finland, IPGG/ESPCI-ParisTech in France, Oxford Univ. in UK (numerical studies), and Harvard Univ. in USA.

Requirements

It is advantageous with an enthusiastic interest and course background in material physics, condensed matter physics, materials science, materials chemistry, nano-science.

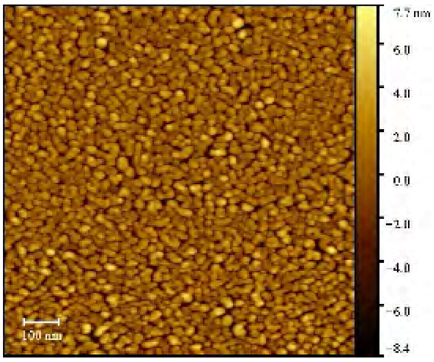
Contact person(s)

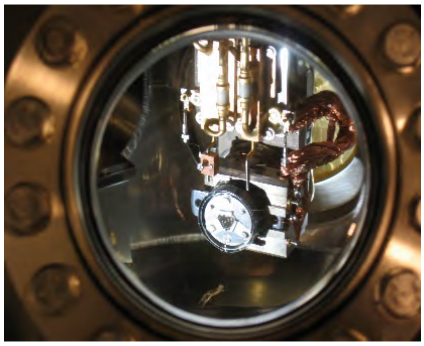
For further details, please contact: Paul Dommersnes (paul.dommersnes@gmail.com), Etien Martinez (etien.martinez@ntnu.no), or Jon Otto Fossum (jon.fossum@ntnu.no).

PROJECT 6:
SURFACE SCIENCE STUDIES OF THE REACTIVITY OF SUPPORTED METAL NANOPARTICLES AND NANOSTRUCTURES

Motivation

Adsorption on nanoparticles is of relevance for many applications in catalysis as well as for sequestration of greenhouse gases. The objective is to investigate and tune adsorption properties of metal nanostructures on different substrates. The reactivity of nanoparticles/nanostructures depends on the size and shape, and depends on interaction with the support.





Figur 1 Left: AFM image of Ni nanoparticles on muscovite mica. Right: Sample holder assembly inside the ultra-high-vacuum chamber.

Role of the student in the project

For practical applications, nanoparticles must be dispersed on porous or layered materials, which contains a large effective internal surface area. However, the present project aims to study properties of metal nanoparticles that are supported on well-defined substrates by surface science techniques in ultra-high-vacuum. The substrates may be clay minerals, which are materials that contain two-dimensional stacks of inorganic layers. One prime example is muscovite mica, where large samples of ordered surfaces exist. Other relevant substrates may be highly oriented pyrolytic graphite or metal oxides. In this project, adsorption of CO, CO_2 and CH_4 on metal nanoparticles/nanostructures on different substrates, will be studied by use of X-ray photoelectron spectroscopy (XPS), temperature programmed desorption (TPD), and atomic force microscopy (AFM). The nanostructured samples serve as model systems for studying doped surfaces by surface analytical tools. The student will perform sample preparation, data acquisition and analysis with assistance from members of the research group.

Requirements

Interest in science and experimental work. Background in condensed matter physics is an advantage. Ability to work independently under supervision in the laboratory.

Contact person(s)

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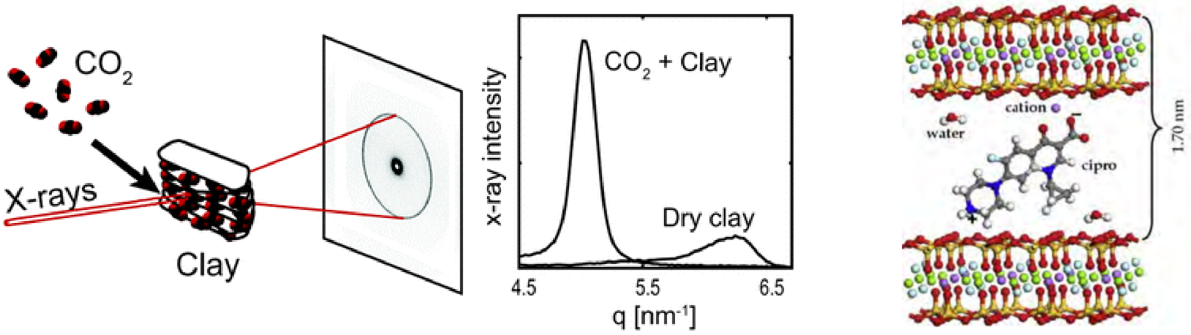
PROJECT 7:
CAPTURE MECHANISMS OF CO_2, METHANE OR DRUG MOLECULES BY NANO-LAMELLAR CLAY SYSTEMS: FROM GREENHOUSE GAS CAPTURE TO DRUG-DELIVERY

Motivation

A large variety of molecules may adsorb onto nano-silicate clay surfaces by means of different mechanisms. The objective of this activity in our laboratory is to understand active fundamental molecular interaction mechanisms at nano-confined clay surfaces. We put particular emphasis on capture of CO_2, methane (CH_4) or drug molecules. In this context clays represent lamellar nano-"container" systems (capturing/transport/release elements). Nano-lamellar clays are unique as molecular carrier "vehicles" due do their large effective surface area with more than 1000 square kilometers of effective surface area contained in one cubic meter, coupled to their tunable surface charge (order of magnitude 1 electron charge per square nm). Actual relevance here is for capturing and sequestration of green-house gases such as CO_2 or methane, or for medical drug delivery by means of clays etc. Our group has already a considerable experience in studies of the nano-fluidics of H_2O and CO_2, as well as in drug capture, and we wish to develop this further using several experimental methods.



Left: Intercalated cations in between the lamella of a stacked nano-layered clay particle may capture and retain CO2 molecules. This results in an expansion of the structure that can be measured by means of standard X-ray scattering methods. See: Intercalation and Retention of Carbon Dioxide in a Smectite Clay promoted by Interlayer Cation, L. Michels, J. O. Fossum, Z. Rozynek, H. Hemmen, K. Rustenberg, P. A. Sobas, G. N. Kalantzopoulos, K. D. Knudsen, M. Janek, T. S. Plivelic & G. J. da Silva, SCIENTIFIC REPORTS BY NATURE 5, 8775 (2015)
Right: Sketch of a possible configuration of a nano-spaced clay compartment with intercalated and captured Ciproflaxicin drug molecules, that can be released in a controlled manner. See: Ciprofloxacin intercalated in fluorohectorite clay: Identical pure drug activity and toxicity with higher adsorption and controlled release rates, E.C. dos Santos, Z. Rozynek, E.L. Hansen, R. Hartmann-Petersen, R.N. Klitgaard, A. Loebner-Olesen, L. Michels, A. Mikkelsen, T.S. Plivelic, H.N. Bordallo, J.O. Fossum, RSC ADVANCES 7, 26537-26545 (2017)

Role of the student in the project

The Master student will work together with a PhD candidate or a postdoc, and will study molecular adsorption, and retention in synthetic nano-silicate clay particles, and aid in modeling the capturing mechanisms. The experimental techniques involved are (synchrotron or NTNU home-laboratory based) X-ray scattering, neutron scattering (at Institute for Energy Technology) at Kjeller or at international neutron facilities. Thermodynamic methods such as TGA or calorimetry will also be employed. International collaboration is integrated in the activities, and the Master project can be designed to contain from weeks to months stays with external partners. The main international partners in these activities are: Institute for Energy Technology at Kjeller, University of Copenhagen (neutron scattering), Texas Tech. University USA (on numerical modeling), USP Sao Paulo Brazil (modeling), Univ. Bayreuth Germany (sample preparation).

Requirements

It is advantageous with an enthusiastic interest and course background in material physics, condensed matter physics, materials science, materials chemistry, nano-science.

Contact person(s)

For further details, please contact: Kristoffer Hunvik (kristoffer.hunvik@ntnu.no) Kenneth D. Knudsen (kenneth.knudsen@ife.no) or Jon Otto Fossum (jon.fossum@ntnu.no)

SEVERAL PROJECTS ON INSTRUMENTATION AND DESIGN OF EXPERIMENTAL SET-UPS CONNECTED TO ALL THE PROJECTS ABOVE

Examples:

A. MEMS and microfluidics, instrumentation

The emphasis of this project is instrumentation and characterization.
The aim of the project is to develop a microfluidic device, "a microreactor", for field-driven self-assembly of nanocomposites. Producing and characterizing (quality and performance) a well-functionig microfluidic devices implies a good design and work in the nanolab cleanroom (production of microfluidic chips). In total the work and studies related to making the device will take more than 50% of the time.

Proof-of-concept experiments are included to demonstrate the sample cell properties. Such experiments and analysis of the results can be a significant part of the project.

The project is suitable for a student who is interested in instrumentation, practical problem solving, and micro- to nanoscale materials characterization. The project contributes to research on nanoparticle interactions and nanocomposites.

The work is independent, but there is a possibility to combine this project with projects B and/or C to certain extent. Students benefit from collaboration.

B. SAXS sample cell, instrumentation

The emphasis of this project is instrumentation and characterization.
The task is to design and build a sample cell for small-angle X-ray scattering (SAXS) characterization of external field-driven structuring of soft matter, such as electric or magnetic field-driven structuring of nanocomposites. The student will work independently on the task, but will get the required training and guidance required for a successfull outcome of the project.
The project is suitable for a student who is interested in instrumentation, practical problem solving, and wants to contribute to research on nanoparticle interactions and nanocomposites.
The work is independent, but there is a possibility to combine this project with projects A and/or C to certain extent. Students benefit from collaboration.

C. Interactions and self-assembly of nanoparticles

The emphasis of this project is instrumentation and characterization.
The dynamics of electrostatically interacting nanoparticles is important for many applications including biological systems, industrial applications, and self-assembly of well-defined new types of nanocomposite materials.
The task of the student is to carry out self-assembly experiments including charged nanoparticles.
The work includes setting up the experiment, where monitoring of self-assembly can be carried out using an optical microscope. The work is independent, but there is a possibility to combine this project with projects A and/or B to certain extent. Students benefit from collaboration. Numerical simulations can be added as an optional/supplementary part of the project, if the student has previous experience of computer simulations.

Requirements

It is advantageous with an enthusiastic interest and course background in experimmental physics, electronics, instrument programming (Matlab, Labview etc)..

Contact person(s)

For further details, please contact: Ville Liljestrøm (ville.v.liljestrom@gmail.com), Kristoffer Hunvik (kristoffer.hunvik@ntnu.no), Steinar Raaen (steinar.raaen@ntnu.no) or Jon Otto Fossum (jon.fossum@ntnu.no)