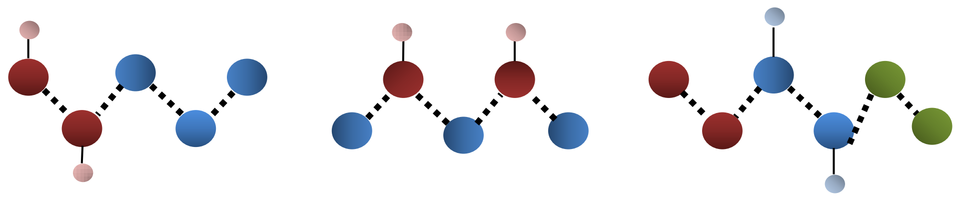
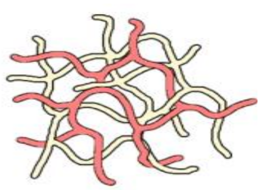
Membrane Preparation and Characterization

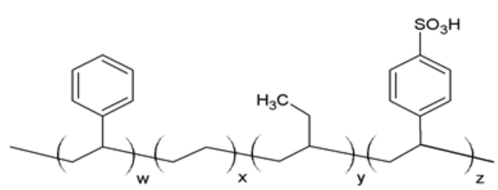
Prepare New Polymeric Membranes for Energy Applications

A membrane can be considered as a selective barrier that allows transport of some compounds while rejecting others. Depending on the application different types of membranes are needed. Given a specific application it is possible to target the desired membrane structure and morphology.

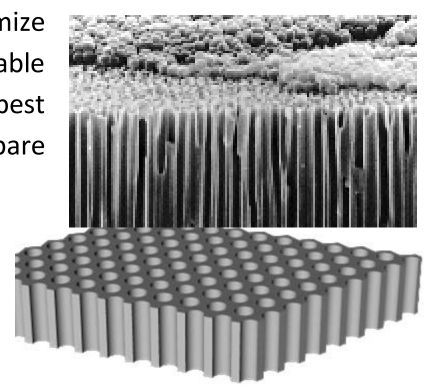


Polymeric membranes are desirable in a lot of applications due to e.g. the high mechanical stability, good selectivity and "easy" preparation on industrial scale. In the figure above is shown three examples of generic structures of some polymer chains. By carefully choosing the monomer units (the building blocks) and the reaction method it is possible to design different polymer structures and morphologies. One application for the polymeric membranes could be for example the flow batteries where a low crossover of the electrolytes (ions) is needed to get a high efficiency. Preparation of polymeric structures for membranes could be a project where you will get to work with organic synthesis (polymerizations), characterization techniques (such NMR, IR, GPC, contact angle, impedance spectroscopy) but also testing the membrane for relevant transport properties (could be selectivity, permeability, charge-discharge).





Surface or pore modifications of support materials can be used to optimize the properties of the exiting support, stabilize a mechanical unstable material and/or get enhanced properties by (hopefully) getting the best from both the used materials. This method can be used to prepare membranes for applications within gas separation where the trade-off between diffusivity, permeability and selectivity is essential. Again synthesis and characterization will be part of the project as well as characterization the produced membrane with respect to the mentioned properties.



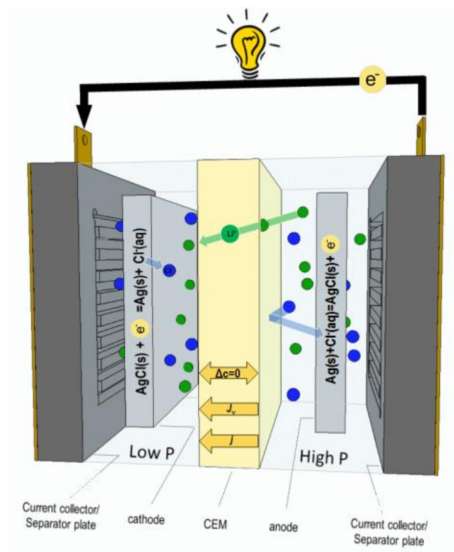
<u>For further information</u>: Anders Bentien, Jacopo Catalano or Mette Kristensen

Great bachelor and masters projects for students from Chemistry, Chemical Engineering and iNano

Electrokinetic Energy Conversion Efficiency of Nano-porous, Ion-conductive Membranes

This project applies membranes for energy conversion, i.e. for transforming energy from one form to another. Kinetic energy, in form of a pressure difference, is converted to electrical energy and vice versa. The main focus of this project is to measure the direct efficiency of this conversion for various membranes.

- ➔ Applying, improving and designing specialized equipment.
- ➔ The use of various sensors (pressure, mass, temperature, potential, current etc.)
- ➔ Developing LabVIEW based programs for collecting data.
- ➔ Hydrophobic surface modification of pores



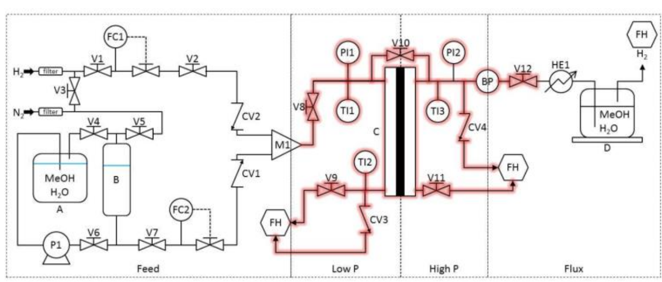
For further information contact: David Østedgaard-Munck or Jacopo Catalano

Great bachelor and masters projects for students from Chemistry, Engineering and Physics

Electrokinetic Hydrogen Compression

In this project the feasibility of using Electrokinetic phenomena for gas compression is investigated. This is a new pathway for refrigerators or, more generally, gas/vapor compression systems.

- ➔ Bake-in of a H_2 compression prototype (available at the Chem. Eng. laboratories).
- ➔ Acquire experience in chemical engineering processes, system design and control
- ➔ Exploring disruptive processes and collecting data never reported in the literature.



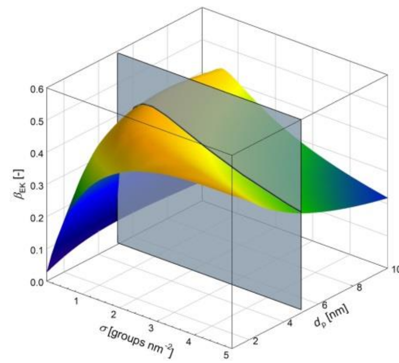
For further information contact: Anders Bentien, David Østedgaard-Munck or Jacopo Catalano

Great masters projects for students from Engineering and Physics

Continuum/CFD Modeling of Pore Nanostructures

Charged ion-exchange membranes, or other films containing pores or channels of nanoscopic dimensions carrying immobile wall charge, can be used for energy conversion (for instance reverse electrodialysis, electrokinetic energy conversion) where the flow of fluid down a pressure or a salinity gradient or through such materials creates an electric current and voltage. Considering ions as point charges, the mathematical theory combines the Navier-Stokes, Nernst-Planck and Poisson equations. In this project you will acquire experience in the description of electro-migration phenomena which characterize not only membrane but in general transport in the exciting new classes of materials such as carbon nanotubes.

- ➔ Modelling of transport properties of nanocapillaries and pore network
- ➔ Simulations of electro-migration of ions
- ➔ Material/polymer optimization



This project requires a good mathematical and physical background and it is part of a collaboration between Aarhus University and Wetsus, European Centre of Excellence for Sustainable Water Technology.

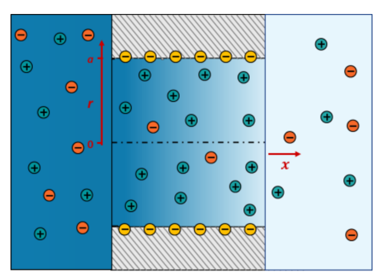
For further information: Jacopo Catalano

Great masters projects for students from Engineering and Physics

Design and Manufacturing of Electrochemical Cells

This project aims to investigate the transport properties of ions typically used in novel energy storage systems (for instance flow batteries) in polymeric materials. The knowledge of the diffusion coefficients is of fundamental importance on designing the batteries' separators for efficient batteries and to improve their cyclability. In particular you will design an electrochemical cell for measuring the ion diffusion coefficient upon a chemical potential driving force and you are expected to integrate UV/VIS spectroscopy probes. You will acquire knowledge on process design, optimization, data acquisition and analysis.

- ➔ Design of set-ups for measuring diffusion of ions
- ➔ Design of Osmometers
- ➔ Data acquisition and analysis (python, matlab, Labivew)



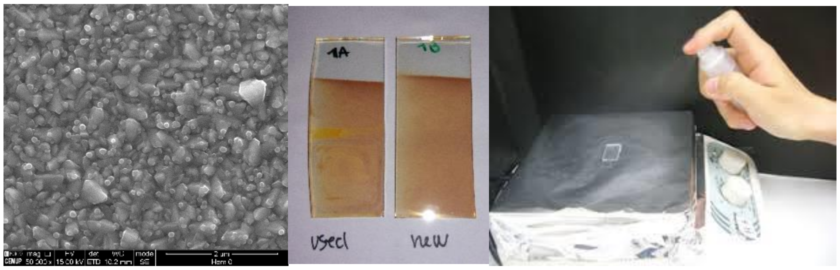
For further information: Jacopo Catalano, Emil Drazevic or Mette Kristensen

Great bachelor and masters projects for students from Chemistry, Engineering, iNano and Physics

Solar Batteries

Optimization of Lab-scale Production of Thin Film Semiconductor Photoelectrodes

We have recently shown that certain electrolytes in redox flow batteries can be directly solar charged (with a bias potential) by putting them into contact with thin-film photoelectrodes and shining light on them. However, the efficiency depends very much on the production method.



You will produce the photoelectrodes under various conditions and characterize them in terms of how efficiently they can charge a selected redox flow battery using a solar simulator. XRD, impedance spectroscopy & SEM measurements can also be included in the characterization.
Possible photoelectrodes are: Ta_3N_5, WSe_2, Fe_2O_3 (hematite)

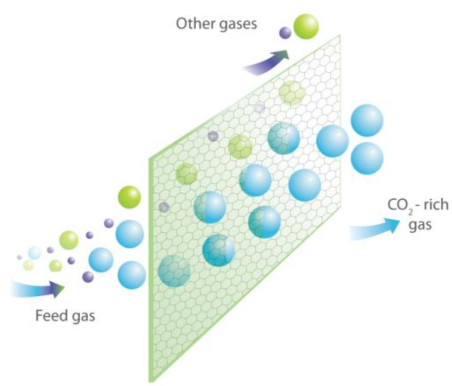
For further information: Kristina Wedege

Great bachelor and masters projects for students from Chemistry and iNano

Novel Membranes for Gas Separation and Carbon Capture

Glassy or rubbery polymer filled with inorganics for CO_2 capture

- ➔ Pore-filling modifications
- ➔ Effect of post-treatment of membranes
- ➔ Gas permeability measurements
- ➔ Structural and microscopic characterization



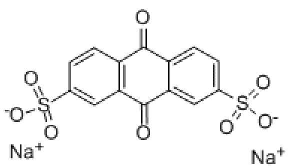
For further information contact: Jacopo Catalano

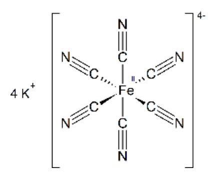
Great bachelor and masters projects for students from Chemistry

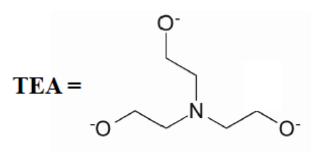
Flow Batteries

Using Electrochemistry to Discover Alternative Electrolytes for Redox Flow Batteries in Basic Environment

It is important to find new and better electrolytes for use in redox flow batteries to improve the technology to a commercial level. Electrolytes that works at pH > 12 are good because crossover can be limited, kinetics improved and the electrolytes can possibly be coupled with solar charging. Electrolytes in basic environment can be both organic or inorganic, e.g. anthraquinones, iron-cyanide complexes or cobalt/iron complexes with organic ligands:







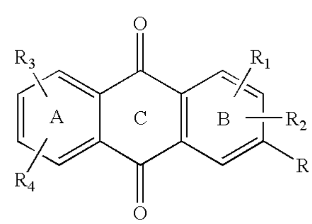
You will determine standard redox potentials, stability and kinetic parameters by using electrochemical methods (e.g. cyclic voltammetry, rotating disk electrode experiments) and will eventually test the electrolytes in a lab scale battery.

<u>For further information contact:</u> Kristina Wedege, Amirreza Khataee or Anders Bentien

Great bachelor (masters) projects for students from Chemistry

Synthesis, Purification and Characterization of Organic Quinone based Derivatives for use in Redox Flow Batteries

Batteries for a future renewable based utility grid must be based on earth abundant raw materials and must be at considerably lower costs. Some Anthraquinones have shown a huge potential in aqueous based redox flow batteries. Some of the important parameters for batteries, e.g., solubility, stability and redox potential are to a large extent determined by the side groups on the Quinones. The goal is to **synthesize organic species** which are not commercially available but are promising as organic redox species. To achieve our goal of finding the best possible "not from the shelf" candidate, we follow two different methodologies. (i) The first approach is to modify quinone structures in order to achieve better solubility and stability. In this case the quinone moiety is substituted with hydrophilic groups to increase solubility. (ii) The second methodology concerns modifying and testing core structures where instead of the oxygen (Quinone derivatives) the nitrogen is the containing core structures like viologen, NAD and FAD analogues.



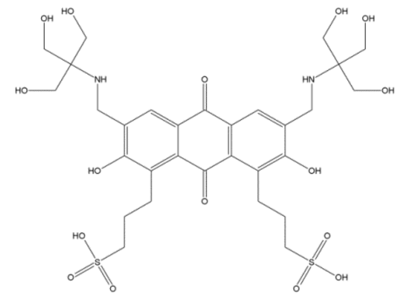
You will synthesize and purify selected anthraquinone molecules from unsubstituted anthraquinone and determine the standard potential by electrochemical measurements.

<u>For further information contact:</u> Emil Drazevic or Anders Bentien

Great masters projects for students from Chemistry

Redox Buffers - a Pathway to All Quinone Flow Battery

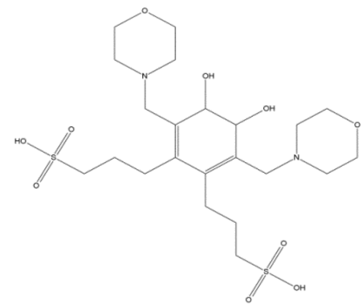
The open circuit voltage of currently feasible all quinone battery is only 0.7 V. The electrode potential of quinones strongly depends on the pH. If the difference in pH on catholyte and anolyte side is 2 pH units, additional 0.12 V can be extracted from the system. For instance the potential of catechol is +0.44 V at pH=6. On the negative side anthraflavic acid has potential of –0.48 V at pH=8. This amounts to 0.92 V of cell potential if this pH difference can be maintained. Good's biological buffers (MES, MOPS, MOPSO) utilize morpholino and sulfonic groups on a single organic molecule. Sulfonic groups act as a strong proton donor while morpholino groups acts as proton acceptors.



TAPS derivative of anthraflavic acid

Inspired by the Goods buffers we intend to attach both morpholino and acidic groups and make quinones-buffers that are incredibly soluble in water and can keep the cell voltage constant during charging/discharging. Some of the possible chemistries are find below/above.

You will do some organic synthesis, basic electrochemical characterization and thereafter some battery tests.



"MOPS" derivative of catehol

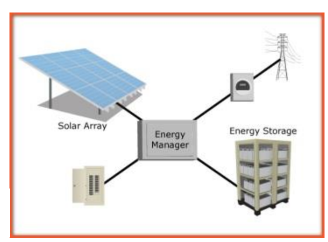
<u>For further information contact:</u> Emil Drazevic or Amirreza Khataee

Great masters projects for students from Chemistry

Optimization Studies for a kW-scale Vanadium Redox Flow Battery and Photovoltaic System

The development of the electric system, due to the strong increase of the distributed and renewable generation, is posing new challenges to the management and control of the power system. Concerning the photovoltaic power generation, one of the major issues is related to its production profile, hardly predictable and manageable, that could cause overloading or overvoltage. This project is related to the development and optimization of control strategies of a kW-scale Vanadium Redox Flow Battery System that is charged with solar power and discharges energy to the local power grid.

kW-scale Redox Flow Battery stack



Schematics of the hybrid energy system

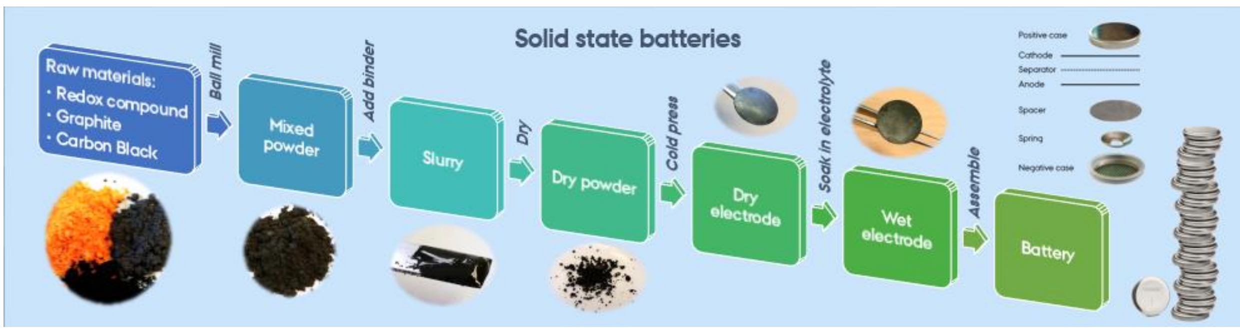
You will work with a state-of-the-art Vanadium Redox Flow Battery stack. Your task will be to develop control strategies for the energy storage system with respect to e.g. power generation and energy generation. Of utmost importance to the project is to consider the interaction between the energy storage and the solar energy system. The behavior of the solar energy system will be mimicked using an industrial power supply.

<u>For further information contact:</u> Luis Carlos Pérez Matínez

Great masters projects for students from Engineering

Solid State Batteries

New materials are experimented in rechargeable aqueous based solid state batteries. Commercial Ni-Cd and Ni-MH batteries outperform in many different aspects, however the former are toxic and the latter appear too expensive for large scale energy storage. Therefore, we have started to look into new anodes for Ni based batteries. Currently we use $Ni(OH)_2$ as the cathode material, and a redox active polymer as anode material. We have achieved 1000 cycles with 60% loss in capacity. Most of the capacity loss (50%) results after 1st charging. It is hypothesized that our polymer has very low polydisperse index i.e. broad molecular weight distribution, which is why smaller molecules escape across the microporous separator and causes irreversible capacity loss. As with any battery technology in its beginnings, many obstacles are on the way. The process of making the batteries is shown below. It is a fun way of doing science! Some of the possible projects are described below, but we can always sit down and hear your own ideas for the projects!



Optimization of Existing Custom made Electrodes

The goal of this project is to make thicker polymer and nickel hydroxide electrodes that can be charged and discharged at a rate of ¼ of the rated capacity. This is a standard charging/discharging rate in large scale energy storage systems. The thicker electrodes will reduce the cost of the battery but that also means electrical resistance will increase and lower the charge/discharge rate. One of the strategies to overcome this problem is to implement carbon fibers into existing electrodes. However, the process of making the electrodes has many other variables, e.g. composition, pressure and pressing temperature of electrodes, electrolyte composition, etc., so there are many other possible ways for achieving the goal.

All Organic Solid State Batteries

The goal of this project is to make an all organic solid state battery with a voltage of at least 1 V in aqueous media. Interesting thing here, besides the low cost potential, is that all organic solid state batteries are environmentally friendly in a sense that they can be burned or biodegraded after use, thus we could avoid the need for specific recycling process. It is anticipated that one side of the battery utilize the existing redox polymer anode while the other side of the battery would utilize water insoluble redox polymer with sufficiently positive formal potential. The idea is to use TEMPO radical, which is insoluble in water, as the cathode material. The problem is once TEMPO is charged it becomes cation which is then soluble in water. In this sense the main research challenge is to make it insoluble and one of the strategies is attaching the TEMPO radical on a polymer backbone. There are existing papers in the literature with recipes for TEMPO radical polymerization, since the rumor is TEMPO is used as cathode in Li ion polymer solid state battery.

Novel Redox Polymer Anodes

The goal of the project is to find a way to synthesize other low cost redox polymers for their use as an anode in rechargeable solid state batteries. This project will be the most research intensive. It will probably include a lot of initial literature reading and teamwork, also with our polymer guys at Hangøvej 2. The unknown state of this project at this point will include lot of risk. But, there could also be some low hanging fruits here.

For further information contact: Casper Clausen, Emil Drazevic or Anders Bentien

Great bachelor and masters projects for students from Chemistry and Chemical Engineering

Projects with Companies

Grundfos and Kamstrup have a range of master projects. If you are interested please contact Anders Bentien

Further Information

To get further information regarding the different projects feel free to contact us by email or come by Department of Engineering on Hangøvej 2.

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