Departmental Overview: FIRST YEARS 27th JAN 2020

Prof PL de Vaal
Department of Chemical Engineering
University of Pretoria

Faculty of Engineering, Built Environment and Information Technology

GENERAL INFORMATION

- Did I make the right choice?
- What is ENGINEERING?
- Structure: Faculties & Departments
- Departmental webpage: www.up.ac.za/chemeng
  - Lecturing timetable
  - Offices: Engineering I, Level 8
- Student Administration: Engineering I, Level 6
- Student Finances: Client Services Centre, HSB

Departmental information

Staff & Students

Academic staff: Total: 16

Students: Total: 915

Undergraduate students (645)

Postgraduate students (270):

- Hons.: 146
- Master’s: 60
- PhD: 39

CURRENT TOPICS

- BIOTECHNOLOGY
- ADVANCED MATERIALS & POLYMERS
- WATER
- ENERGY
- OPTIMISATION

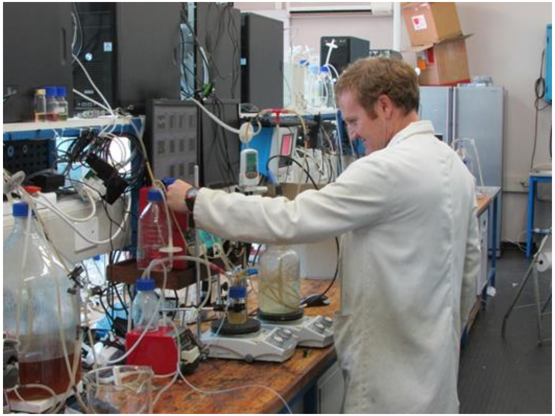
Research Areas

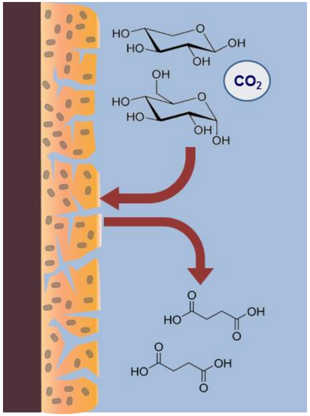
- Biochemical Engineering & Bioprocessing
- Advanced Materials, Polymers, Clays, Tribology & Product Development
- Water Utilisation & Environmental Engineering
- Energy Systems, Modeling, Optimisation & Control

Bioreaction Engineering

Platform Chemicals of Tomorrow

- Biomass-derived (biorefinery)
- Microbial metabolites (Biofilms)
- Bulk production (continuous processing)





Bioprocessing & Biorefining

Wood Beneficiation - Biorefining

- Biomass conversion via fast pyrolysis
- Extracting hemicellulose → C5-fermentation
- Processing black liquor
- Study to identify potential for local conditions
- RSA calibration of international data
- Black liquor to gas
- Gasification and alternatives
  - gasification & FT
  - direct liquefaction/hydrogenation
- Attainable region approach
- Identification of technology hurdles
- Biofilms

Advanced Materials, Carbon, Fluorine, Polymers & Clays

- **Extensive Analytical Equipment & Capabilities**
  - **The Institute of Applied Materials**
    - Graphene & applications.
    - Production of nuclear grade carbon from coal.
    - Synthesis of graphite from local pitches
    - Processing of bulk graphite
    - Use of graphite intercalation compounds as functional additives in polymers.
  - **Polymer Centre**
    - Modification of polymer properties by additives and by reactive processing.
      - Flame retardants for polyolefins
      - Volatile corrosion inhibitors for plastic packaging film
      - Malaria Vector Control

"Green" mining detonators

- Pyrotechnics in mine detonators
- "Green" time delay compositions
- Safer processing of pyrotechnics
- Non-destructive burn rate measurements
- Thermite replacement for primary explosives
- On-site detonator manufacture

AEL Mining Services

Pyrotechnics in time-delay fuses and mine detonators

- **Drivers:**

  Operational safety:

  No failures allowed

  Environmental concerns:

  Heavy metal compounds

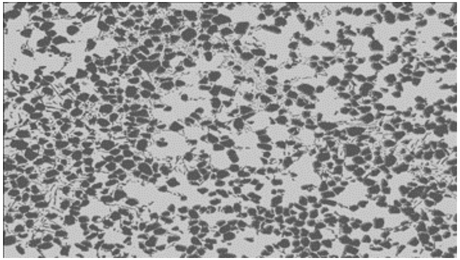
  Cost minimisation:

  Mass production (> 10^6/day)

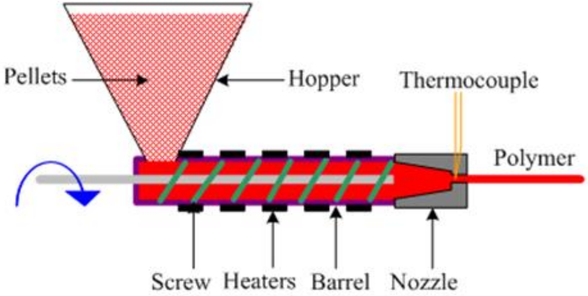
AEL Mining Services

Polymer processing

- Problems "go away" when the either the fuel or the oxidant forms a continuous liquid phase that can be solidified into a matrix when mixing is complete
- The advantages posed by plastics processing and additive manufacturing become possible with a thermoplastic matrix



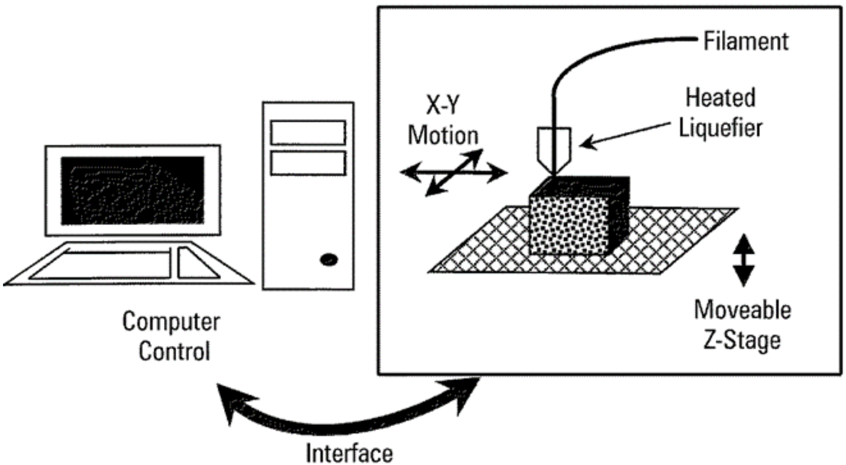
Particulate filled polymer

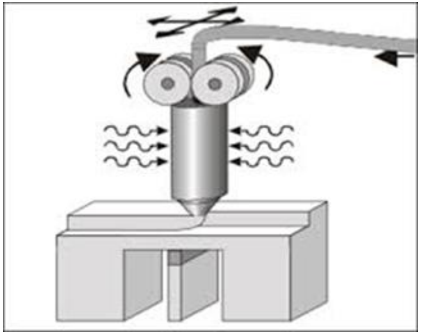


Continuous extrusion of a polymer filament

Aim: Print detonators on site

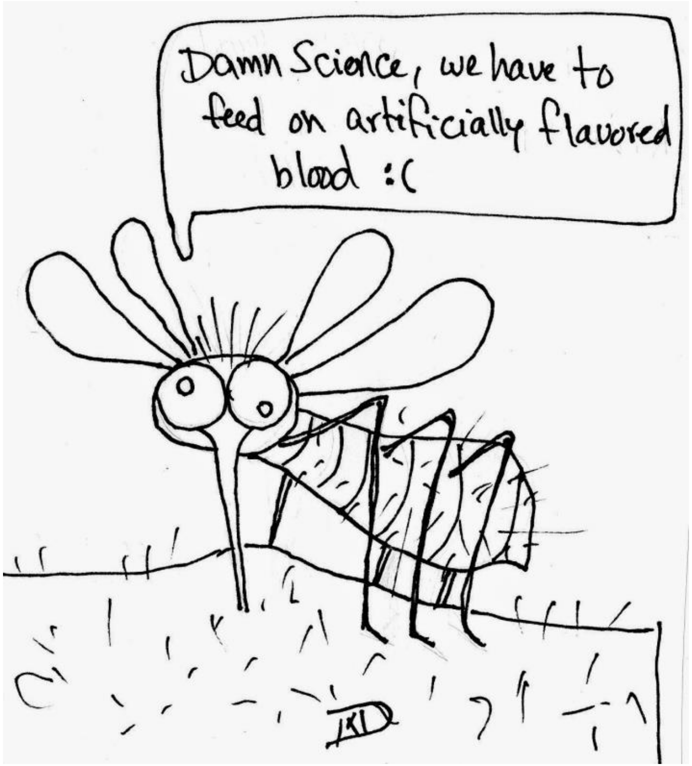
- **Design extrudable pyrotechnic compositions suitable for polymer strand extrusion and the 3D printing technique fused deposition modeling (FDM) also called fused filament construction**





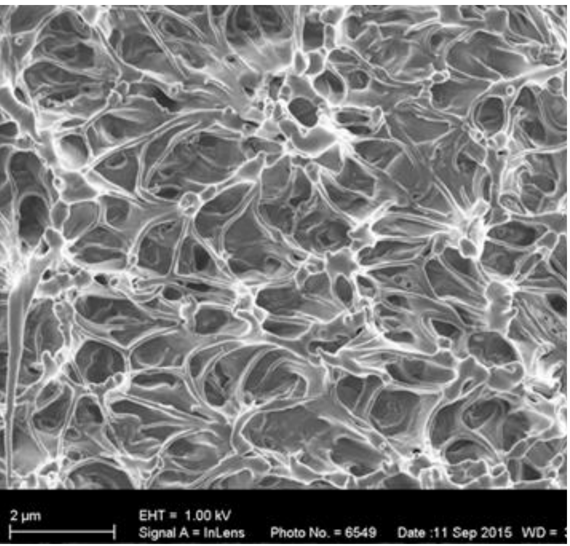
Mosquito-born diseases

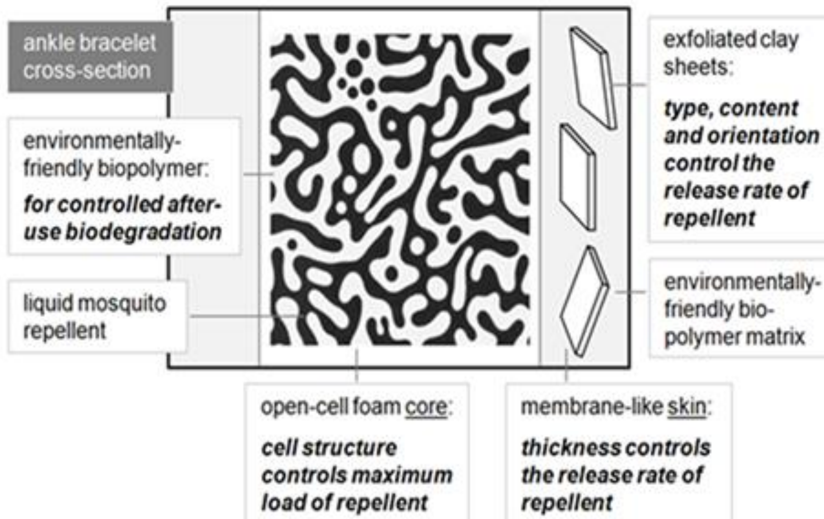
Chemical engineering concepts can be exploited to make a small contribution to improved vector control strategies



1. Polymer solution: Nanotechnology

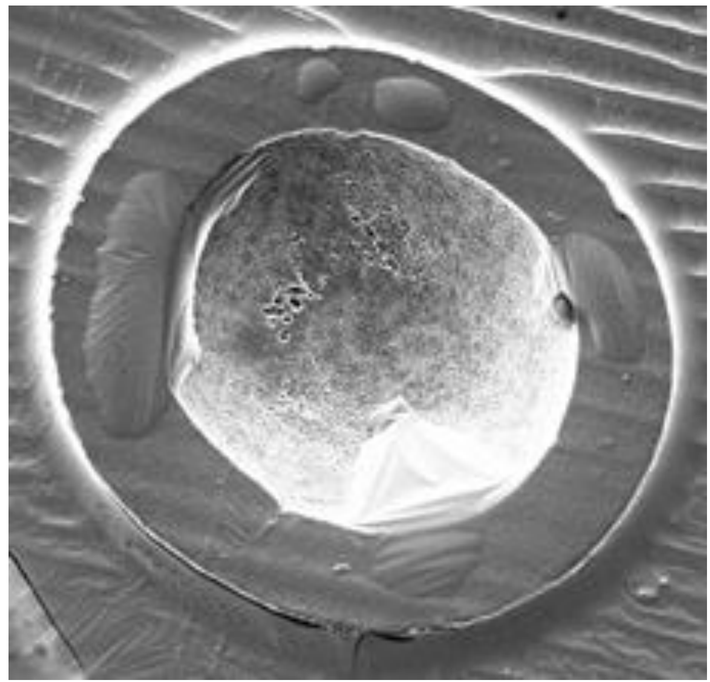
Controlled release of mosquito repellents from microporous polymer bracelets





2. Textile solution: Bi-component fibre-based repellent socks

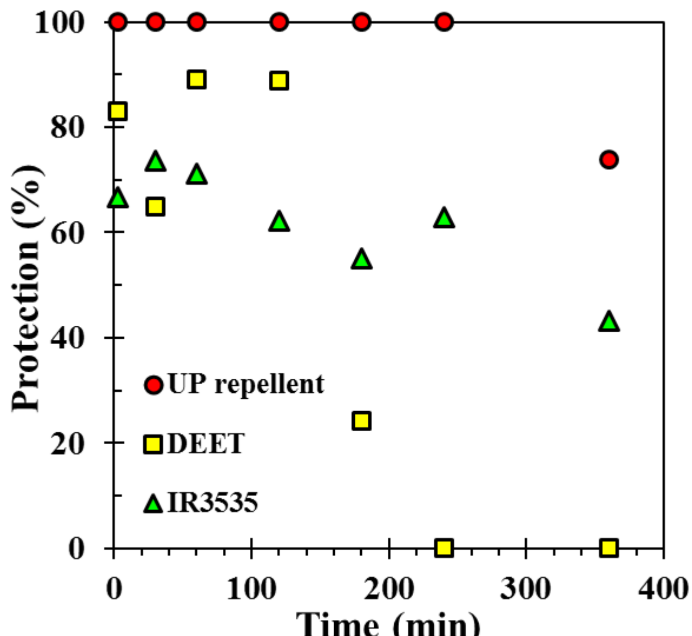
Fibre filament cross-section



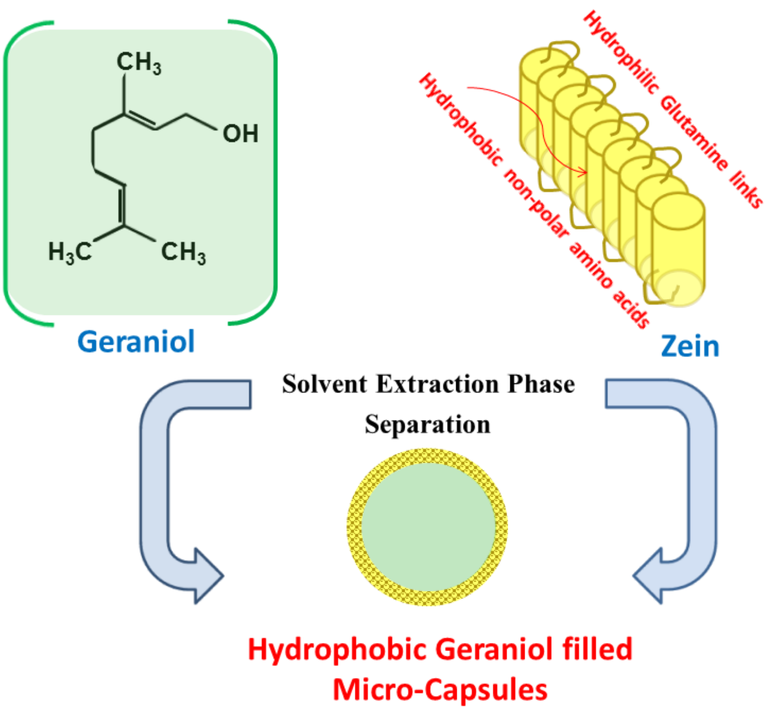
3. More effective topical repellents

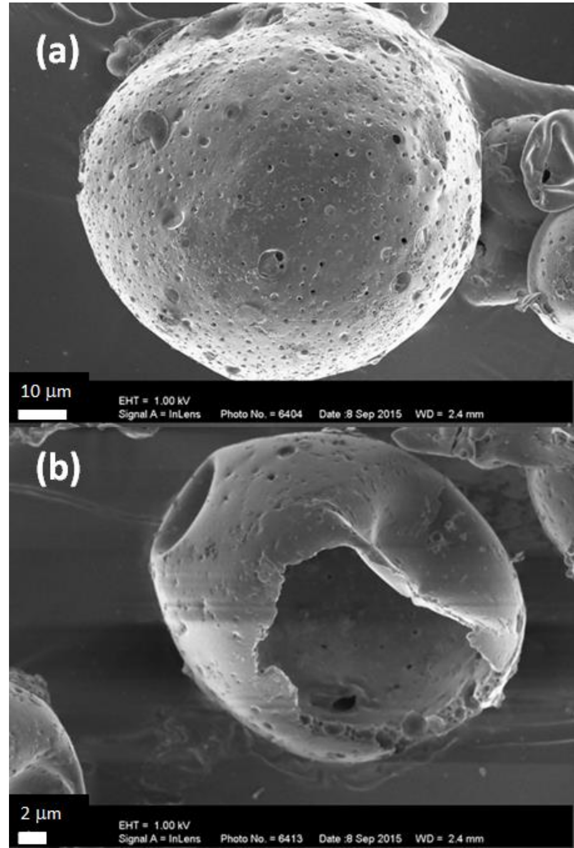
Protection of a novel UP repellent exceeds the performance of DEET and IR3535

Arm in cage test



4. Micro-encapsulated larvicide





Phase change materials (PCM's)

- Solar energy as a resource is highly variable
- Direct utilization is difficult, especially at peak consumer usage
- Efficient storage of captured energy is critical
- Several possible solutions exist to this problem including new and innovative options such as PCM's
- PCM's are latent heat storage materials
- A PCM can store between 5 and 14 times more heat per unit volume than sensible storage materials such as water or minerals like rock

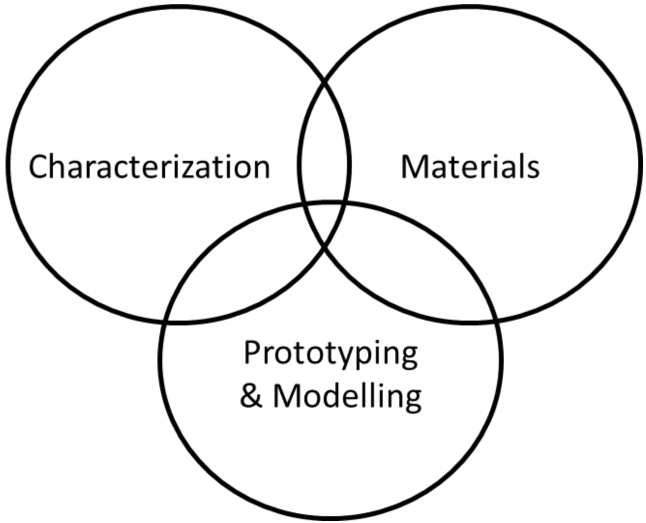
Facilities

- **We are quite well equipped with a variety of standard characterization techniques (TGA, DSC, DMA, TMA, BET, etc.)**

Bulk materials research group

Our aim is to bring together three core facets to produce the correct material for any application

- SEM, TEM, EELS,
- P-OM, XRD, XRF,
- FTIR, Raman,
- UV-Vis, TGA,
- TPD, TMA,
- DMA, DSC, BET, Pycno,
- ICP-MS-AES,
- EDX, WDX, XPS, MALDI-TOF, rheology…



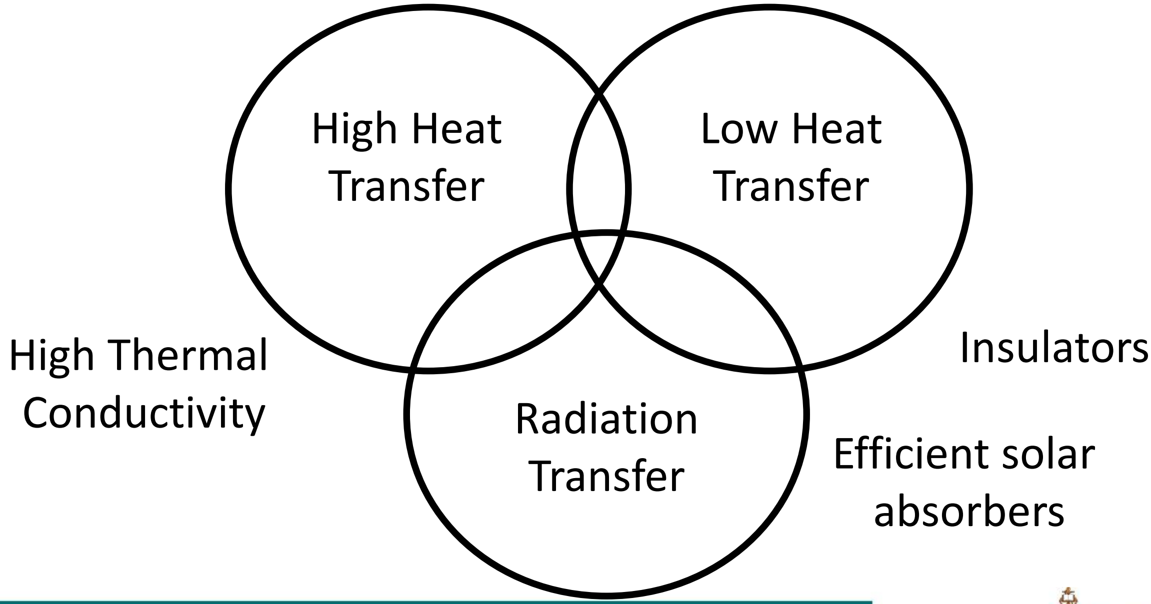
Carbon
PCMs
Optics
Glass-metal
Insulators
Ceramics
Carbides
Nano

Thermal diffusivity
C_p & enthalpy
Segmented parabolic
Tracking Fresnel
Fluidized bed granulator

Finite volume
Solid State

Work in the group is focused on these three properties

Energy Transfer



Solar Facilities

- A new design parabolic collector

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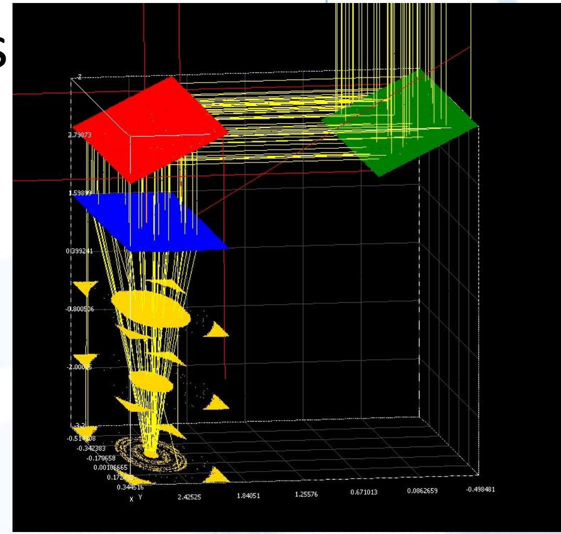
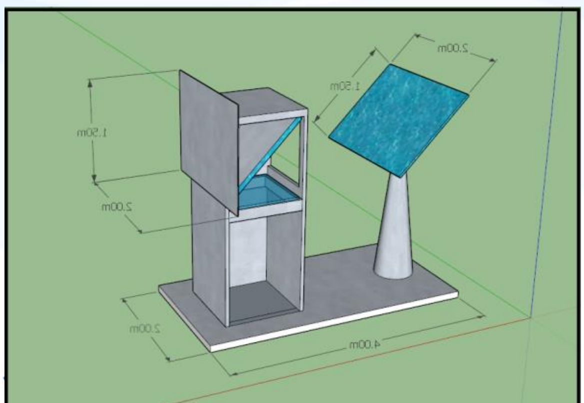
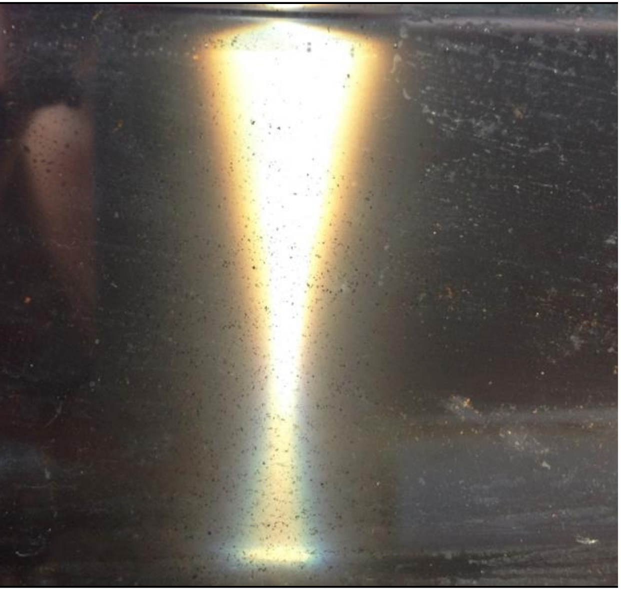
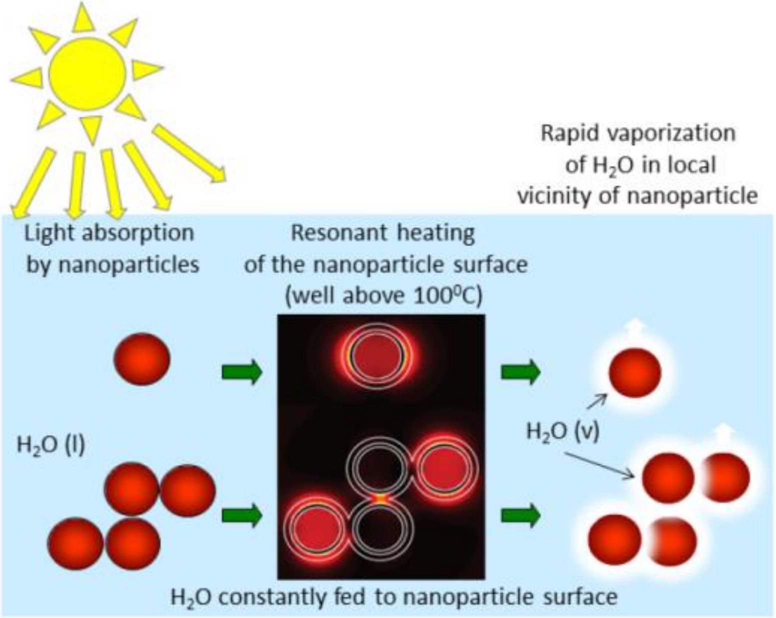
1 m^2 Fresnel lens system: concentration of up to 1500 suns!





Solar desalination - WRC

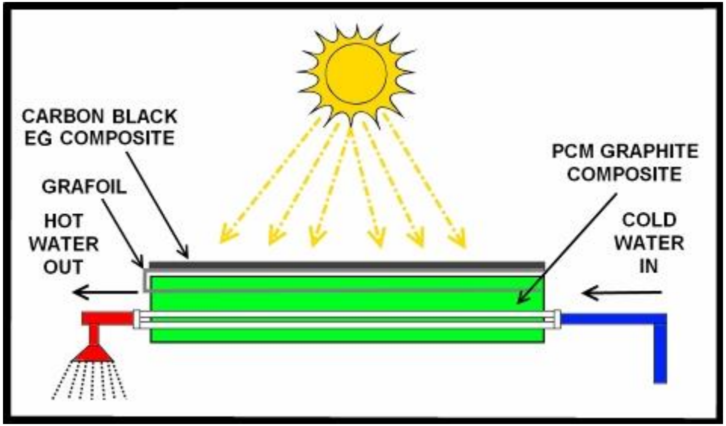




Why not combine energy capture and storage?

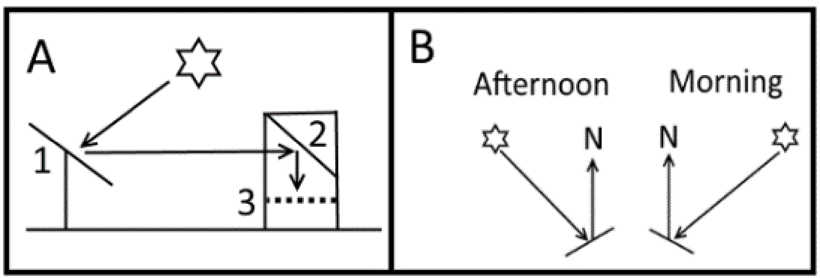
Current work is aimed at combining capture and storage into a single step.

It is planned to integrate this concept into a small scale water heating application for field testing.



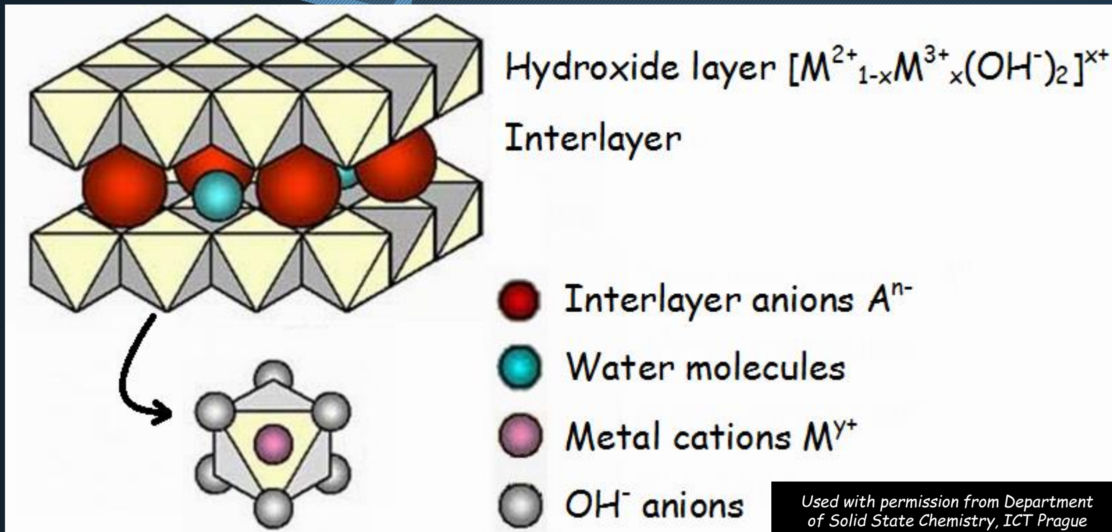
Small scale solar concentrator

Additional testing was completed using real solar radiation. A lab-scale platform has been constructed to track the sun. Light is reflected onto a Fresnel lens and concentrated onto the sample surface. This gives a better indication of real world performance.



Layered double hydroxides (LDH's): Structure, synthesis, modifications and applications

The structure of LDHs



Used with permission from Department of Solid State Chemistry, ICT Prague

Hydrotalcite natural mineral:

$$Mg_6Al_2(OH)_{16}CO_3 \cdot 4H_2O$$

$$Mg_4Al_2(OH)_{12}CO_3 \cdot 3H_2O$$

LDH Synthesis

- Co-precipitation method
  - $M^{2+}(aq) + M^{3+}(aq) + CO_2 + H_2O \rightarrow LDH$
- Mixed dissolution-precipitation method
  - $MO_2(s) + M_2O_3(s) + CO_2 + H_2O \rightarrow LDH$
- Reconstruction method
  - $4MO_2 \cdot M_2O_3(s) + CO_2 + H_2O \rightarrow LDH$

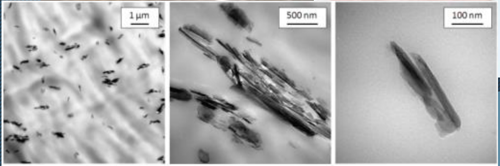
Green zero effluent dissolution / precipitation of run-of-mine oxides with

- $MgO + Al(OH)_3 + 2NaHCO_3 + H_2O \rightarrow LDH + Na_2CO_3$
- $MgCO_3 + heat \rightarrow MgO + CO_2$
- $Na_2CO_3 + H_2O + CO_2 \rightarrow 2NaHCO_3$

LDH Applications

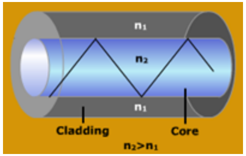
Known applications of LDHs

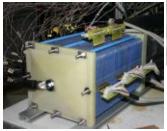
- Flame retardants
- Smoke suppressants
- Functional additives
- Heat stabilisers for PVC
- Adsorbing agents
- Pigment for polymers
- Catalysts
- Controlled release agents
- Polymer nano-composites



Features, Benefits & Advantages of F-polymers

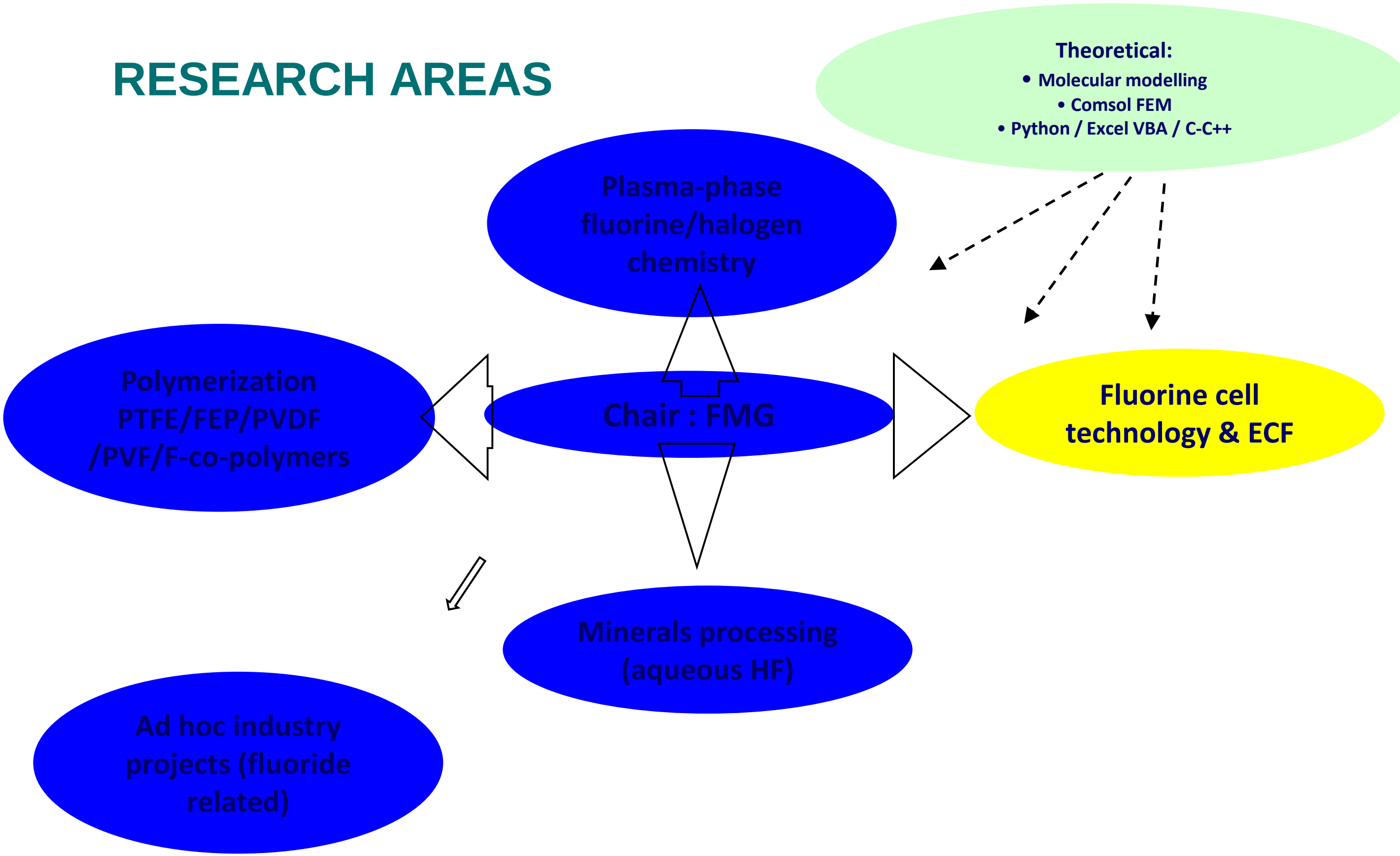
- *Low refractive index:*
  - Optical fibers and coatings
- *High oil, water and soil repellency:*
  - Textiles, leather, paper, wood, glass, concrete, stone, metals protection
- *Low surface energy:*
  - Lubricity, release
- *High chemical, thermal, oxidative stability*
  - Protective coatings
- *Very low surface tension*
  - Speciality surfactants and fire fighting agents
- *Very strong organic acids*
  - Catalysts and proton exchange membranes





SARChI Chair for Fluoro-materials Science & Process Integration

RESEARCH AREAS



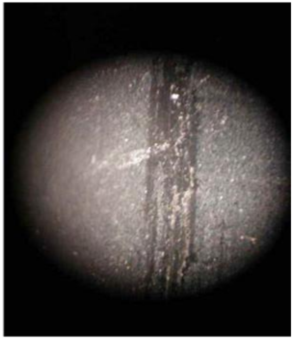
SARChI Chair for Fluoro-materials Science & Process Integration

Polymer laboratory

Multi-purpose Fluorination Pilot Plant (MFPP) @ Pelchem

Tribology

- Lubricity of fuels
- Lubricant Performance
- Lubrication modeling
- Biotribology
- Nanoparticles & nano-emulsions
- Nanofluids



Lubricant performance assessment

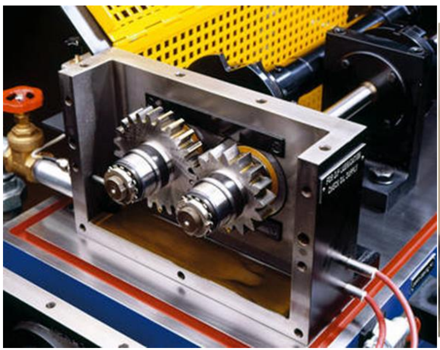
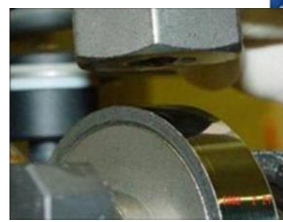
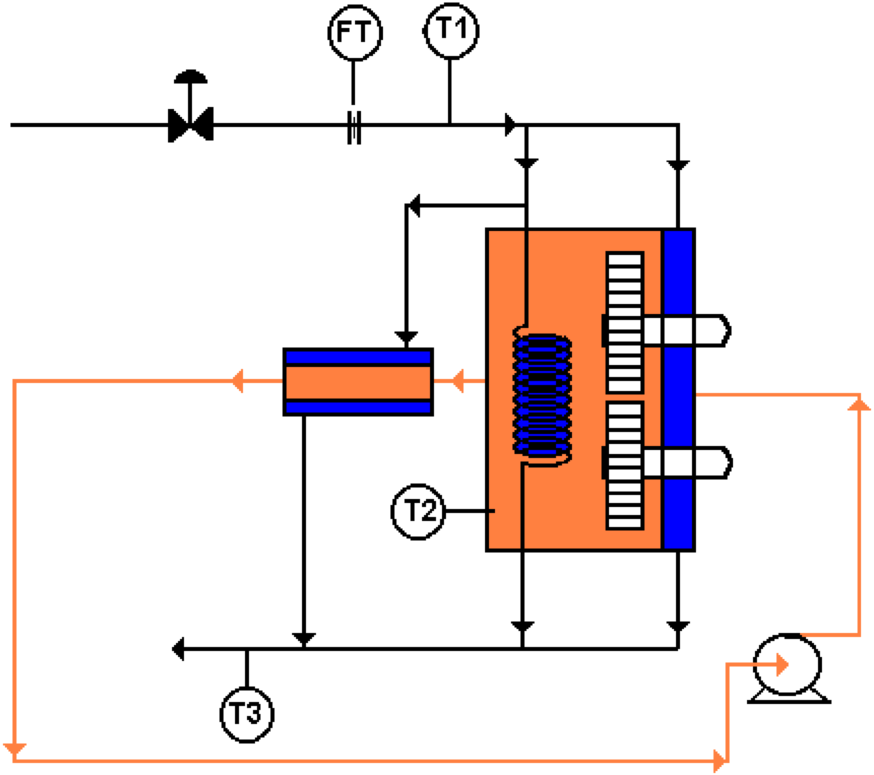


Figure 2: Pinion tooth After 30 hours @ L.S. 10

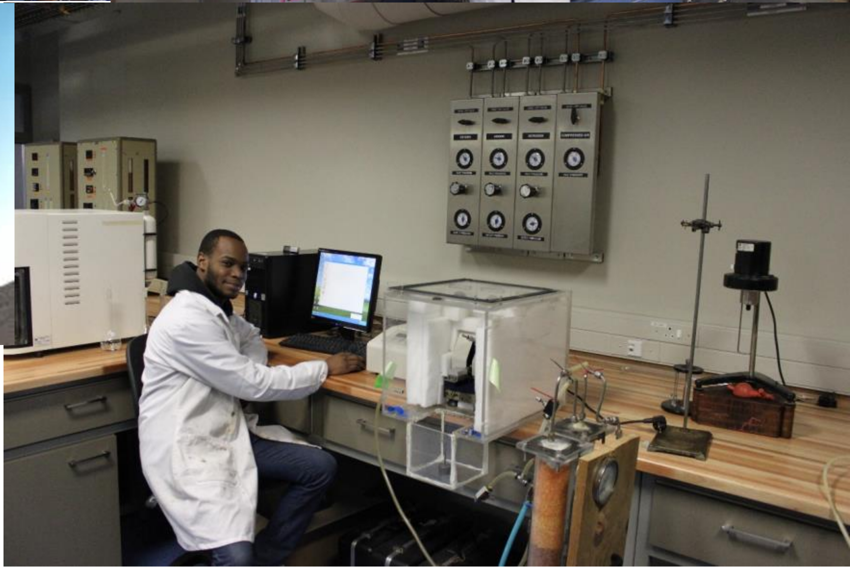


Lubricant Performance

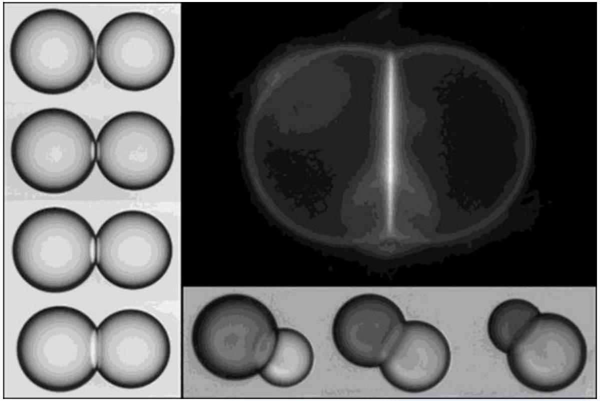


SAIT

"understanding lubrication & wear"



Emulsion breakdown mechanisms



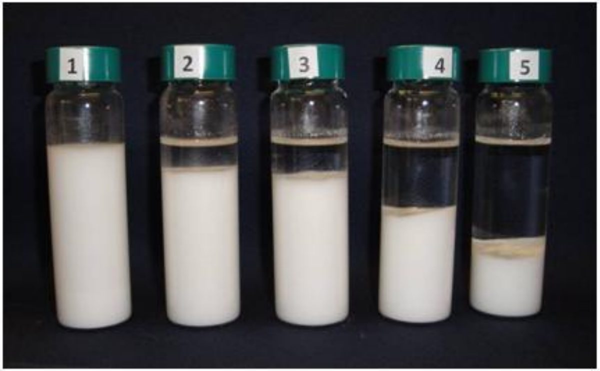
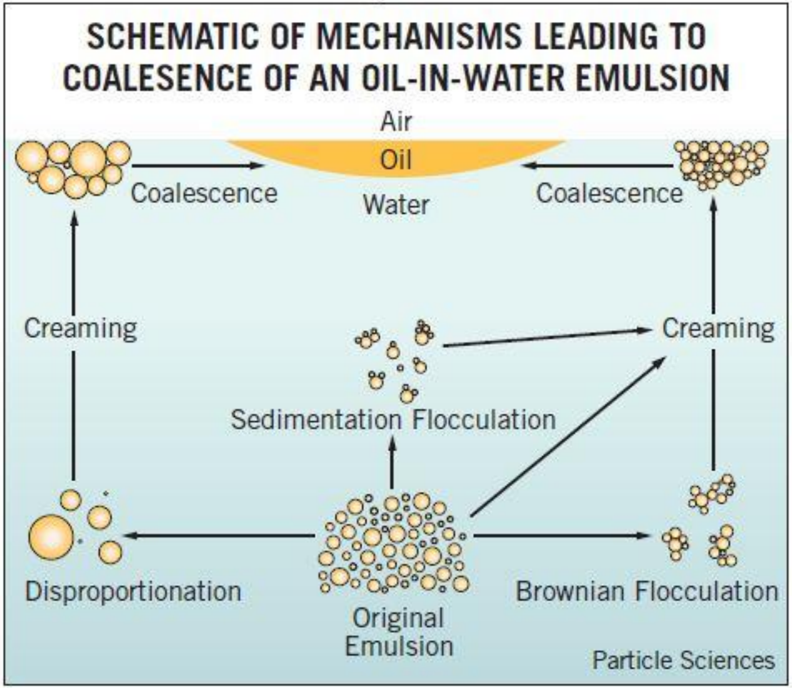
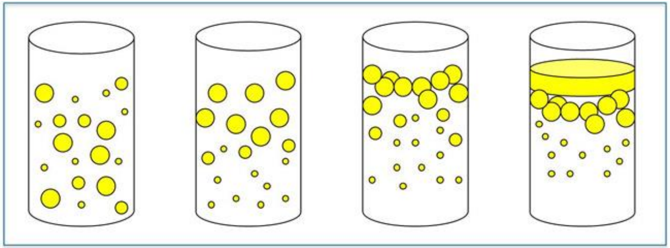


Figure 1





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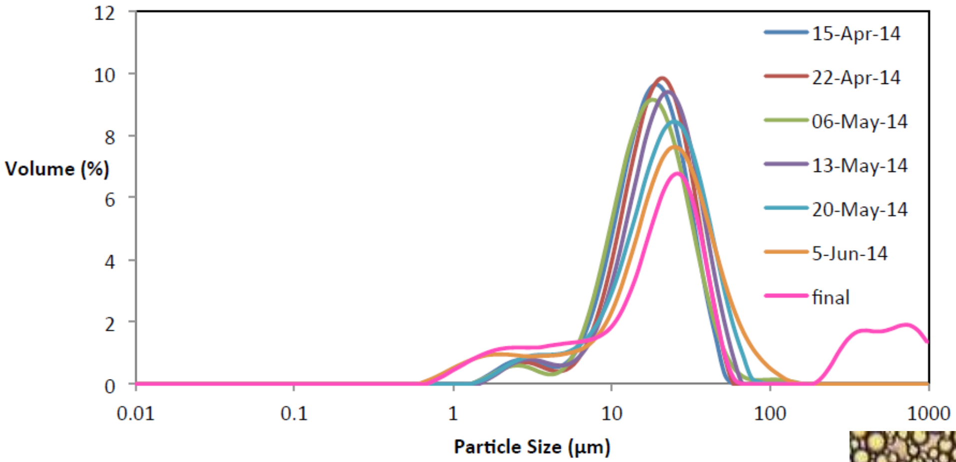
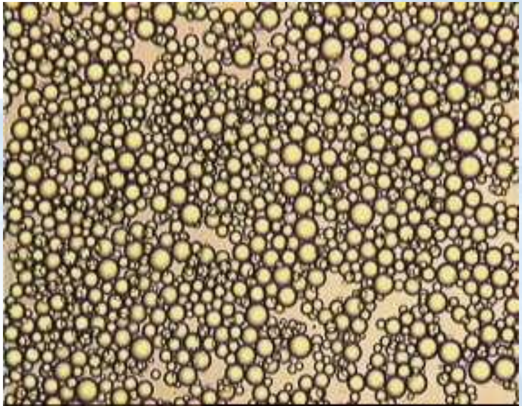
Particle size distribution





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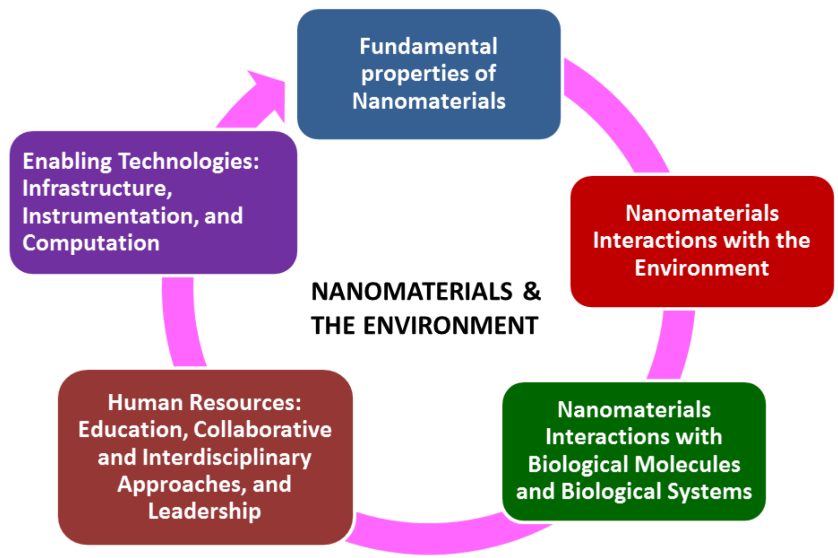
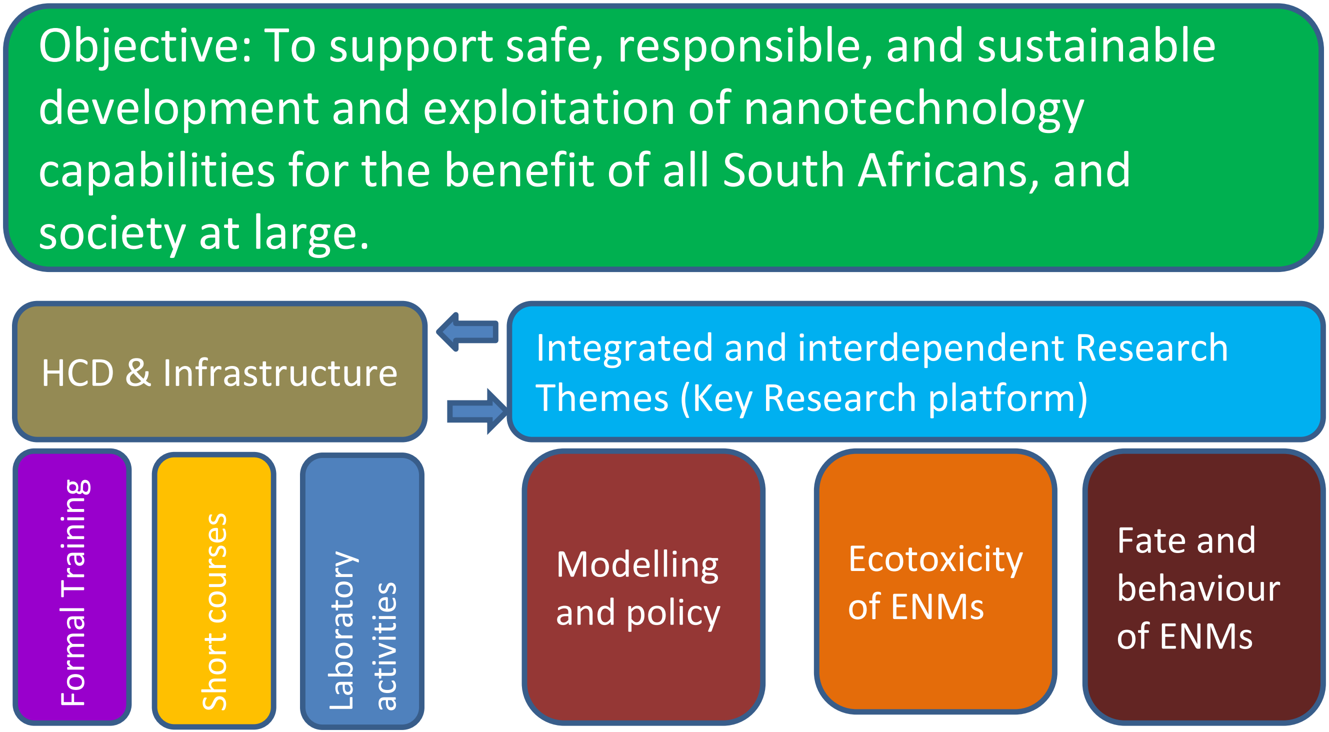
Research areas and enabling environment…



Overarching scientific objective



Water Utilisation & Environmental Engineering

- Drinking water treatment
- Industrial wastewater treatment
- Waste utilisation
- Biological treatment
- Environmental impact
- Waste minimisation

Water Utilisation & Environmental Engineering (contd)

- **Dispersion modelling**: (AERMOD, CALPUFF) Particulate matter from opencast mining, identification of diffuse sources from ambient measurements, atmospheric deposition over the Highveld and Waterberg areas as a result of fossil fuel use.

- Application of simple and economical **pollution measurement methods**: Dust deposition buckets, passive diffusive tubes.

- Pilot scale **Circulating Fluidised Bed (CFB) unit** planned to test emissions from various unconventional fuel sources in SA – coal discard, biomass. Desulphurisation test work and work on metal emissions could be done on such a unit.

Process Modeling, Optimisation & Control

- Advanced Process Modeling
- Closed Loop Process Identification
- Nonlinear Model Predictive Control (MPC)
- Fault detection
- Control loop performance optimisation
- Plant-wide control performance indexing
- Automated plant start-up and shut-down (ASM)
- Batch process control
- Scheduling

Control loop ranking