UAH The University of Alabama in Huntsville
Department of Chemical and Material Engineering

Manufacturing of Metamaterials
Wetting Issues on Engineering

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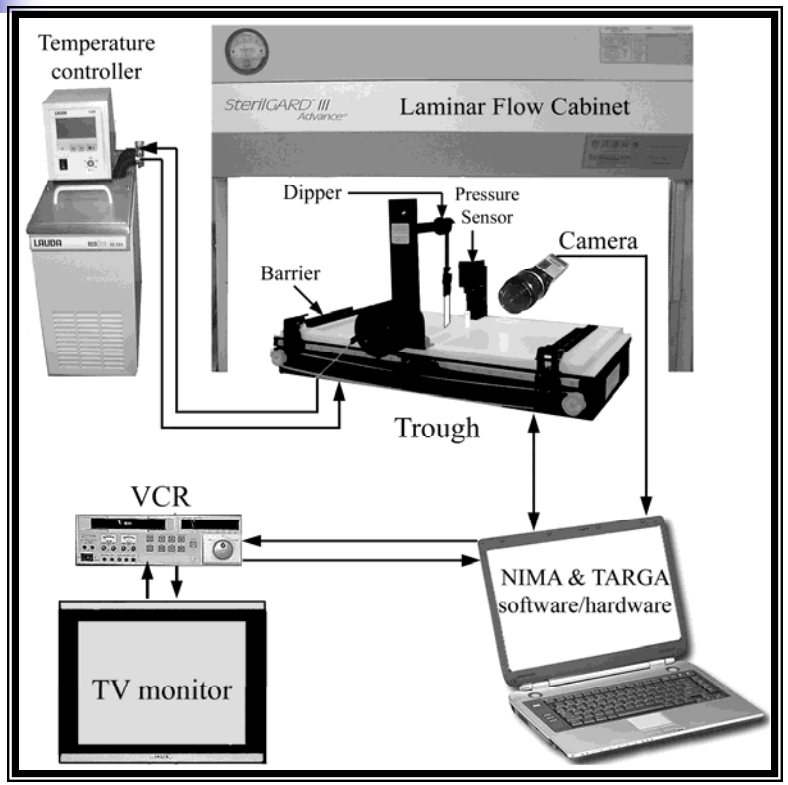
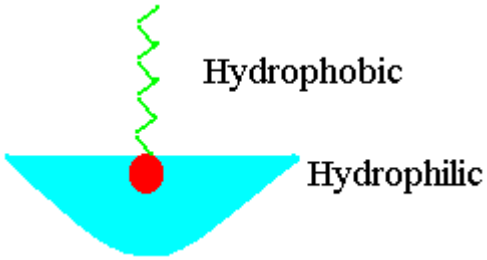
Chemical and Materials Engineering

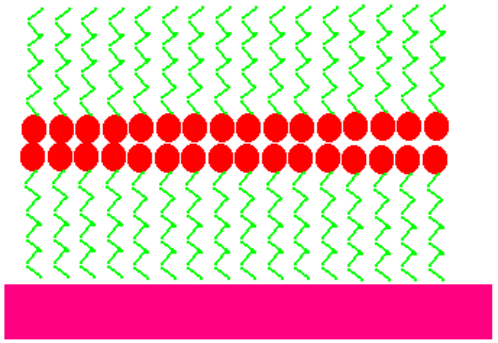
Overview of Research

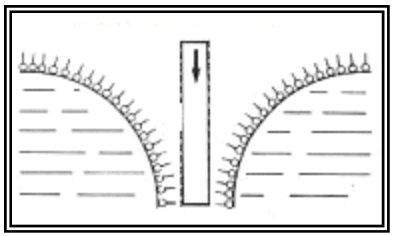
- Langmuir-Blodgett ultrathin film deposition.
- Langmuir-Blodgett film properties
  - Search for Metamaterials, one layer at a time.
- Wetting and capillary phenomena
- Materials Research and Education

Langmuir Trough and Film Deposition

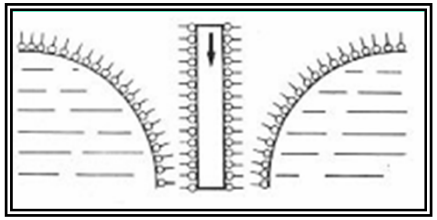




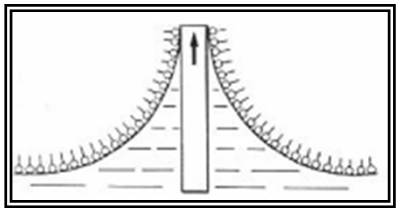




X-TYPE

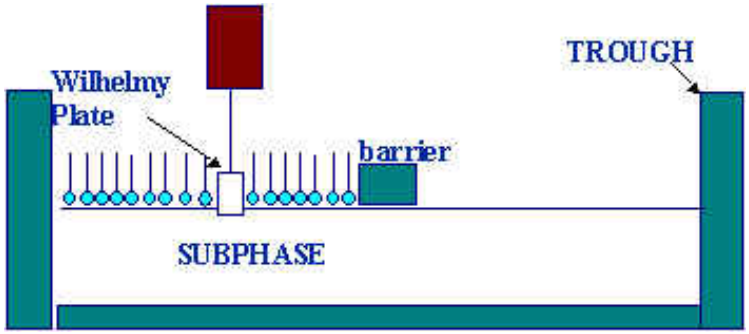


Y-TYPE

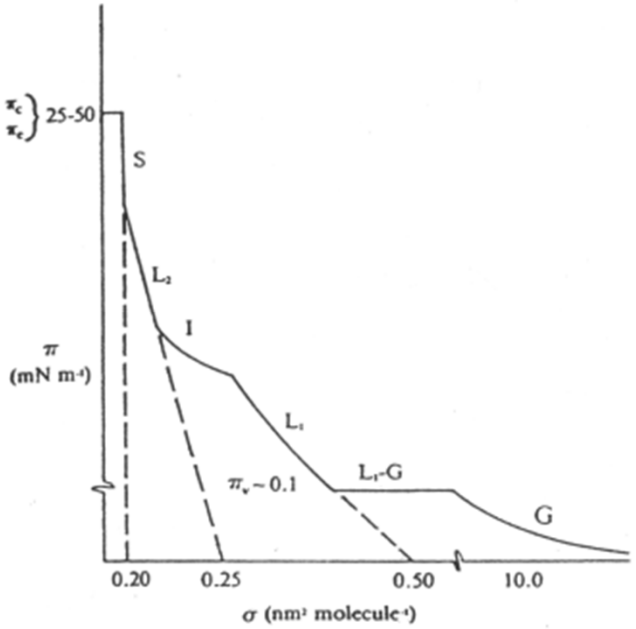


Z-TYPE

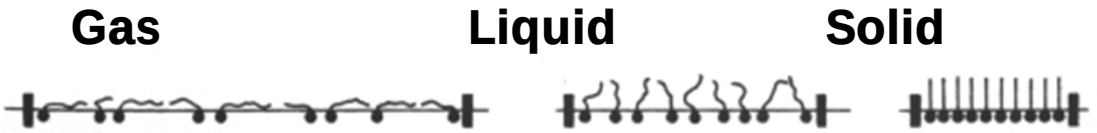
LANGMUIR-BLODGETT TECHNIQUE



- LANGMUIR MONOLAYER AT AIR/WATER INTERFACE CAN BE USED TO ATTACH ANY MOLECULES IN SUBPHASE

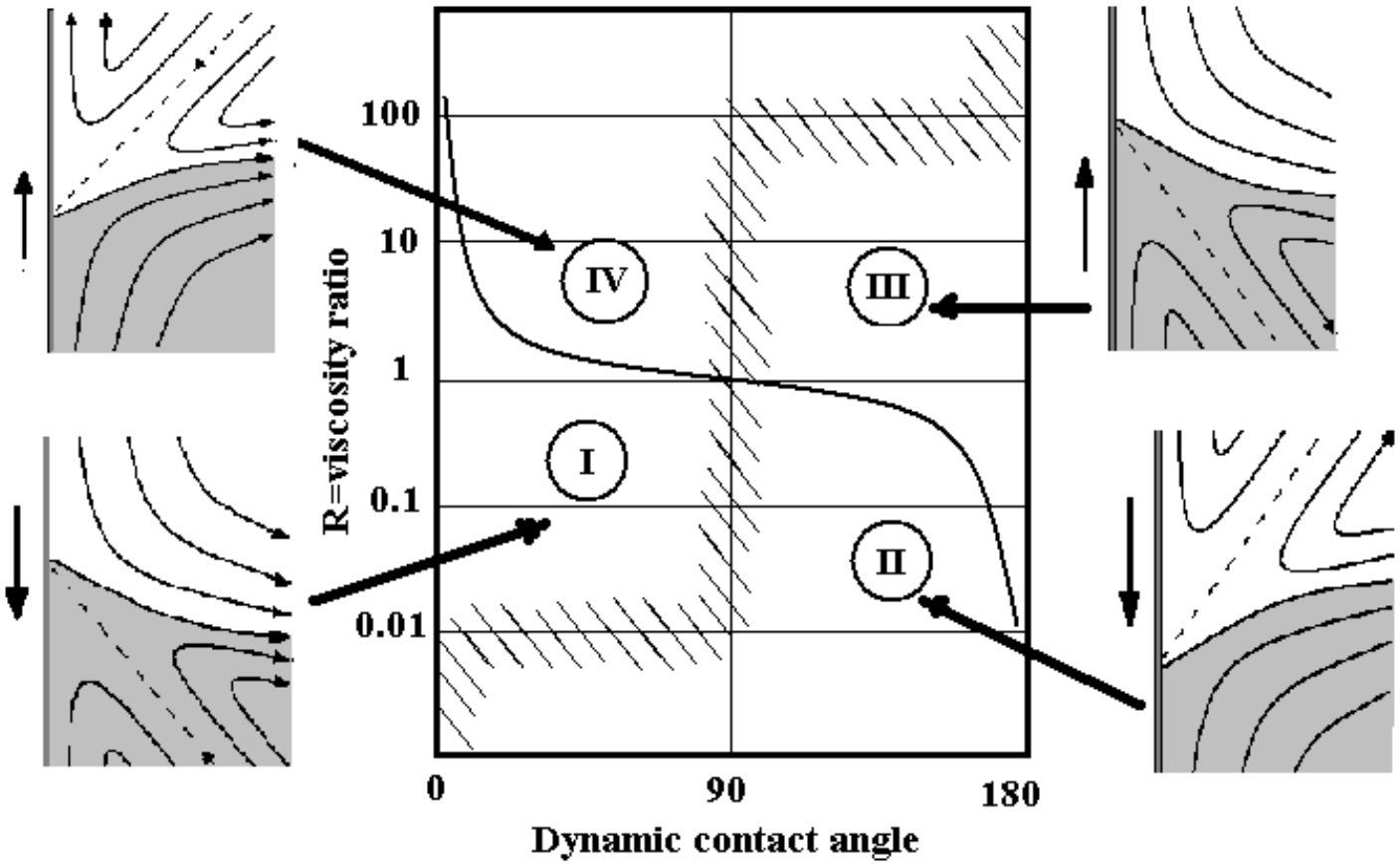


- BIGGEST ADVANTAGE OVER SAM: MECHANICAL COMPRESSION OF THE MONOLAYER



Flow Patterns near Moving Contact Lines

Savelski et al. JCIS (1995), Fuentes and Cerro, Experiments in Fluids (2005)



Mechanics of Langmuir-Blodgett Depositions:

R. Cerro, JCIS, vol. 257, 2003 - E. Diaz & R. Cerro, JCIS, 285 (2) (2005) 686.

Effect of Subphase pH and Counterions:

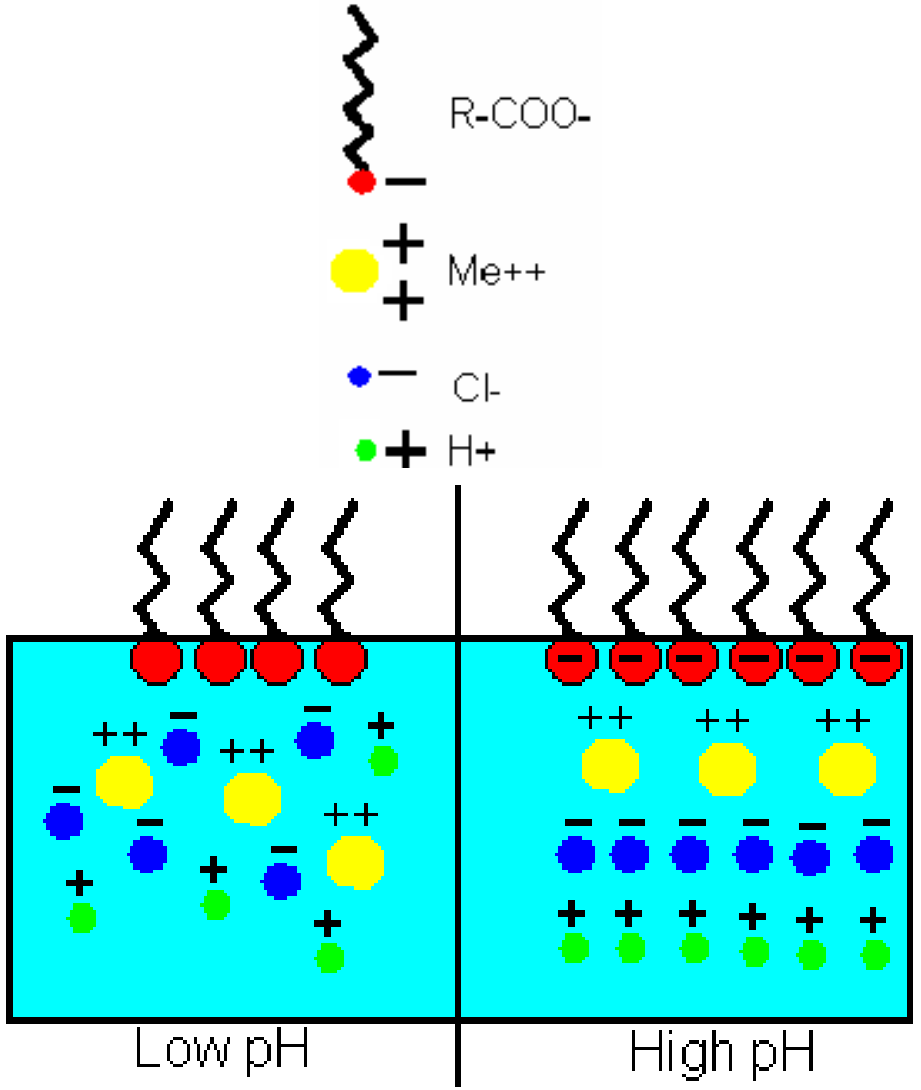
Diaz and Cerro, Thin Solid Films, 2005

- SUBPHASE pH:
  - IONISED MONOLAYERS:

$$R\text{-}COOH \leftrightarrow R\text{-}COO^{-} + H^{+}$$

$$pH = pKa + \log\left(\frac{R\text{-}COO^{-}}{R\text{-}COOH}\right)$$

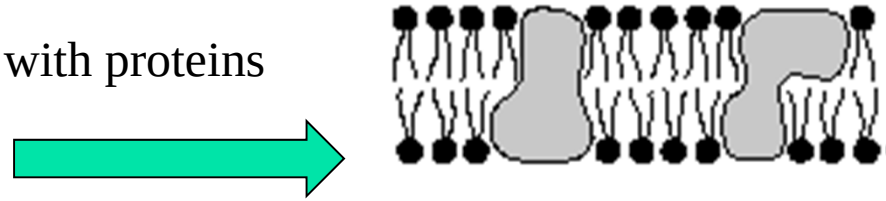
  - DEPOSITION OF IONISED MONOLAYERS
  - STABILITY OF MONOLAYER



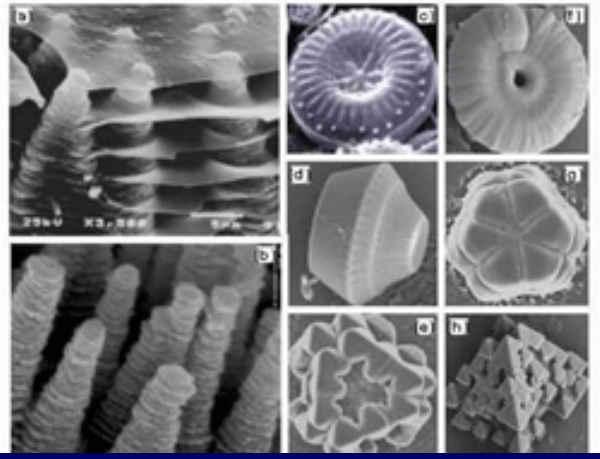
Langmuir-Blodgett Films: Applications

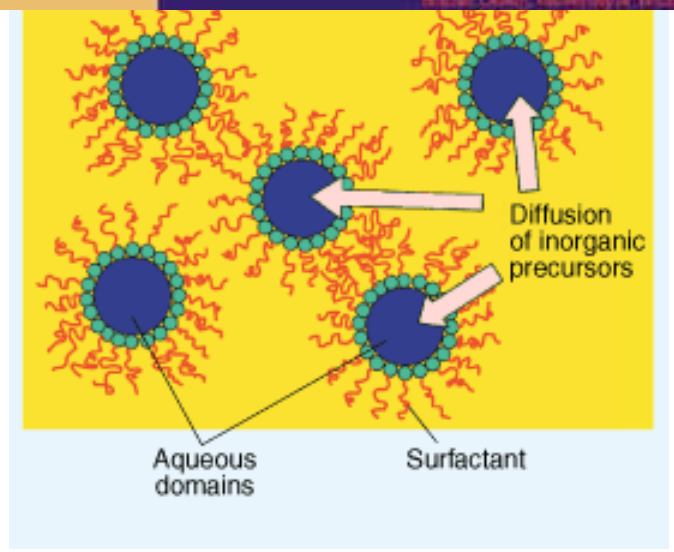
- **Molecular Recognition:** P. Pedraz, F. J. Montes, R. L. Cerro and M. E. Diaz, Characterization of Langmuir biofilms built by the biospecific interaction of arachidic acid with bovine serum albumin, Thin Solid Films **525, 121-131, (2012)**
- **Trans-membrane proteins:** K. Tantawi, R. Cerro, B. Berdiev, M. E. Diaz, F. J. Montez, and J. D Williams, Investigation of Transmembrane Protein in Lipid Bilayer Membrane Supported on Porous Silicon, J. of Medical Engineering Technology (2012)
- **Photon-efficient solar cells:** Photovoltaic materials via membrane-mimetic approach. NSF proposal September 2009 – J. Guo and R. Cerro
- **Ordered arrays of quantun dots:** NSF proposal, J. Weimer, J. Guo and R. Cerro, 2013

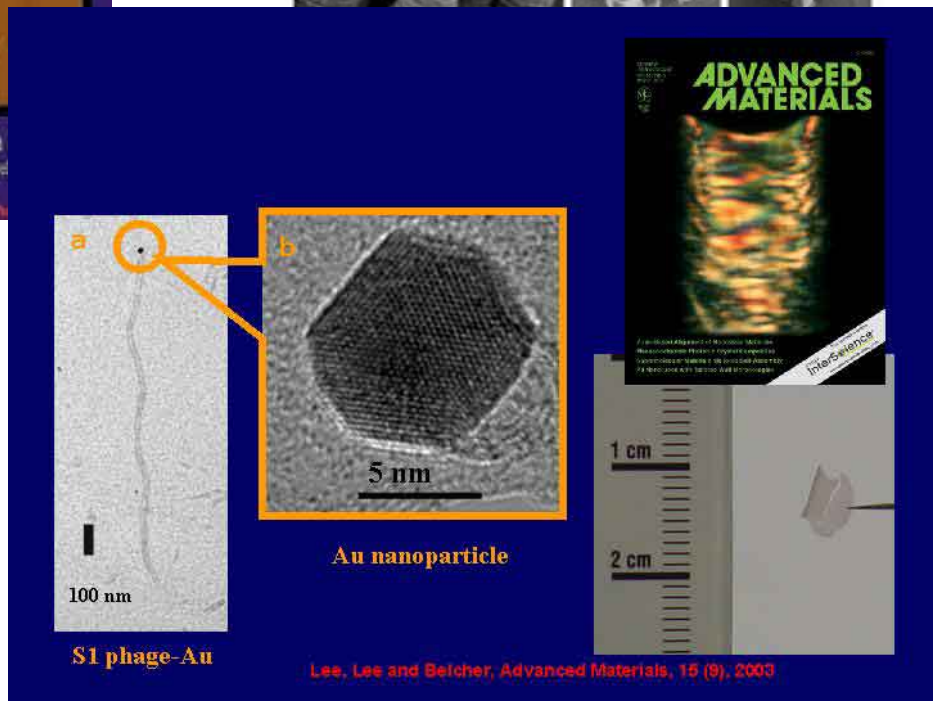
Model of natural membrane with proteins embeded in a lipid bilayer



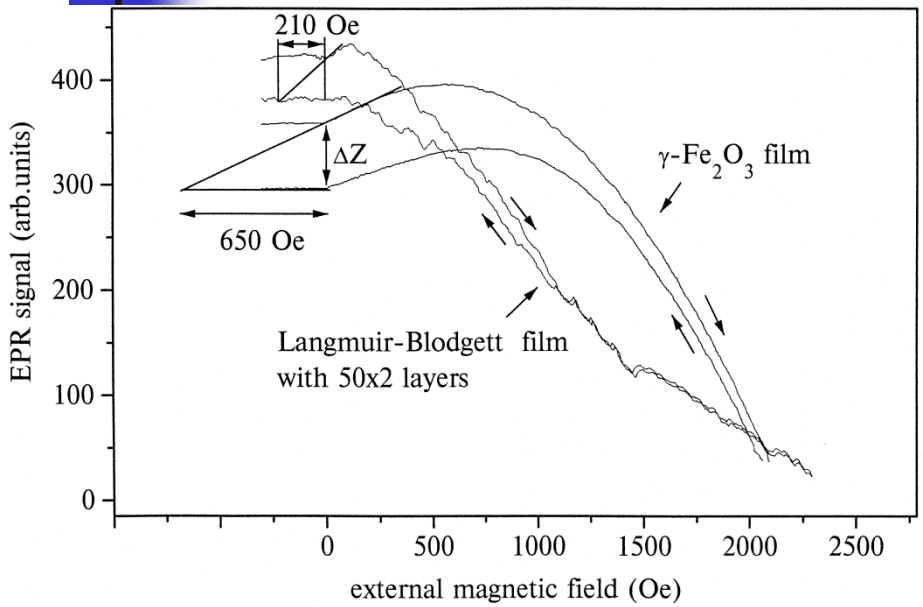
Nanomaterials via Biomimetics





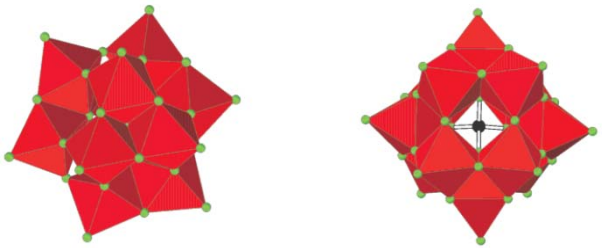


Many other Applications: Magnetic Materials



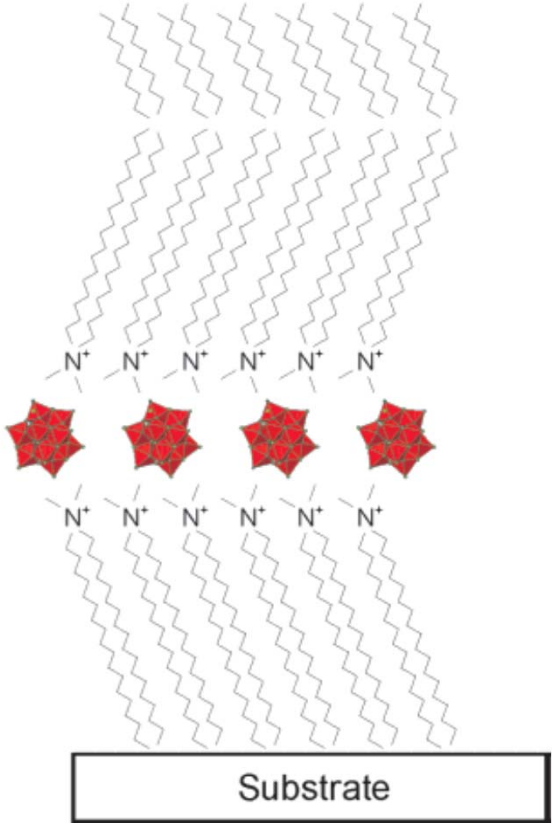
Khomutov et al., Mat. Sci. & Eng. (1999)

2D-magnetic materials

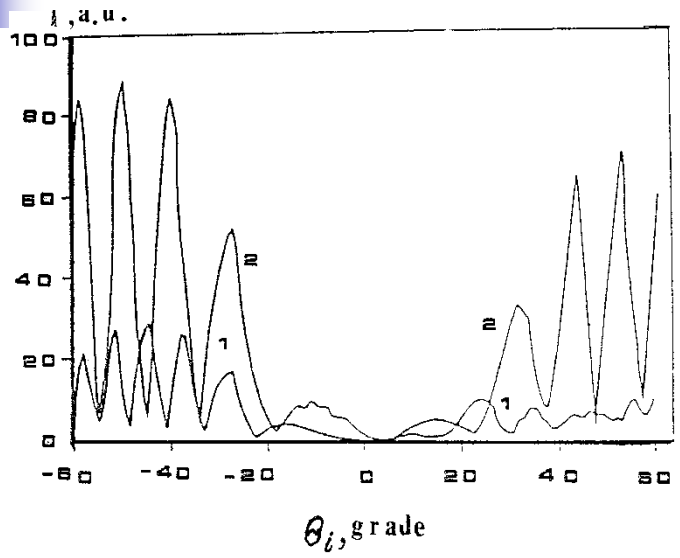


Mitzi, Chemistry Materials, (2001)

Incorporation of Keggin polyanions.

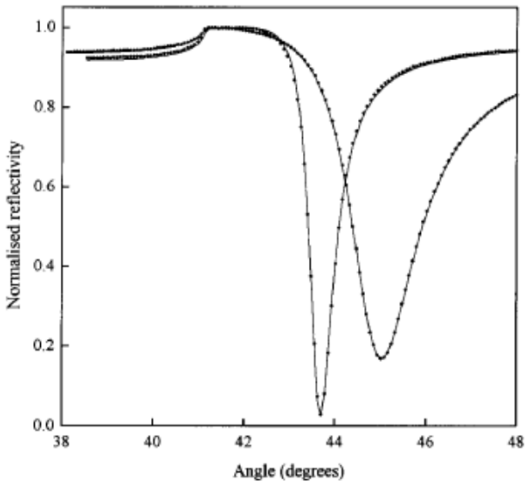


Applications: Nonlinear optical materials



Angle dependency for Second Harmonic Generator intensity for LB films containing photochromic compounds.

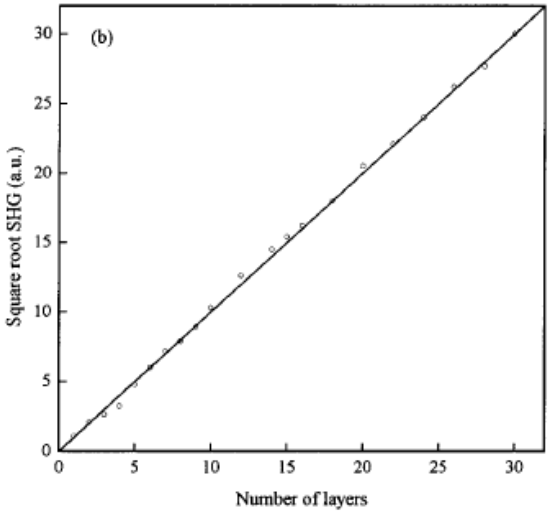
Barachevsky & Chudinova, Mat. Sci. & Eng. (1999)



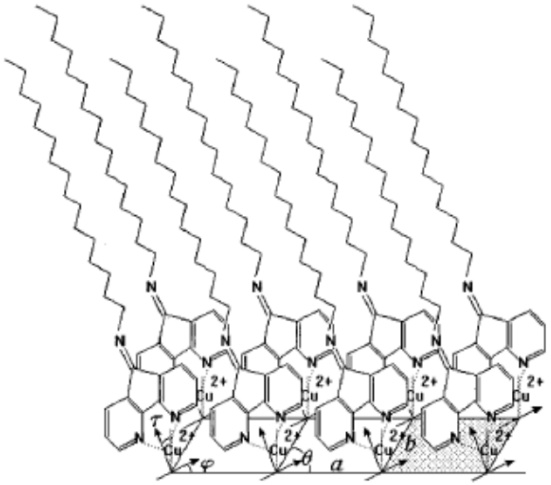
Normalized reflectance versus incident angle.

Square root of SHG intensity.

Ashwell et al. Langmuir, (1998).



Applications: Selective crystal formation



Latice structure of monolayer and copper ions.

Tang and Tai, Langmuir, (1997).

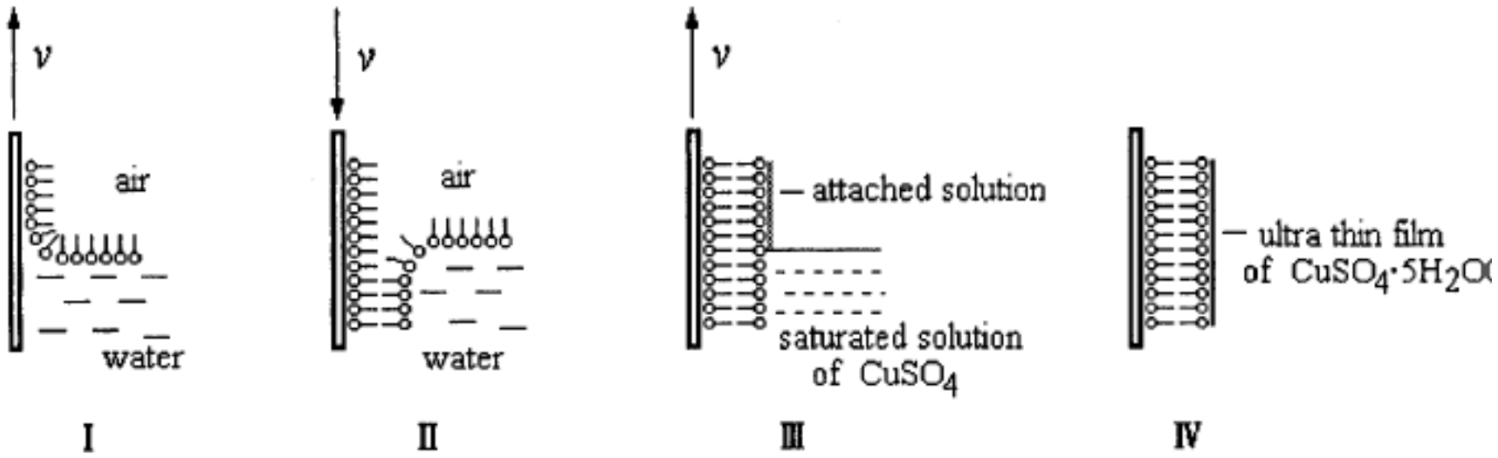
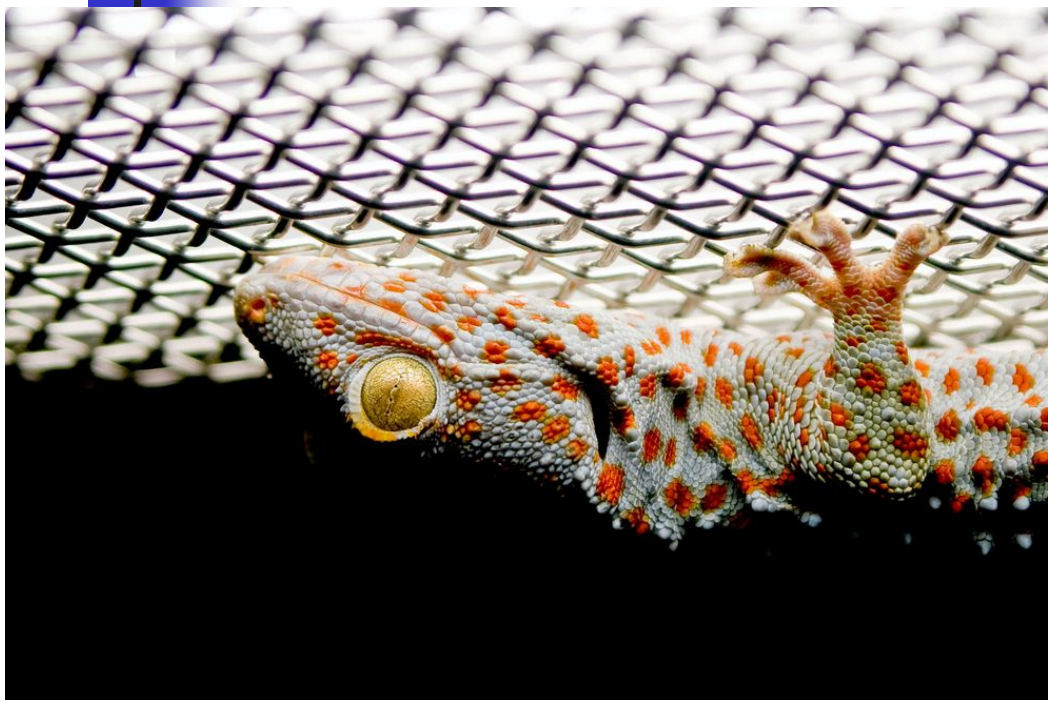
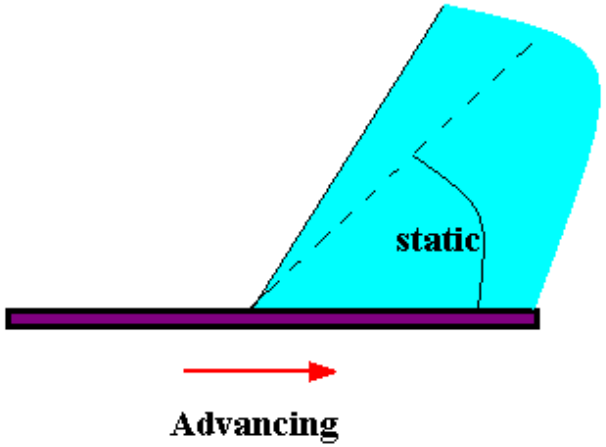
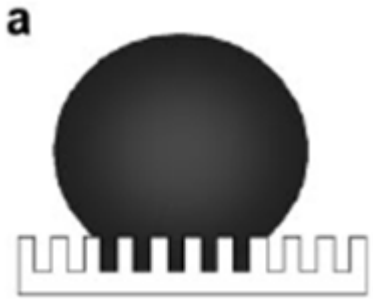


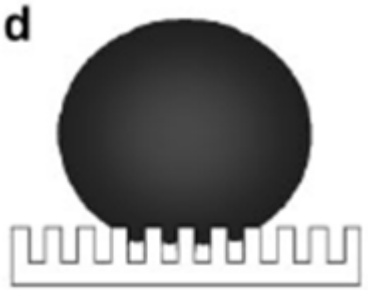
Figure 2. Growth scheme of ultrathin crystal films (crystal face) by the Langmuir–Blodgett technique.

Wetting precedes adhesion!!





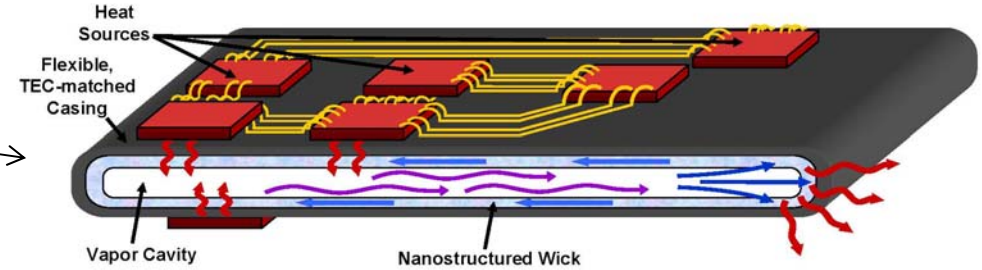


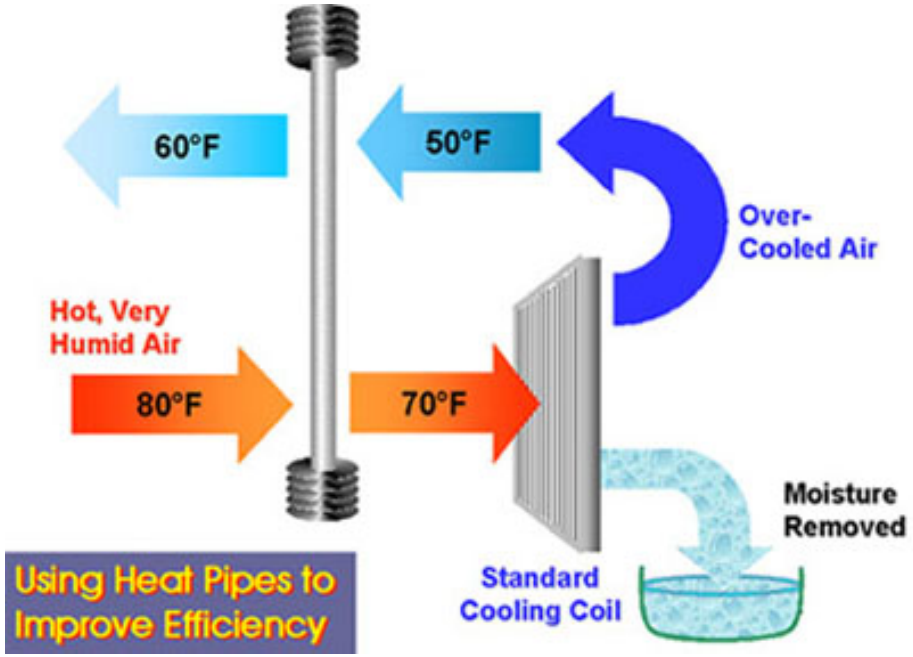


M. Elena Diaz, Michael D. Savage, and Ramon L. Cerro, Wetting, Contact Angles and Capillary Phenomena, Convertech Review (Japan) (2012).

Wetting in boiling and condensation

Cooling electronic circuits

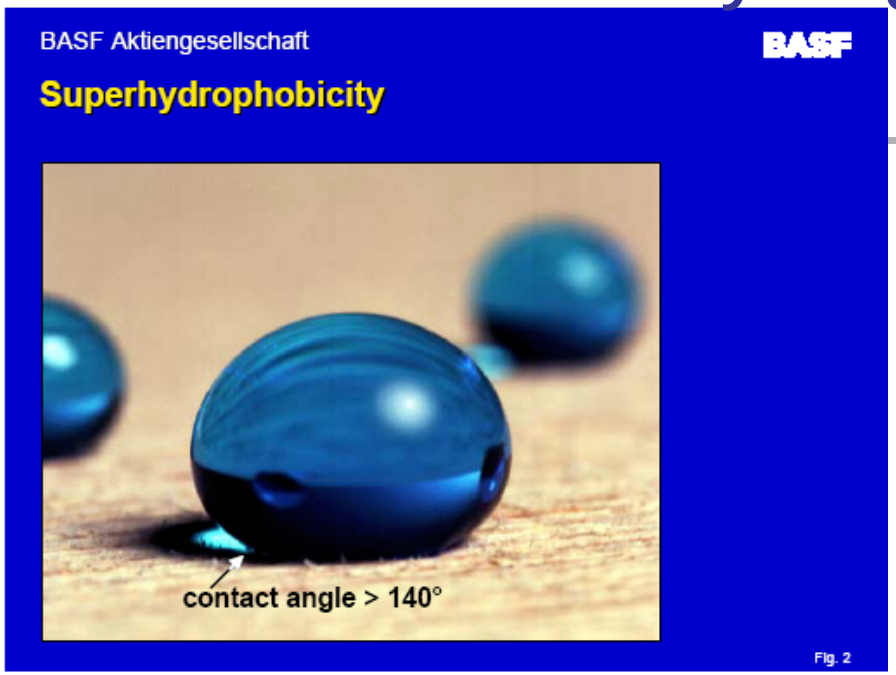




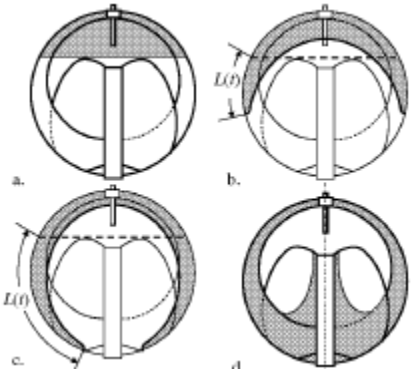
Heat pipes rely on boiling and condensation of the cooling liquid.
Micro-heat pipes are about 1 mm in diameter.

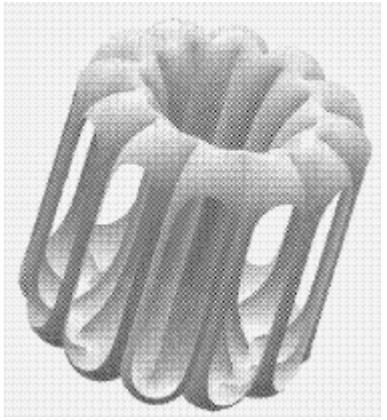
R. Shaw and R. Cerro: SBIR Phase I Report. An optimally designed, MEMS fabricated, enhance surface, boiling heat sink for passive immersion cooling of integrated circuits, 2001

Many engineering applications:

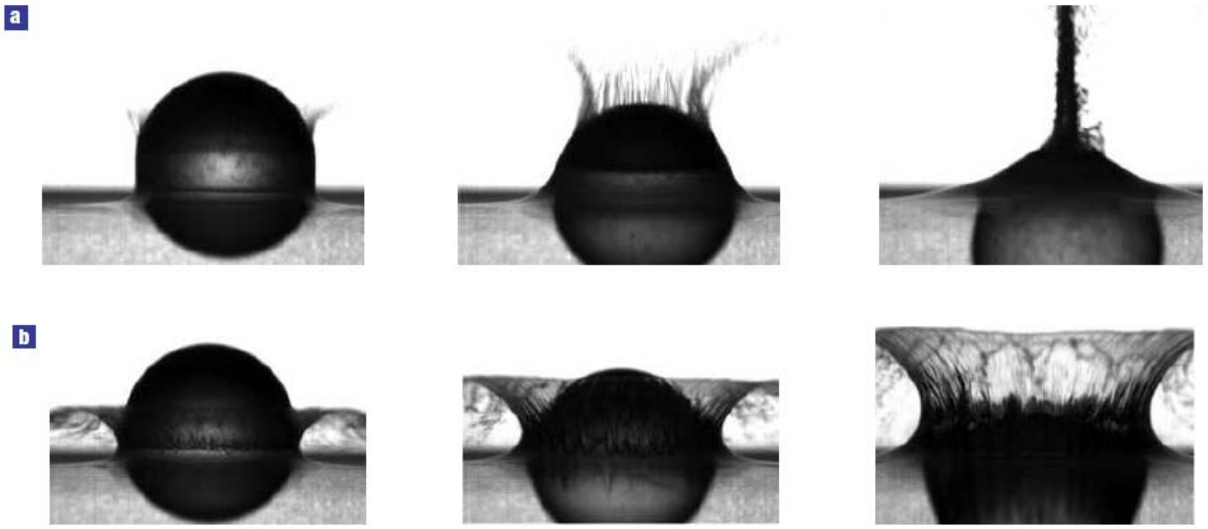


Super-hydrophobic, self-cleaning surfaces.





Liquids inside tanks in space



Solid sphere impact on water:

Wetting

Non-wetting

Conclusions:

- Langmuir-Blodgett are the path to metamaterials.
- Wetting has many engineering applications.
- Teamwork already in place to develop applications
  - UAH: Guo (ECE), Weimer (CME). Williams (ECE)
  - Salamanca (Spain), Leeds (UK), Santa Fe (ARG).