Manufacturing of Metamaterials
Wetting Issues on Engineering

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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**

Hydrophobic

Hydrophilic
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

**Diagram:**
- Wilhelmy Plate
- Trough
- Subphase

**Graph:**
- 
- **Phase:** Gas, Liquid, Solid
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- Sigma (nm²/mole) vs. Pi (mN/m)
- Regions: S, L₀, L₁, G, L₁-G
- 

Flow Patterns near Moving Contact Lines

Mechanics of Langmuir-Blodgett Depositions:
Effect of Subphase pH and Counterions:
Diaz and Cerro, Thin Solid Films, 2005

**SUBPHASE pH:**
- Ionic Monolayers:
  \[ R\text{-COOH} \rightleftharpoons R\text{-COO}^- + H^+ \]
  \[
pH = pKa + \log \left( \frac{R\text{-COO}^-}{R\text{-COOH}} \right)\]
- Deposition of Ionic Monolayers
- Stability of Monolayer

![Diagram showing low and high pH conditions](image)
Langmuir-Blodgett Films: Applications


- **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 quantum 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

Using Nature’s Tools to Synthesize Nanoelectronic Materials

- Self Assembly
- Recognition
- Nanoscale
- Self Correcting

Bio-mediated Synthetic Materials & Devices

- Protein Assisted Magneto-electronic Heterostructure Assembly

Aqueous domains
Surfactant

Diffusion of inorganic precursors

100 nm
5 nm

Au nanoparticle

Lee, Lee and Belcher, Advanced Materials, 16 (9), 2003
Many other Applications: Magnetic Materials

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.


Normalized reflectance versus incident angle.
Square root of SHG intensity.
Applications: Selective crystal formation

Latice structure of monolayer and copper ions.


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

Wetting in boiling and condensation

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

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).