

Innovating Through Sustainable Chemistry

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**Vision and Opportunities for Translating
Green Nano to Manufacturing**



Center for Sustainable Materials Chemistry



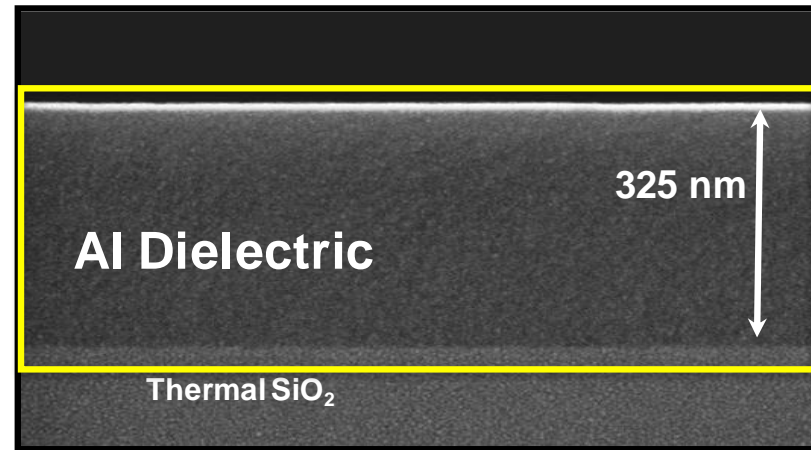
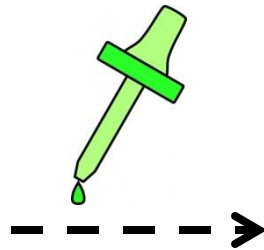
Center for Sustainable Materials Chemistry NSF Center for Chemical Innovation

**Conduct curiosity-driven and use-inspired
research**

**to enhance the green chemistry toolbox
with new methods and new techniques
that will advance the scientific enterprise
and transform the next generation of products**

**Prepare students to become the next generation
of sustainability chemists**

An Inorganic Solution Approach

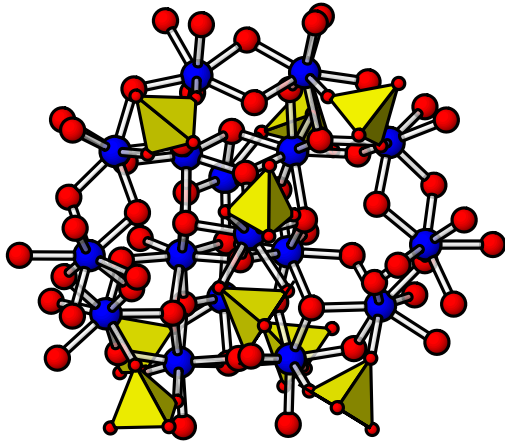


**Vacuum quality inorganic thin films
with the speed, low cost, and
convenience of water processing**

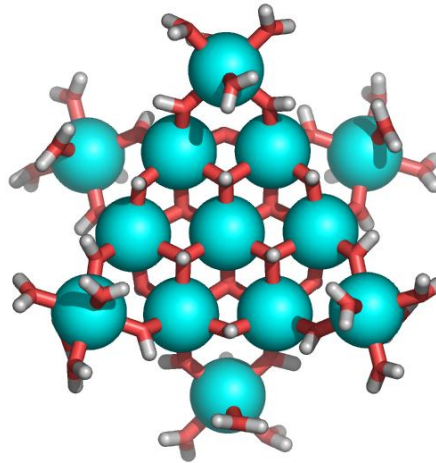
Key Attributes

- **Environmentally benign aqueous precursors**
- **Dense films**
- **Planarization layers: atomically smooth surfaces**
- **Ultra-thin and thin films**
- **Low Temperatures**
- **Highly scaleable formulation process**
- **Spin coat, mist coat, or printable**
- **Organic-free, oxygen-precise film compositions**
- **Directly patternable**

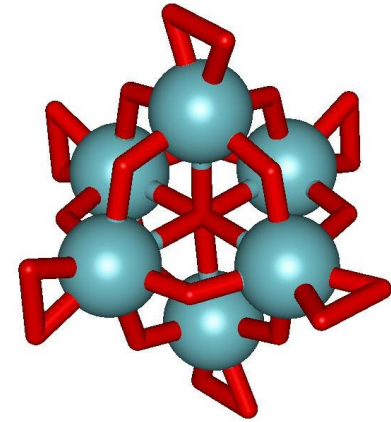
Nanoclusters



Hf_{17}



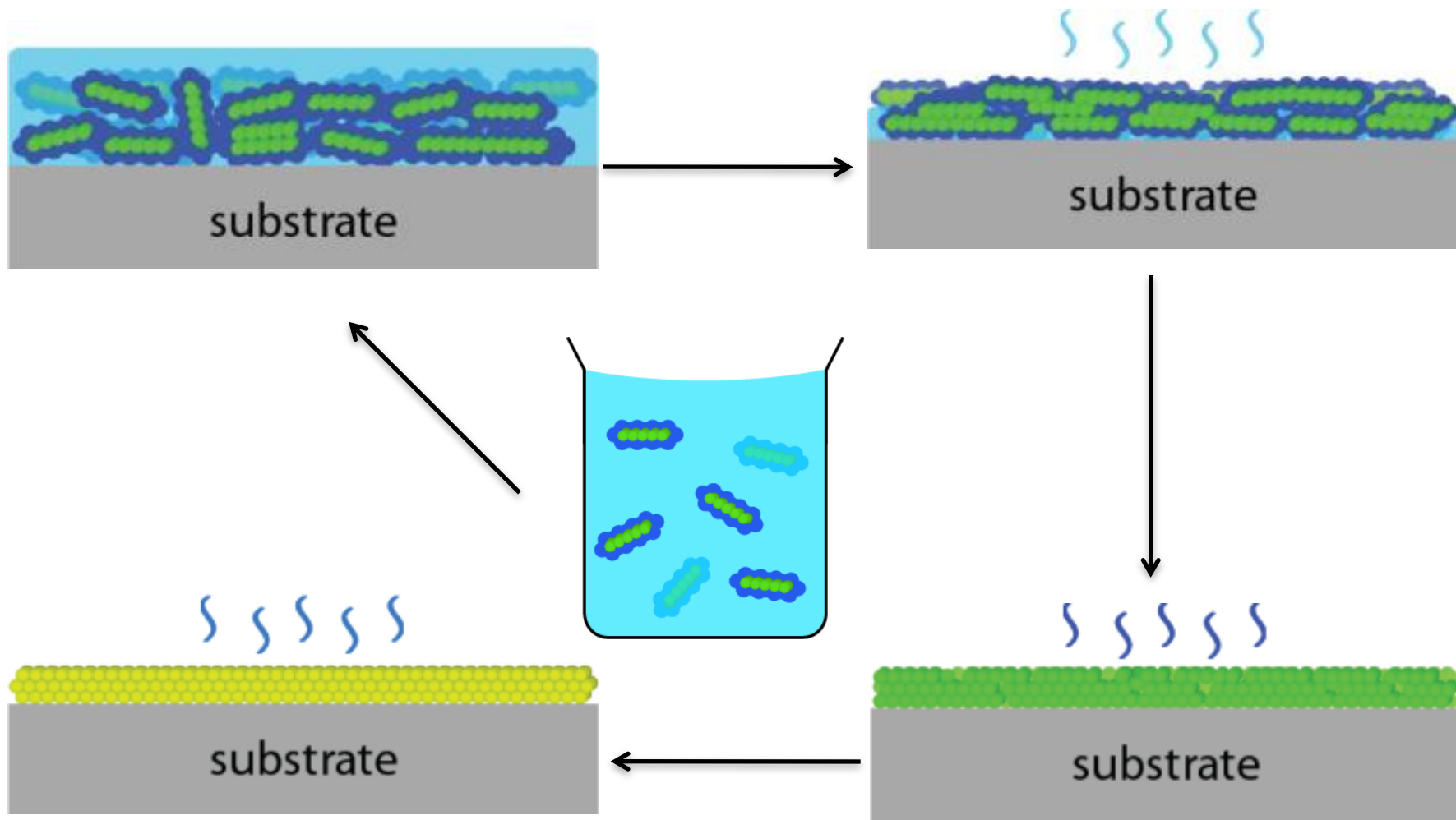
Al_{13}



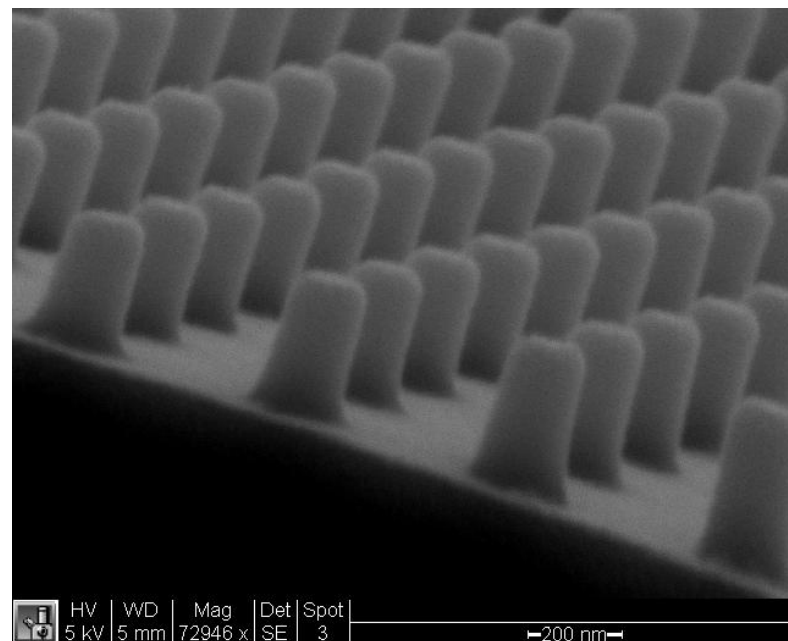
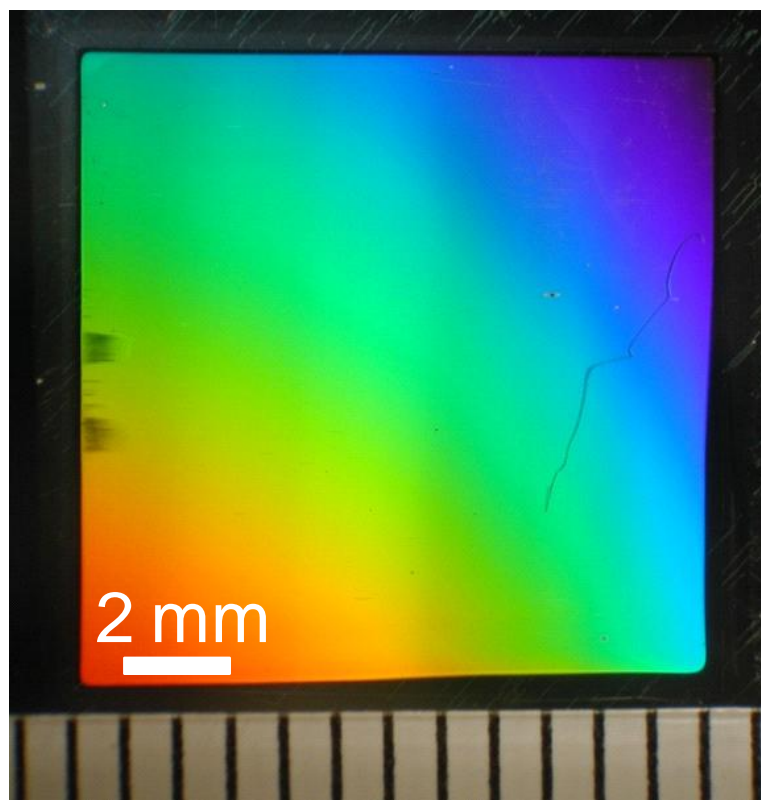
Nb_6

- Film precursors
- Disease detection and treatment
- Environmental applications

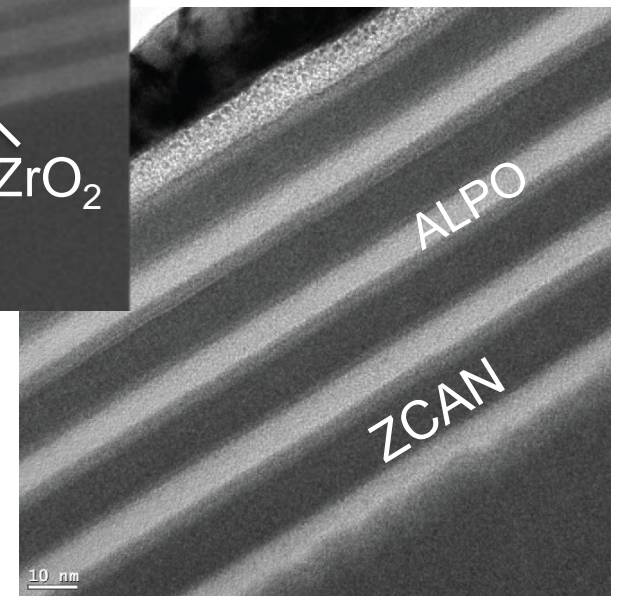
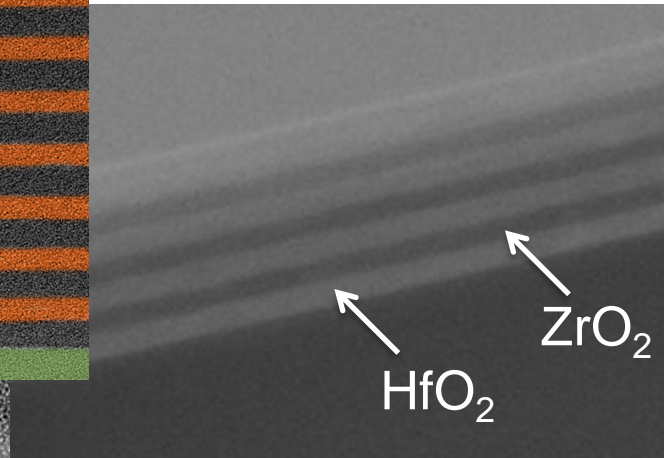
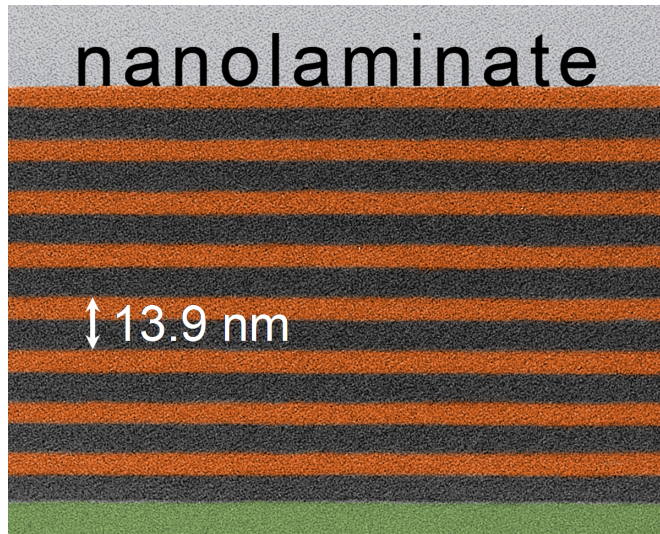
Living Films



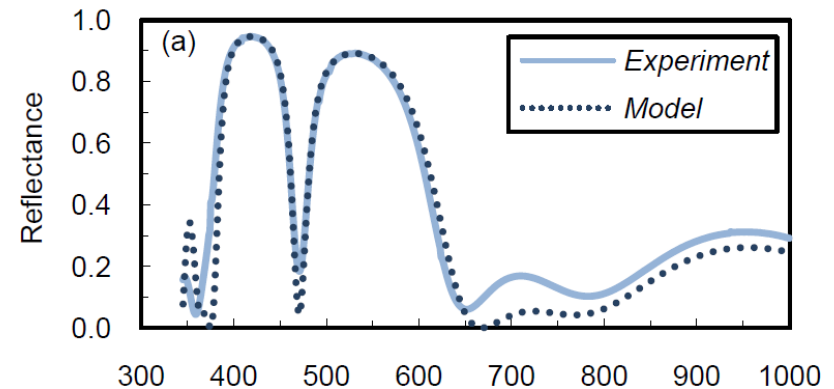
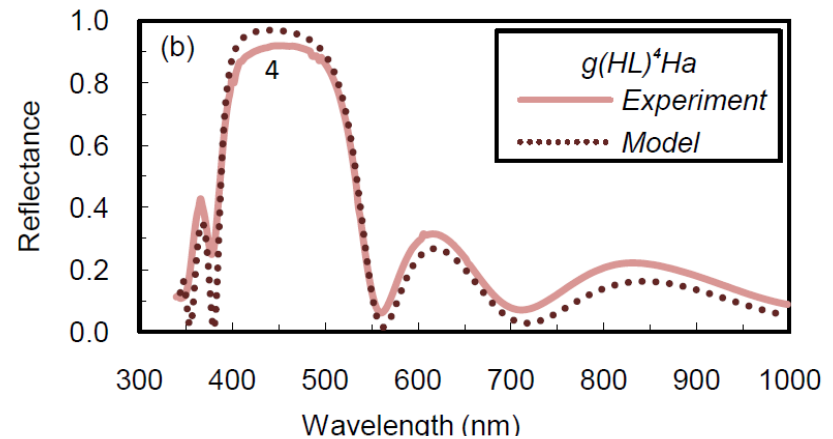
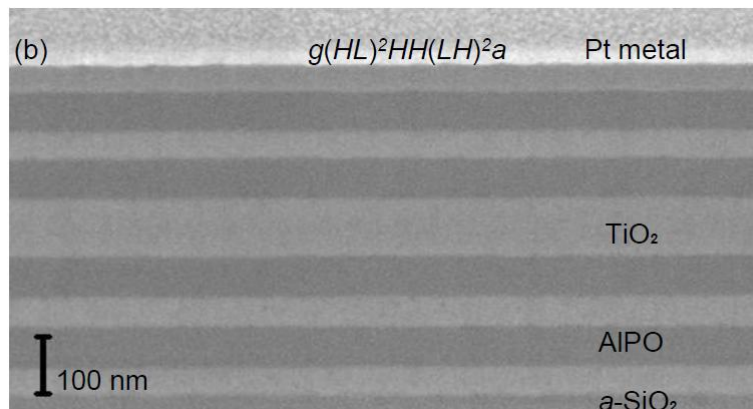
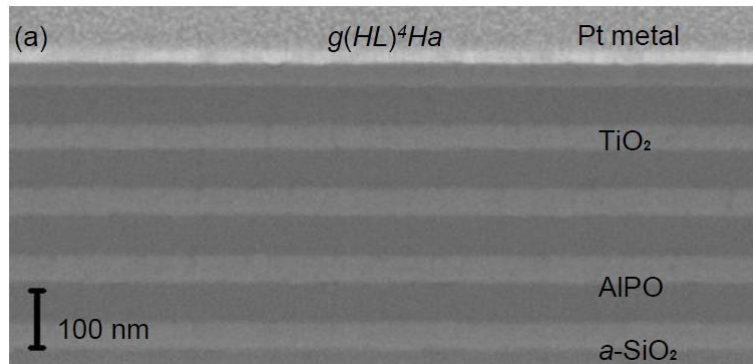
Nanoimprinting Functional Oxides



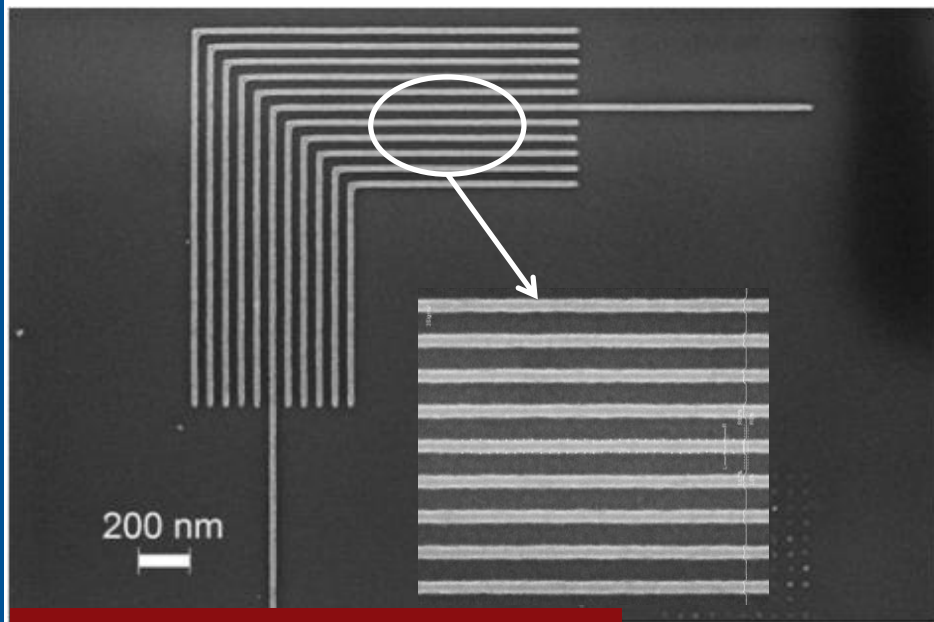
Precision Nanolaminates



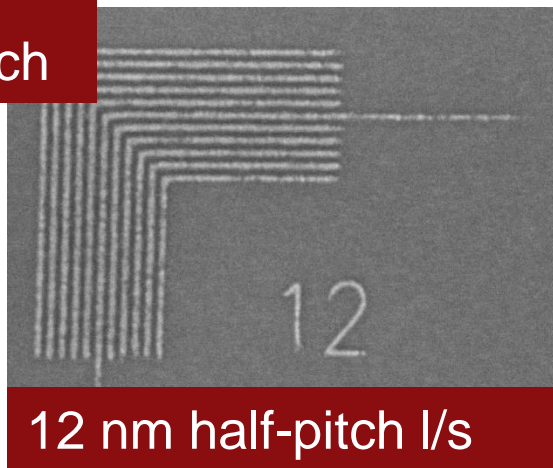
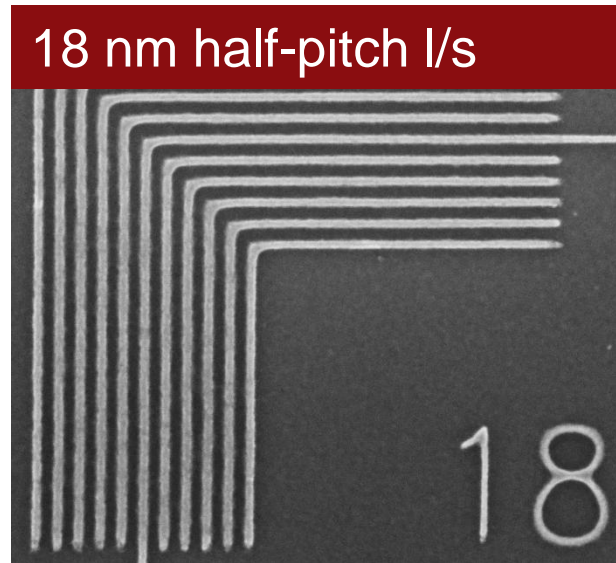
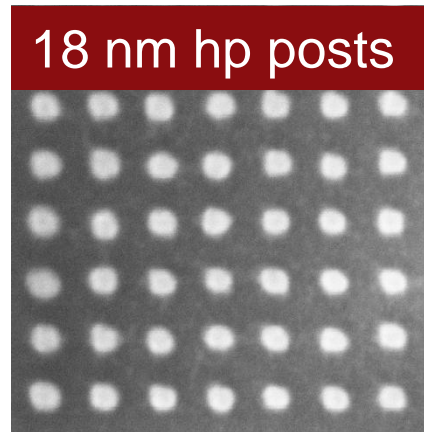
Bragg Reflectors and Microcavities



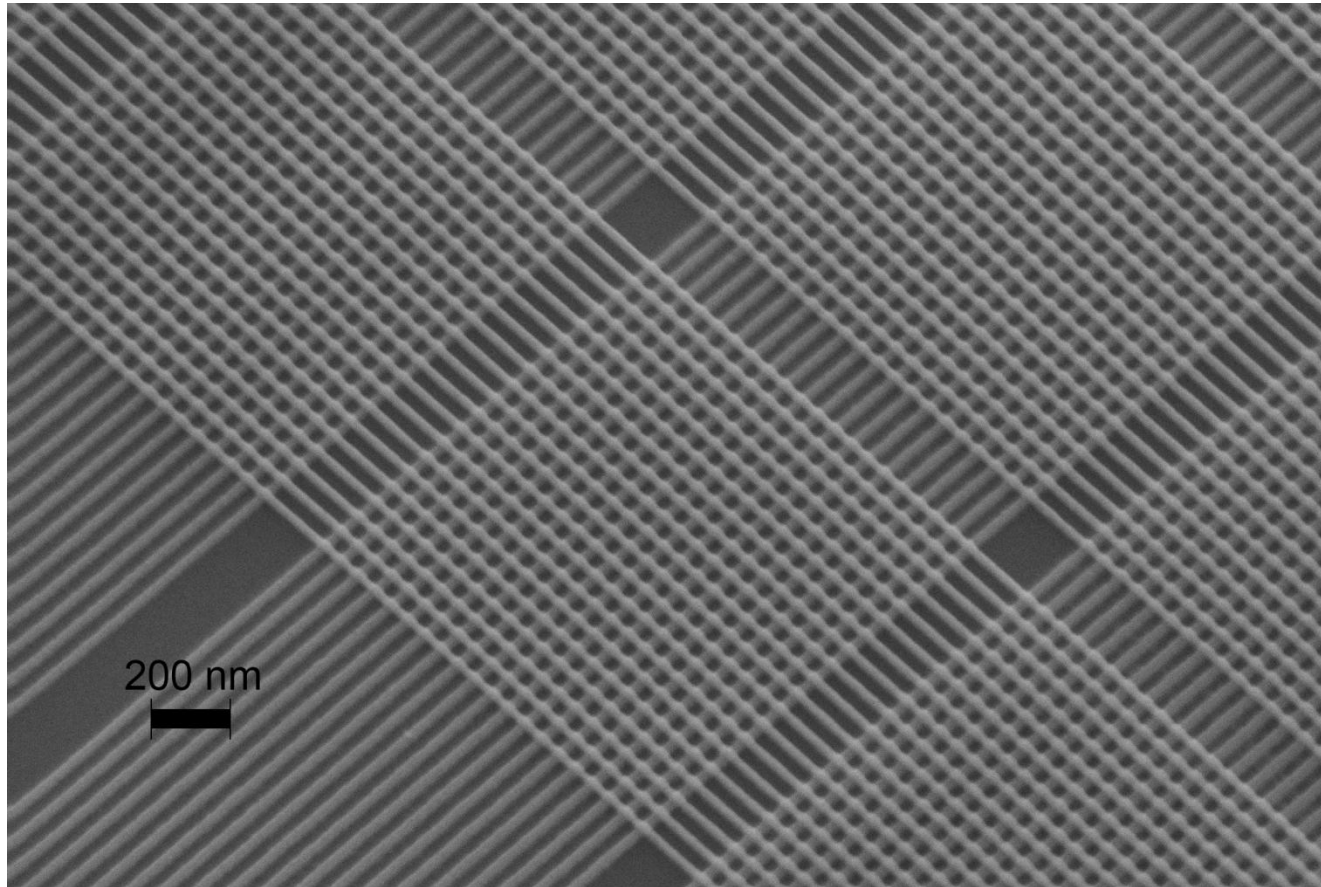
High Resolution Lateral Patterning via EB



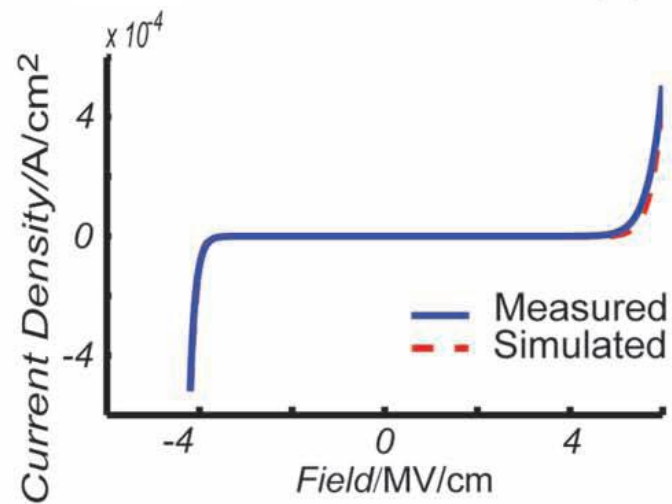
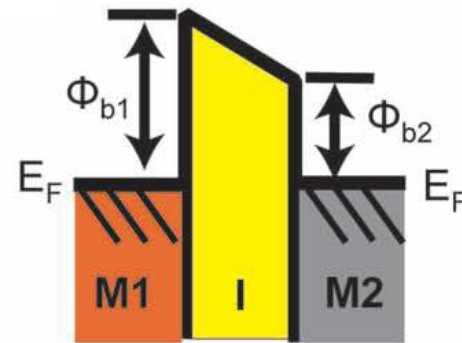
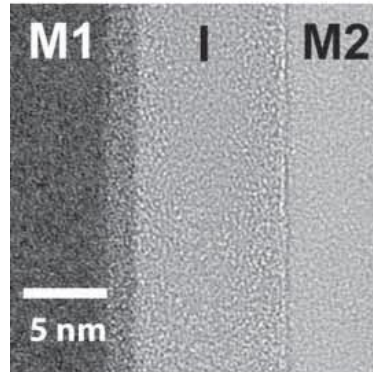
LWR 1.6-1.8 nm
CD 21 nm, 60 nm pitch



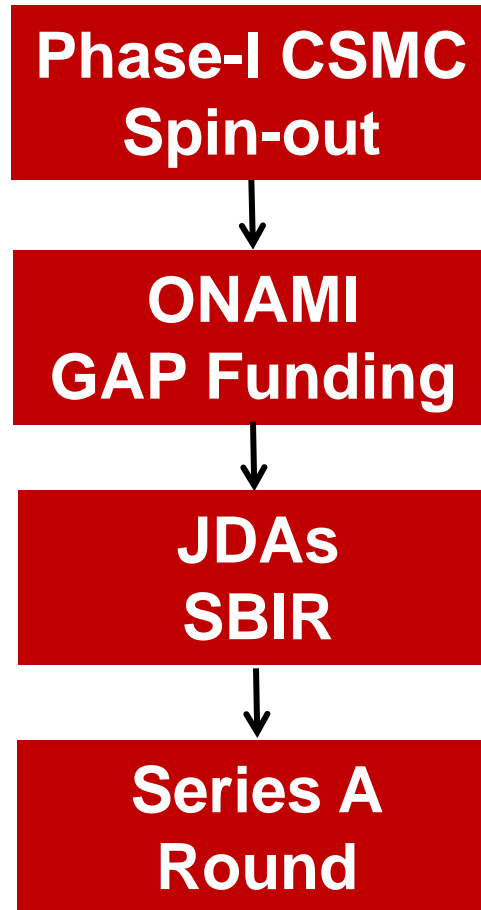
Beam-Directed 3D Inorganic Nanoassembly



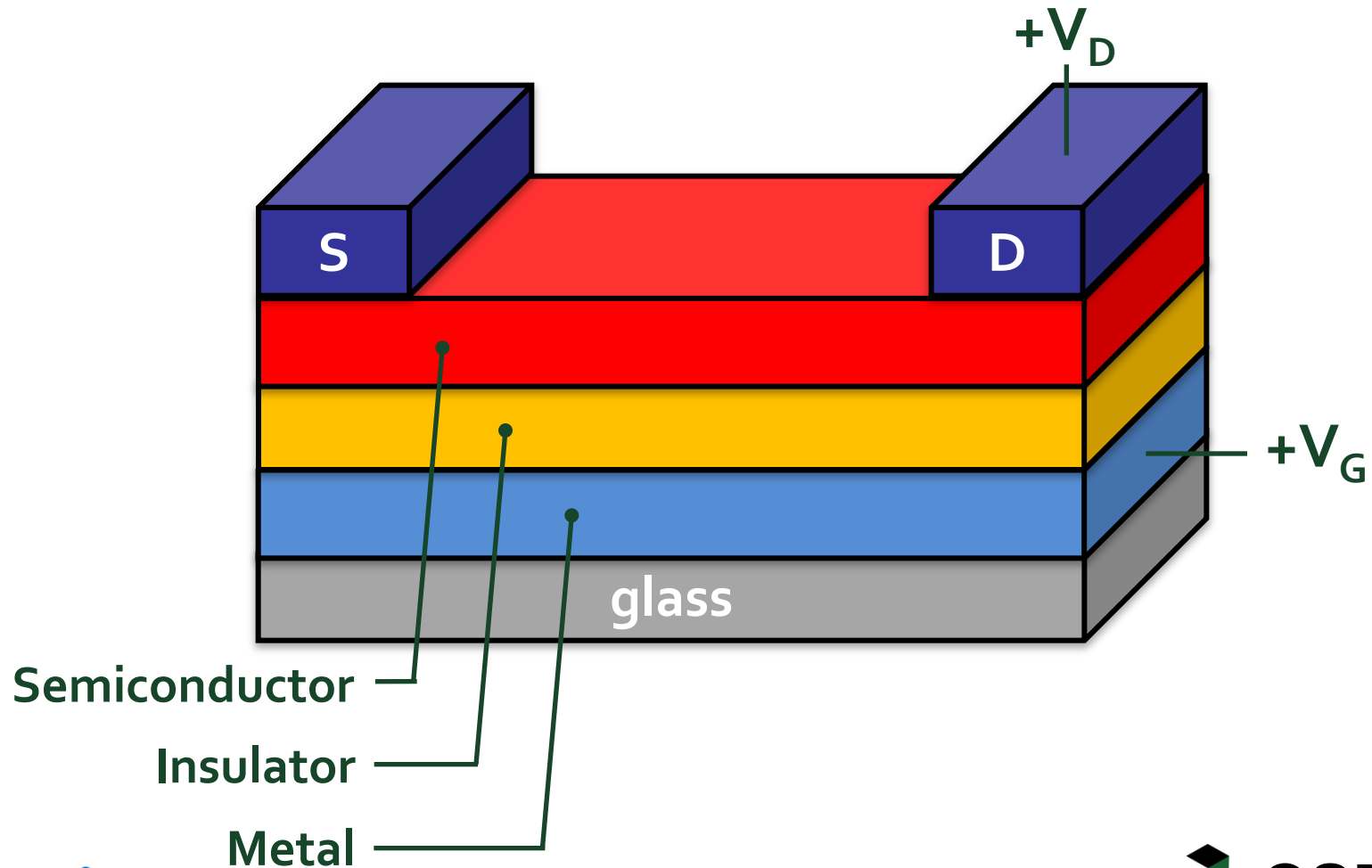
Tunneling Electronics



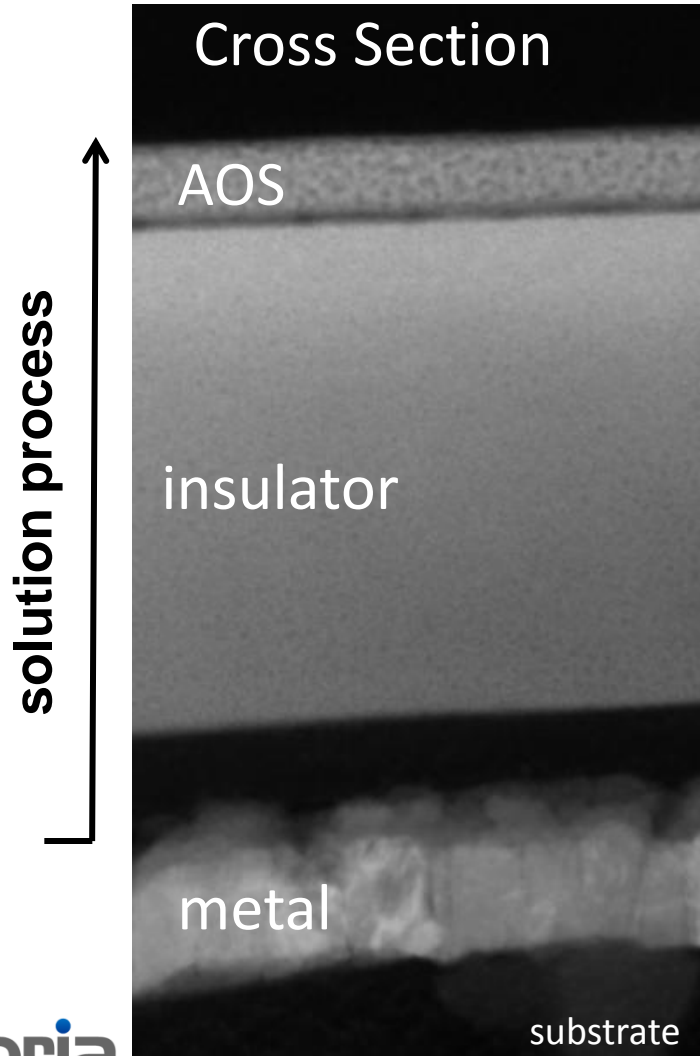
Inpria Corporation



Solution-Processed Thin-Film Transistors



Display TFT



AOS + Oxide Insulator

$T < 350\text{ }^{\circ}\text{C}$

Gen-2 glass: $> 2,000,000$ TFTs

$I_{\text{on}}/I_{\text{off}} = 10^7$

$\mu = 5\text{ cm}^2/\text{V}\cdot\text{s}$

PBTS - $< 1\text{ V}$ shift

Display TFT Array Fabricated with Water-Based Precursors



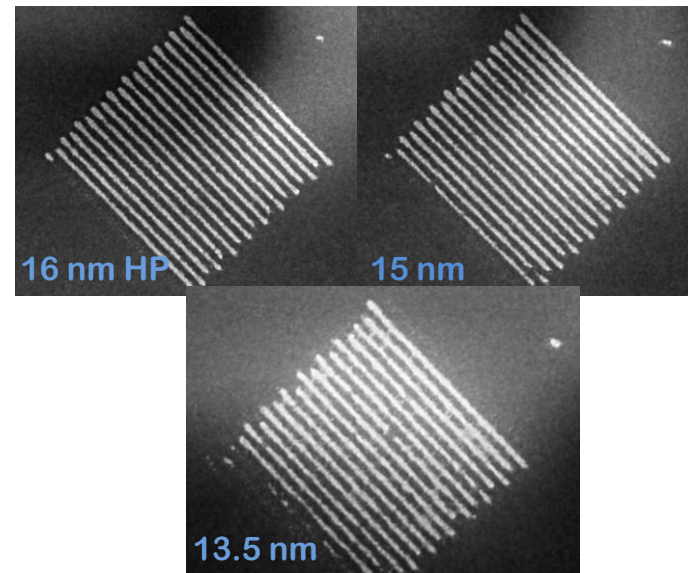
2,000,000 transistors



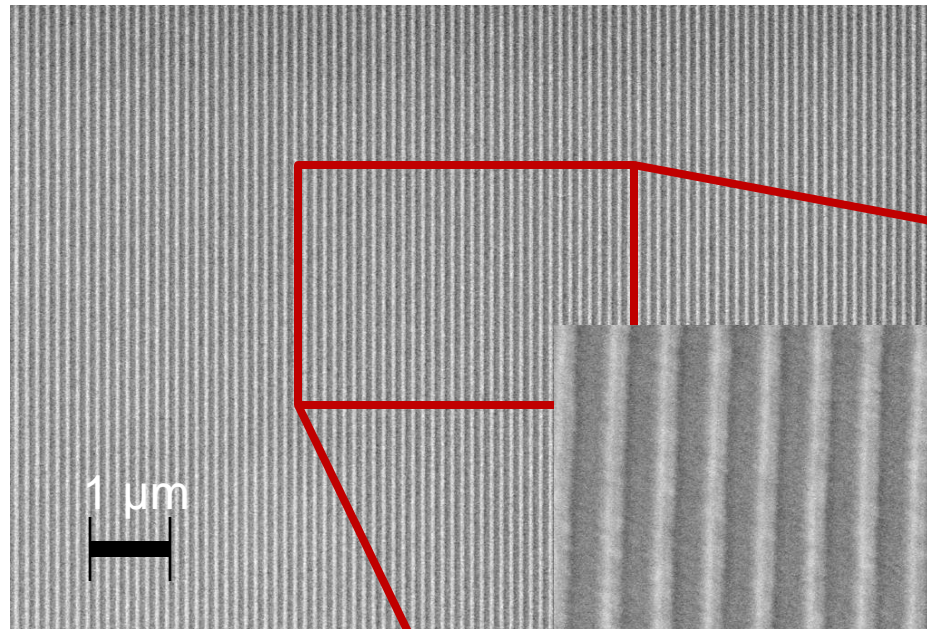
Inpria: Pushing EUVL Resolution



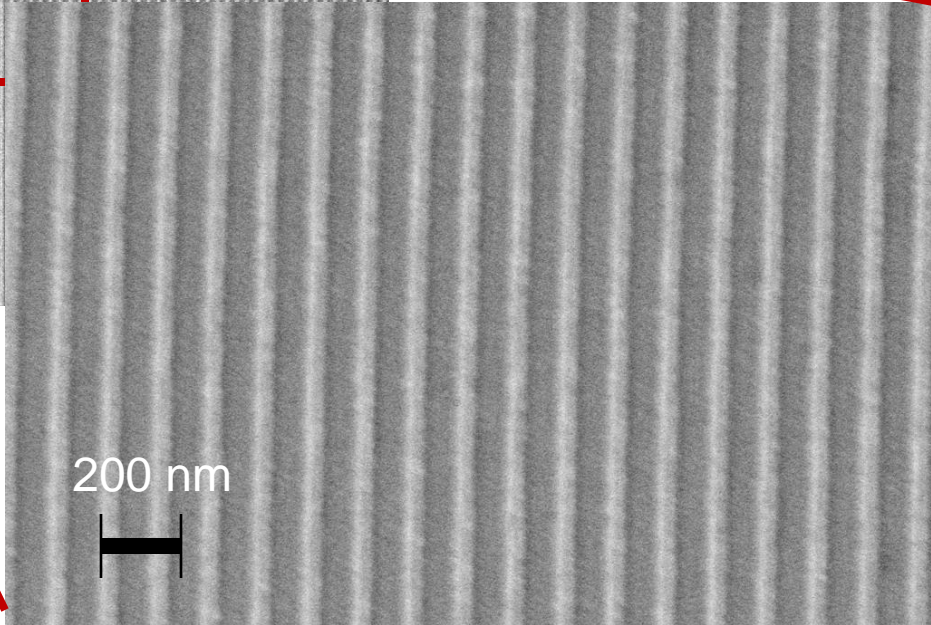
EUVL Production Tool



Directly Imaged Hardmask via ArF Exposure



Dose: 20 mJ/cm²
CD 40 nm, 60 nm half-pitch
by dry interference imaging



Compositional tuning of optical properties

A New Toolbox for Nanomanufacturing

- Environmentally Benign Aqueous Processing
- Planar Surfaces & Interfaces
- 1, 2, and 3D Control of Nanostructures
- *In-Situ* Chemistry: Top-Down meets Bottom-Up
- Large-Scale Manufacturability

Application Spaces:

Semiconductor

Display

Data Storage

Energy

Optics

Acoustics

Corrosion Barriers

Thermal Barriers