Nanotechnology for Energy Conversion, Storage, and Utilization

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

The Relationship Between the Meter and the Nanometer can be Understood Better in Monetary Terms

A dollar bill is to a billion dollars, as a nanometer is to a meter.

There are a 1000 million dollars in a billion, and there are 1000 thousand dollar bills in a million dollars.

Thus a nanometer is 1000X1000X1000 times smaller than a meter, just as a dollar is 1000X1000X1000 smaller than a billion dollars.

Nanotechnology deals with objects having at least one dimension in the range of nanometers, typically from 1 to 100 nm.

A nanometer is to an inch as an inch is to 400 miles.

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Nanotechnology Has Broad Energy Implications

Layers and Composites	Nanocluster and Tubes	Nanoporous Membranes
Efficient Lighting	Catalysis for Chemical Processing	Chemical Separations and Purification
Permanent Magnets for Motors	Hydrogen Storage	Fuel Cells and Batteries
Low Friction/ Wear Resistant Surfaces	Artificial Photosynthesis	Sensors and Detectors
Photovoltaic Energy Generation	Electrodes for Batteries and Fuel Cells	

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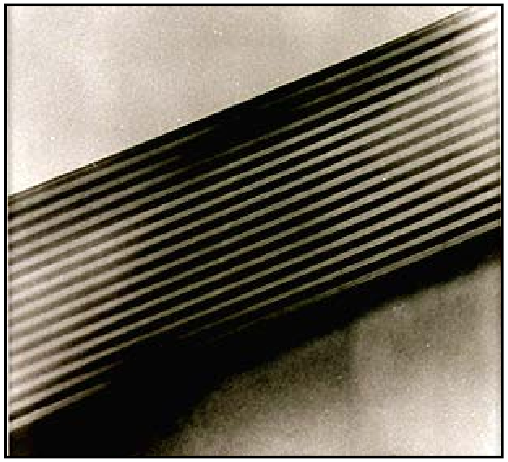
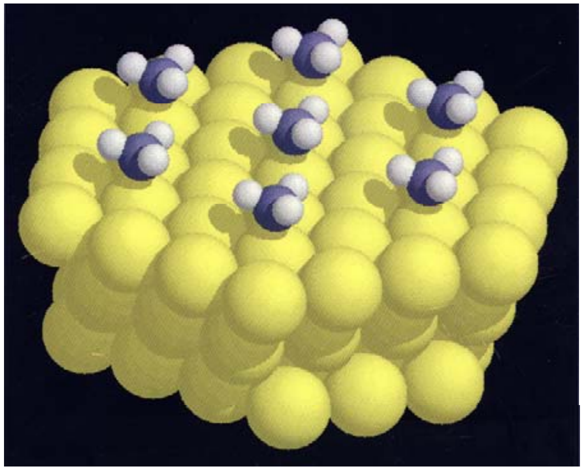
Nanostructuring is Key to Novel / Enhanced Functionality

Layered-Structures



- Electronics/ photonics
- Novel magnets
- Tailored hardness

Nanocrystals



- Novel catalysts
- Tailorable light emission
- Supercapacitors

Manufacturability will lead to revolutionary advances in technology.

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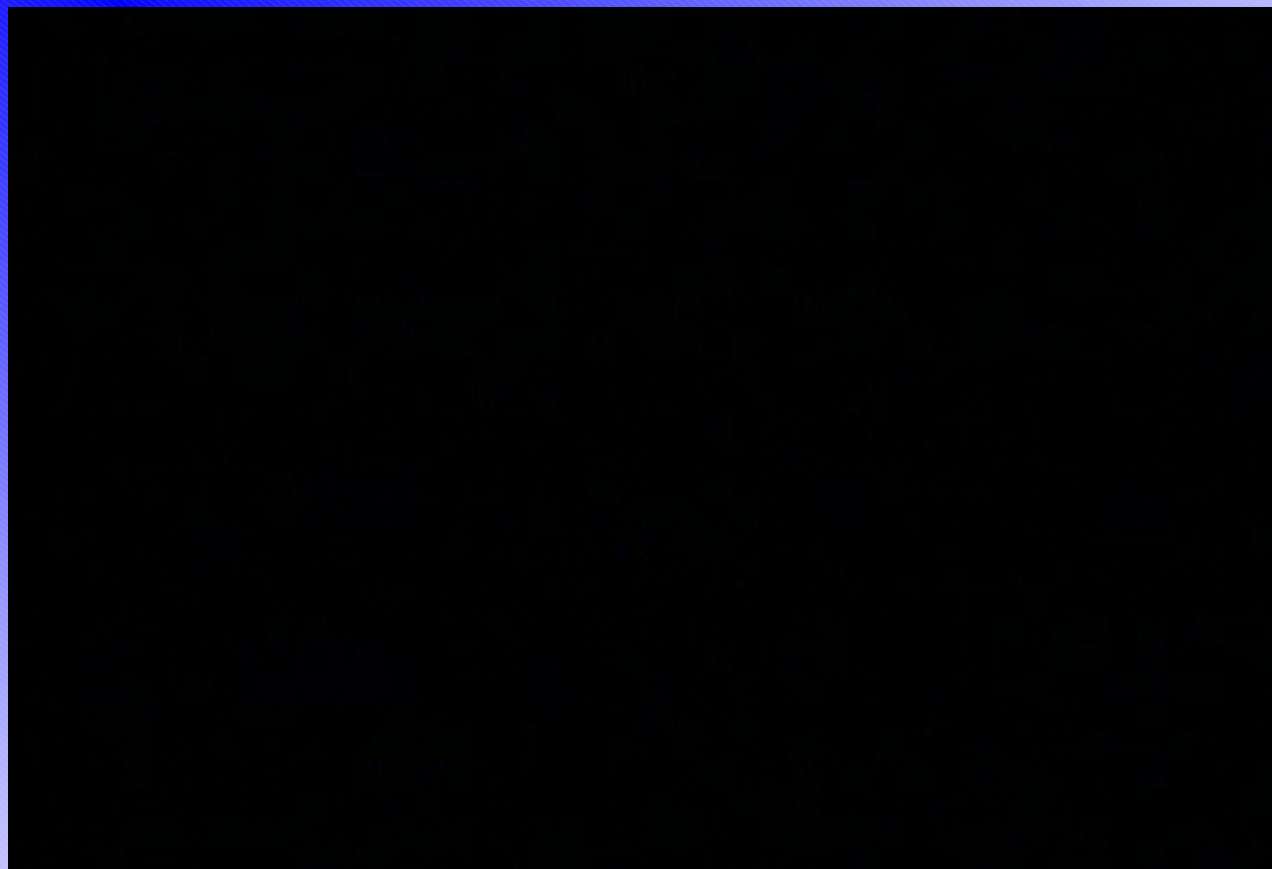
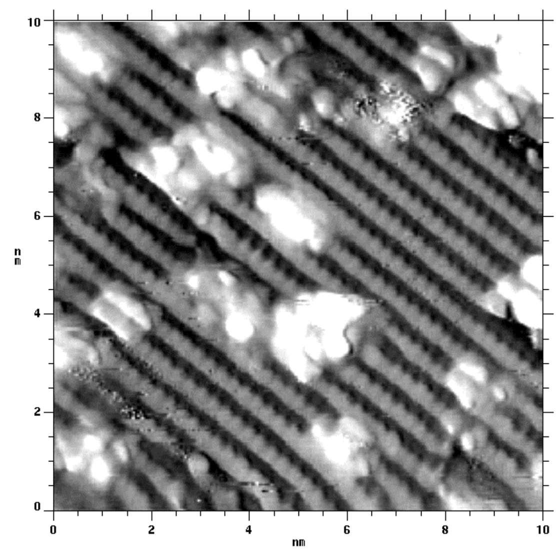


Nanoclusters Increase Efficiency of Catalytic Processes

Low temperature catalytic combustion, oxidation of hydrocarbons, reduction of nitrogen oxides.

Two atomic layer thick clusters show maximum efficiency.

STM image (2.0 V, 2.0 nA) of Au clusters on the TiO_2(110)-(1×1) surface. Quasi-2D Au clusters (lengths of 1-2 nm and heights of 1-2 atomic layers) and 3D Au clusters (lengths of 2-3 nm and heights ≥ 3 atomic layers) are observed for 0.1 ML Au coverage.



D. Wayne Goodman (Texas A&M)

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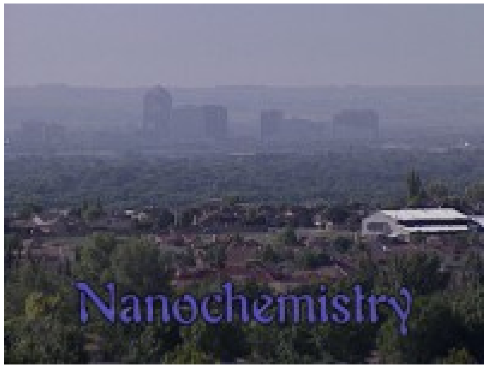
Cleaning up our Water and Creating an Inexhaustible, Nonpolluting Fuel – Two Potential Ways to Apply Nanotechnology Toward Real-World Problems

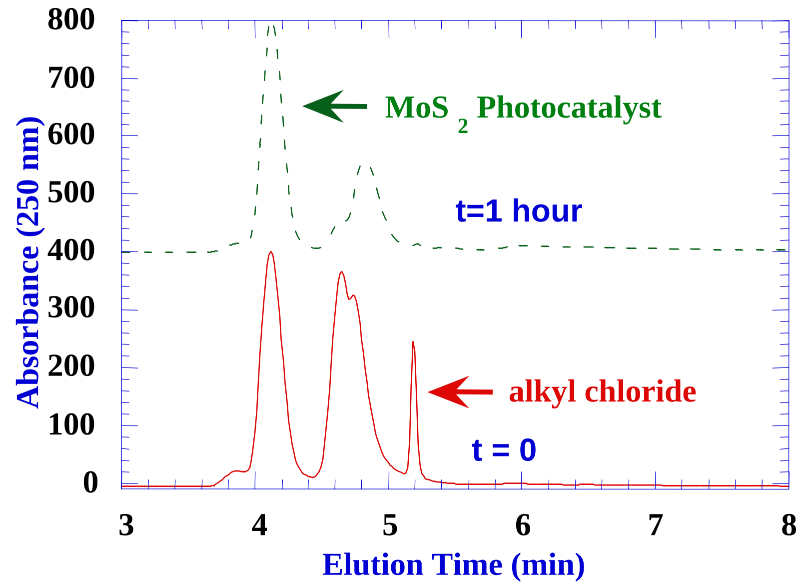


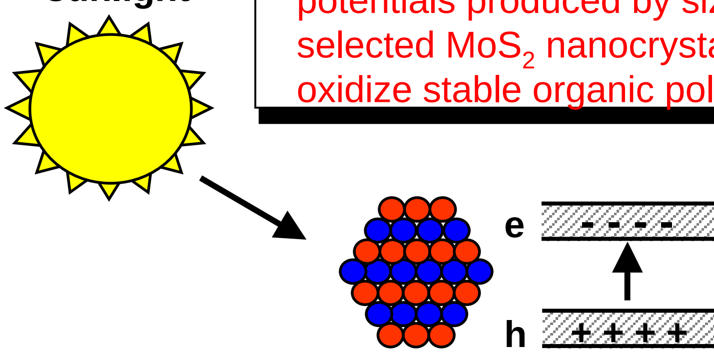
- **In the search for cleaner air, nanoclustered catalysts could help destroy pollutants using the energy from sunlight.**
- **Controlling the size of the nanoclusters determines the ability of the catalyst to decompose pollutants. Quantum effects that come into play at ultra small sizes greatly increase their effectiveness.**
- **Also, these same catalysts have the potential to produce fuels like hydrogen by the decomposition of water and hydrogen sulfide, using sunlight.**

Semiconductor Nanocrystals Breakdown Organic Pollutants

High oxidation/reduction potentials produced by size selected MoS_2 nanocrystals can oxidize stable organic pollutants

3 nm nanocrystals photo-oxidize alkyl chloride





+ chlorinated aromatic + H_2O —(electron/hole transfer reactions)→ CO_2 + HCl

- **Environmental remediation**
- **Solar photocatalysis/fuel production**

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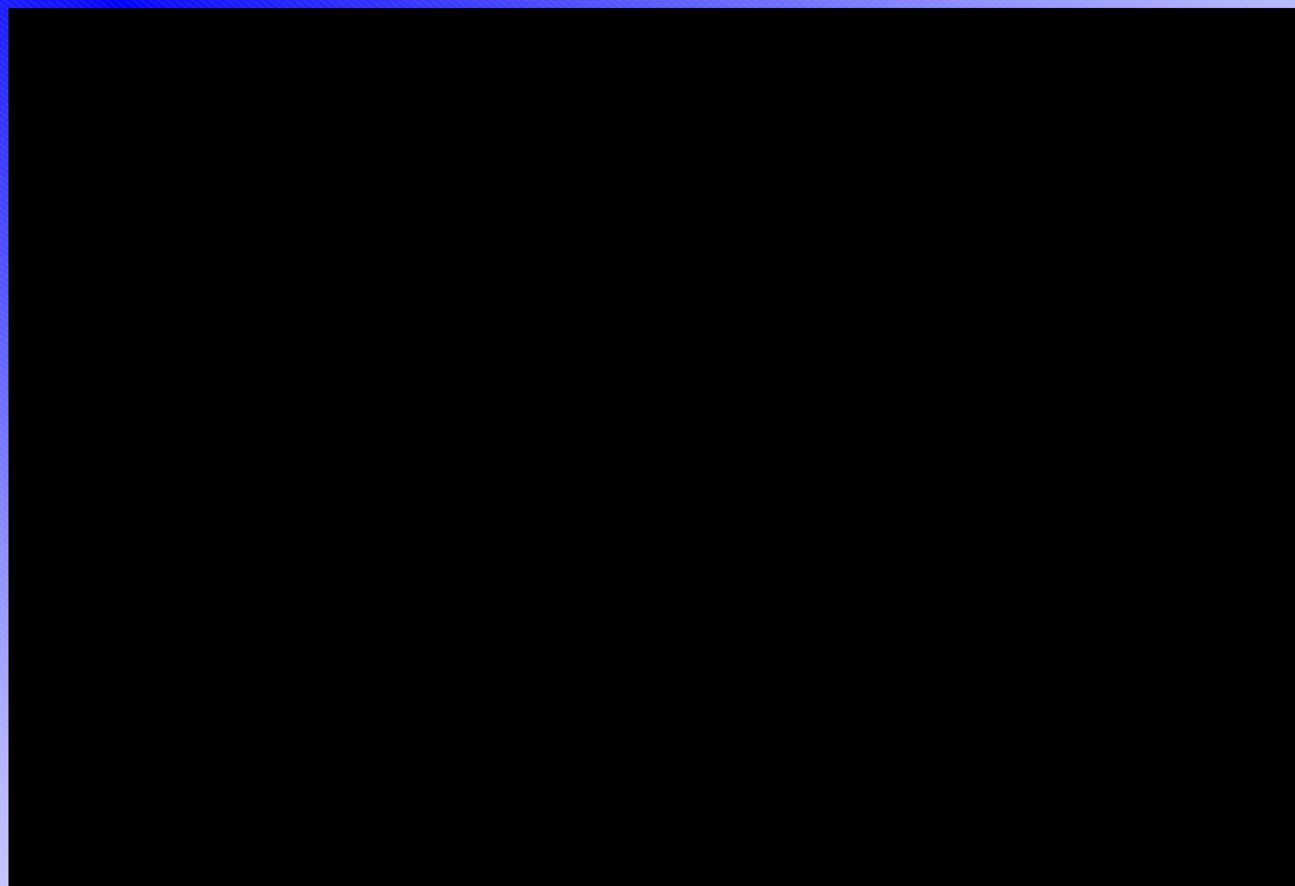
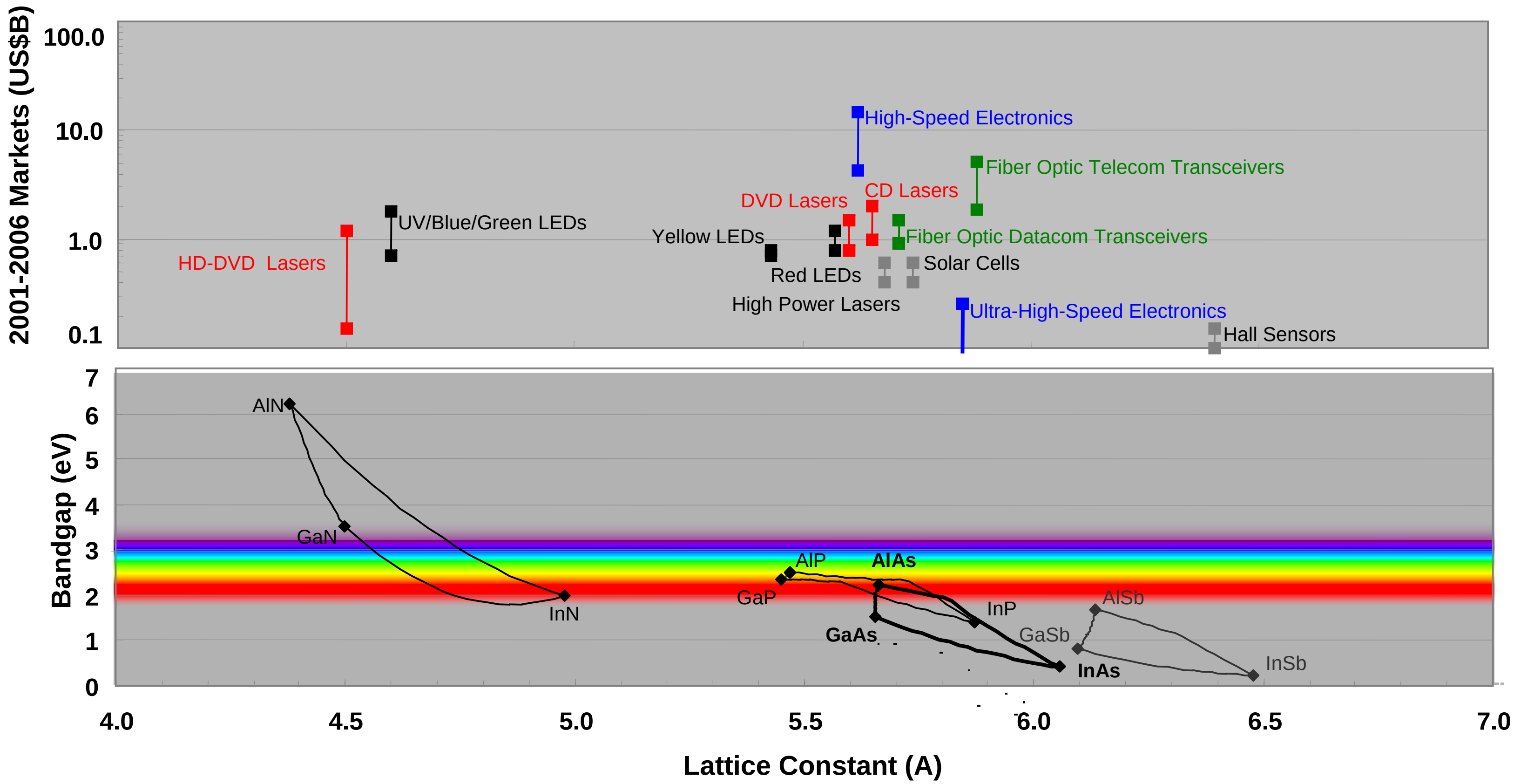


Nanoscale Layered Materials Enable Light Sources of all "Colors"



- **Fiber Communications (IR Lasers/Detectors)**
- **Optical Storage (IR, Red, UV Lasers)**
- **Solid-State Lighting (Red, Green, Blue LEDs/Lasers)**

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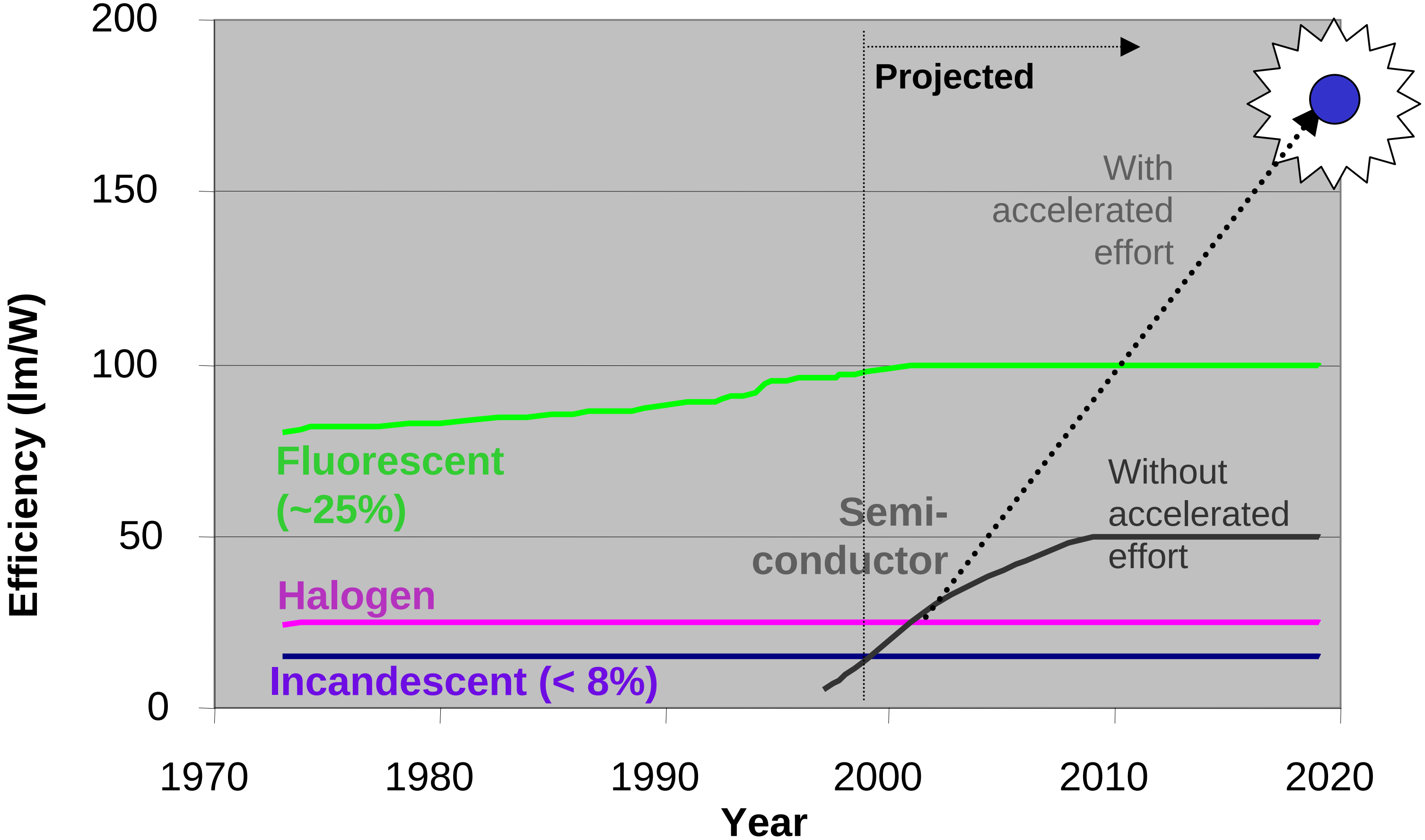
Conventional Lighting is Relatively Inefficient



Energy Efficiency: Solid-state lighting is potentially **10X and 2X more efficient** than incandescent and fluorescent lamps, respectively.

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Specialty Applications are Currently Driving Advances

Red LEDs 10X more efficient than red-filtered incandescents

LED Bulbs Getting Green Light in County

■ **Traffic:** Old stoplight variety is being replaced with cost-effective ones that last longer and use 90% less electricity.

By CATHERINE BLAKE
SPECIAL TO THE TIMES

The red and green stoplights may seem a little brighter these days, but local cities aren't playing a holiday trick on you. Some stoplights are indeed more radiant, and they won't be taken down once Christmas is over.

For the past few years, cities across California have replaced energy-draining incandescent bulbs in traffic signals with a longer-lasting light technology, called LED, that uses 90% less electricity. And in the face of today's increasingly volatile power markets, many local cities are applying for a state grant to help them change thousands more in coming years.

Although most drivers won't likely notice the difference, upon close inspection the LEDs, or light-emitting diodes, give stoplights a pinpoint look, with rows and rows of small dots instead of a soft glow. These bulbs are consistently bright, with a darker hue.

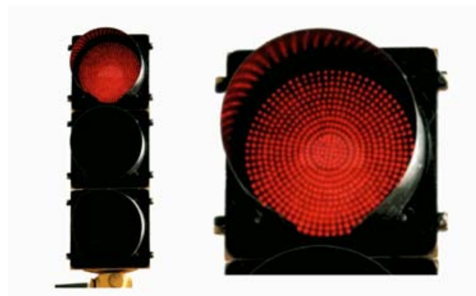
In contrast, incandescent lights are strongest in the center and the light fades around the edges. When LEDs are shut off, there is no afterglow.

Most importantly, considering the threats of rolling blackouts, a light-emitting diode uses only 10% of the electricity. If the entire state exchanged its 4 million incandescent stoplights for LED bulbs, the cumulative savings would be $95 million a year, ac-

MEL MELCON / Los Angeles Times

LED traffic light, replacing incandescent bulb, lasts 10 years and uses 90% less electricity.

Please see ENERGY, B5



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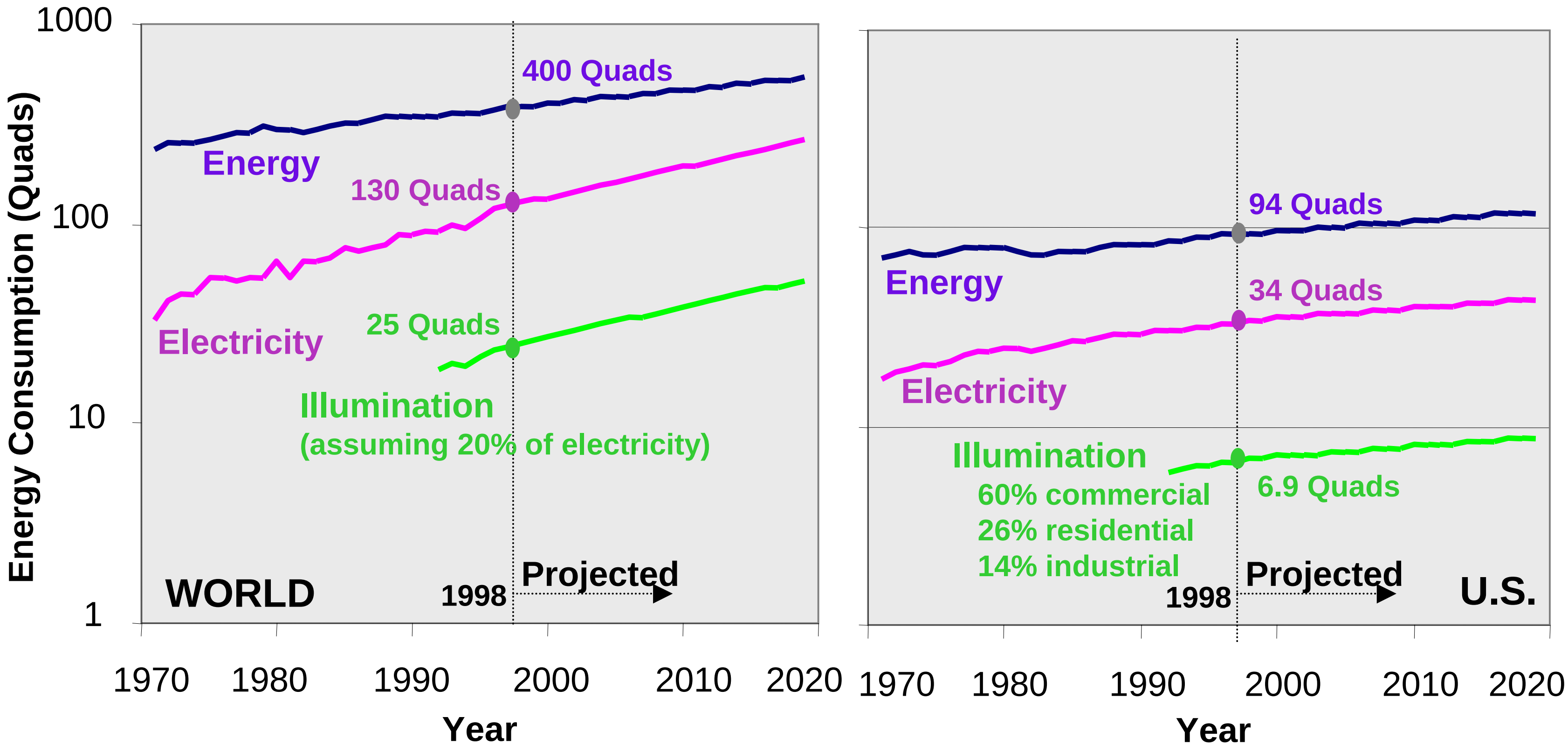
Significant Energy Savings are Possible!



~20% of U.S electricity consumption is for general illumination

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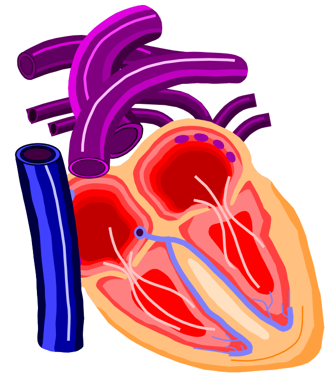
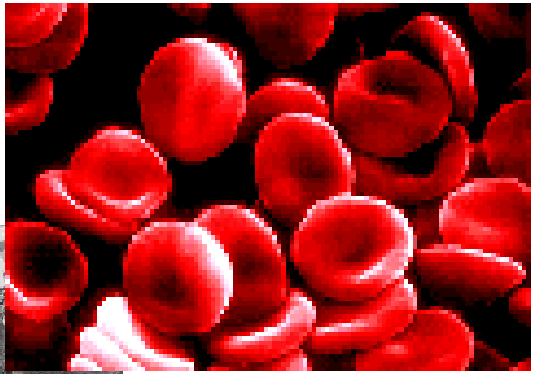
Living Systems use Nanotechnology to Achieve Micro- and Macro- Function

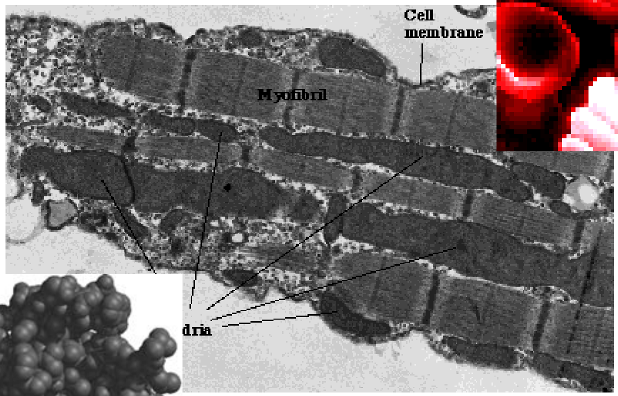
Integrated structures combine multiple length scales and functions.



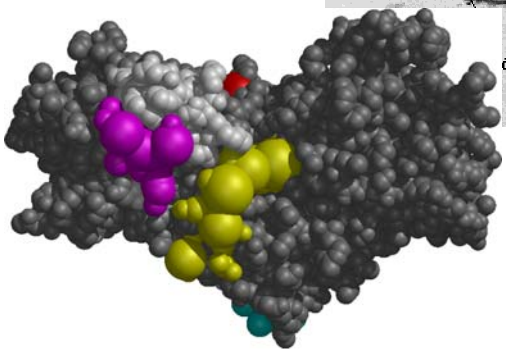
Organs and Tissues



Cells



Sub-cellular mechanical structure



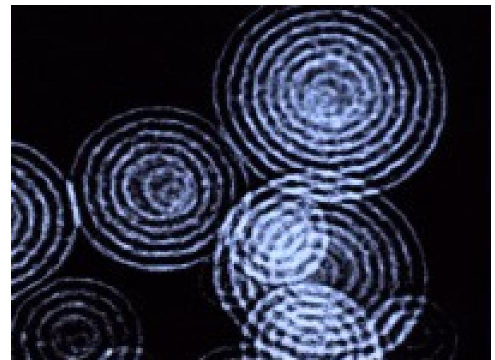
Molecules and Chemical Pathways

Self-Assembled Monolayers Mimic Natures Processes

- Simple methods organize molecules and molecular clusters into precise, pre-determined structures.

- Nature provides many examples of intricately organized architectures such as sea shells -- whose self-assembly is choreographed by molecular interactions.

- Researchers are applying similar strategies to spontaneously organize new nanocomposite and mesoporous materials. In fact, these nanomaterials are already helping to attain scientists' vision for new technologies.



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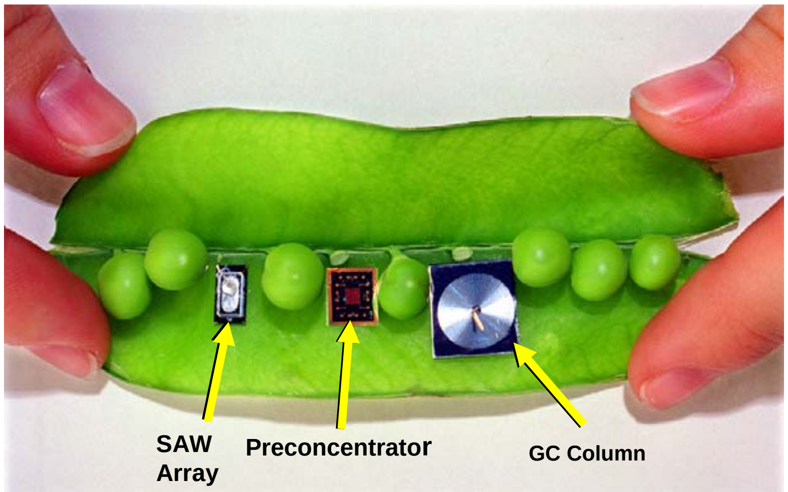
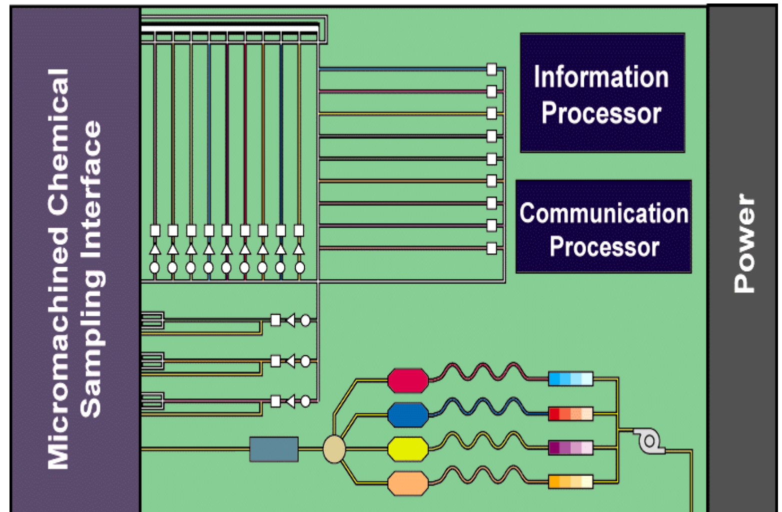
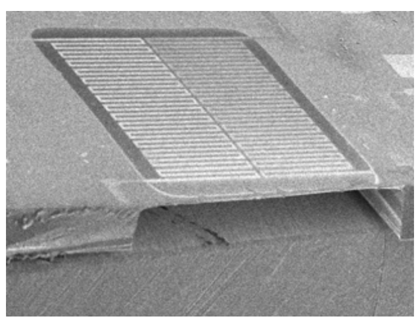
µChemLab Benefits from Materials that are Tailored on Scale of Molecules

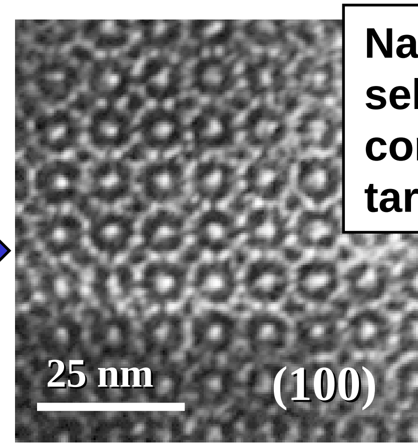




Highly parallel analysis channels



Micro-scale heater



Nanoporous film selectively concentrates target analytes.

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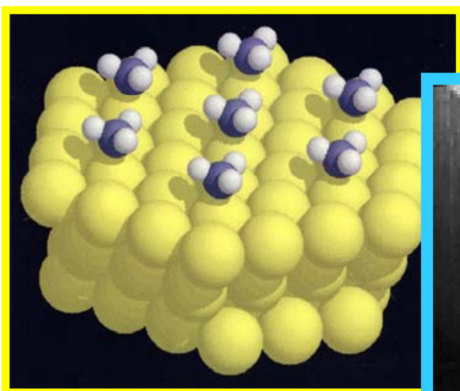
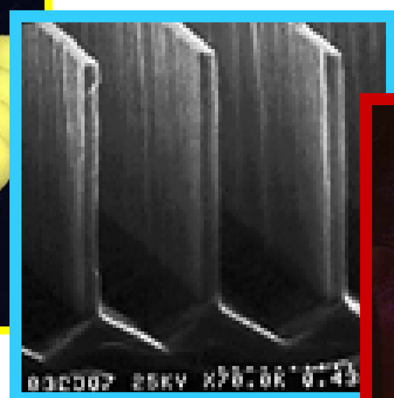
Nanotechnology is Moving from Discovery to Application

Exploring the path from scientific discovery to the integration of nanostructures into the micro/macro world

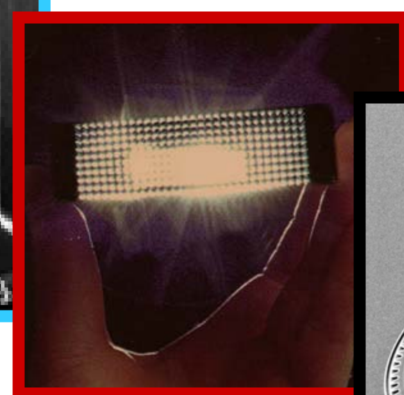
Exploration ↔ **Discovery** ↔ **Design**



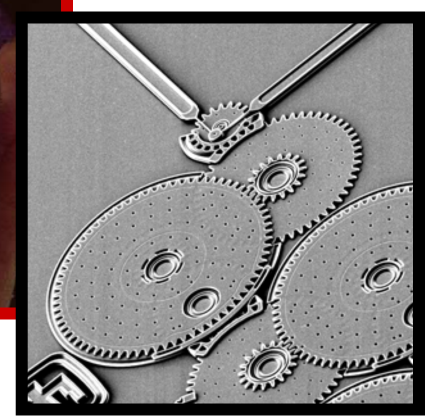
Theory and Experiment



Synthesis and Processing



Performance



Integration

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