



# A Few Small-tech Answers To A Few Energy-tech Questions

Neil S. Cameron





# Outline

- **Notions of size**
- Fabrication cost?
- Catalysis: is there a best of both worlds?
- ...and the PV envelope?
- Conclusions and acknowledgements

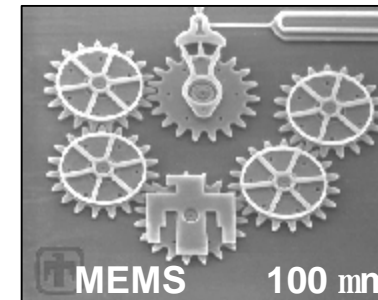
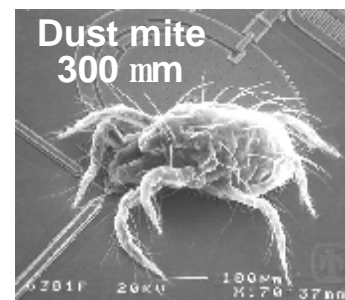
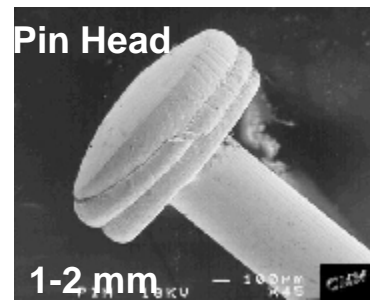
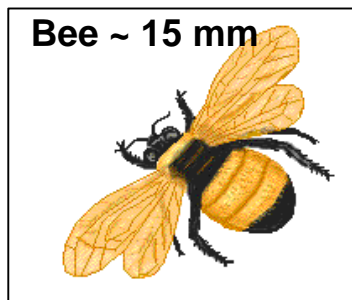


# Nano

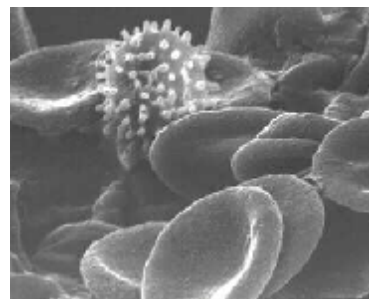
greek "*nanos*" or latin "*nanus*": dwarf

factor  $10^{-9}$

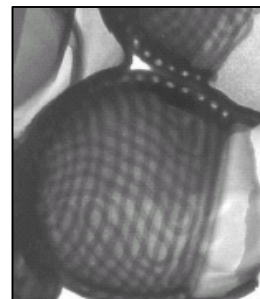
$10^{-3}$  m = milli ;  $10^{-6}$  m = micro ;  $10^{-9}$  m = nano



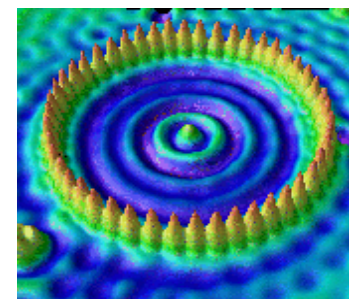
~ 50 mm wide



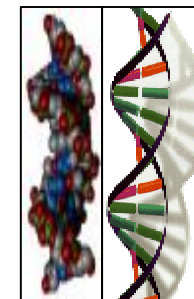
Blood cells ~ 7mm



Copolymer ball ~ 500 nm



48 Fe atoms on Cu diameter 14 nm



DNA ~2 nm



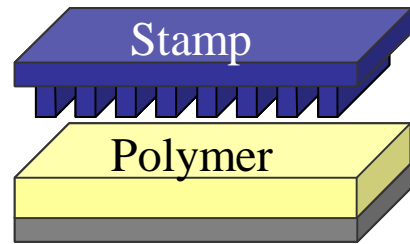


## Outline

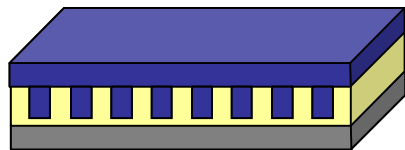
- Notions of size
- **Fabrication cost?**
- Catalysis: is there a best of both worlds?
- ...and the PV envelope?
- Conclusions and acknowledgments



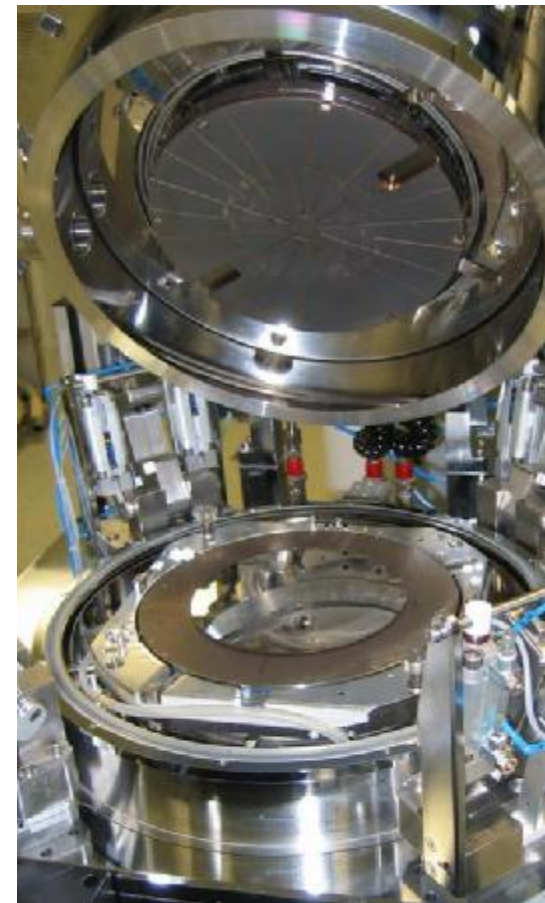
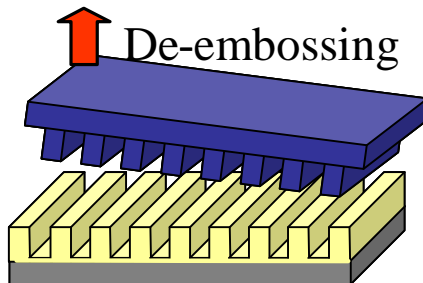
# Hot Embossing Lithography



Embossing ↓



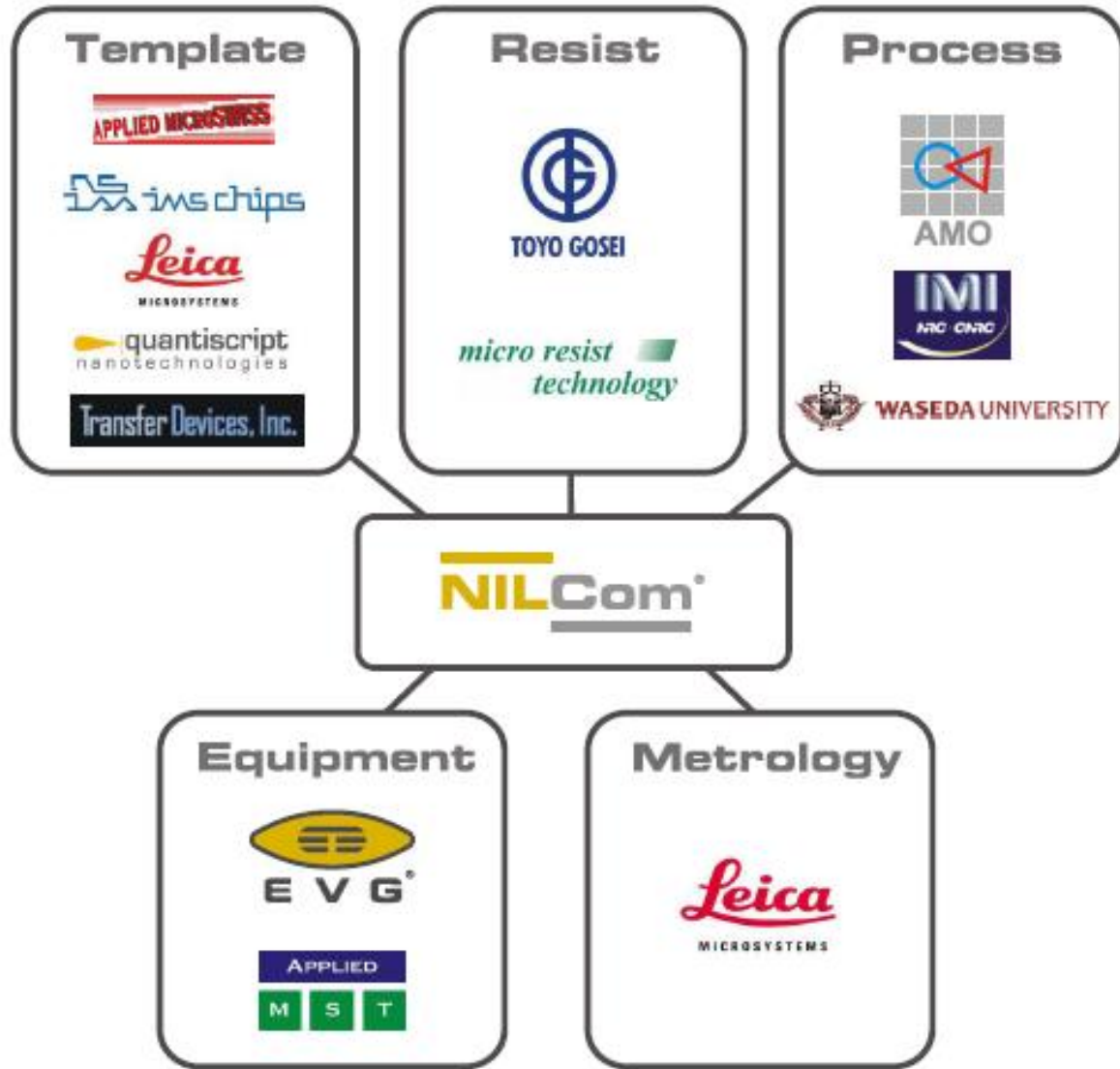
↑ De-embossing



- Cameron, N. S.; Roberge, H.; Veres, T.; Jakeway, S. C.; Crabtree, H. J., "High fidelity, high-yield production of microfluidic devices by hot-embossing lithography." *Lab Chip* **2006**.
- Cameron, N. S.; Ott, A.; Roberge, H.; Veres, T., "VT-CFM for HEL Release Layers." *Soft Matter* **2006**.



# NILCom.org



NIL:

- Hot Embossing Lithography
- UV Imprint Lithography
- MicroContact Printing
- ...

NILCom technology platform:

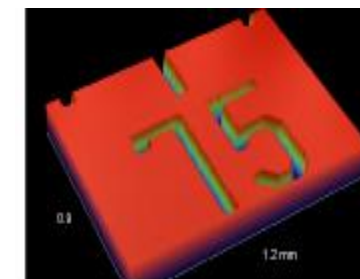
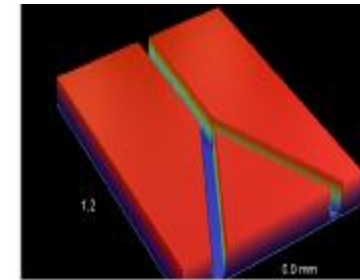
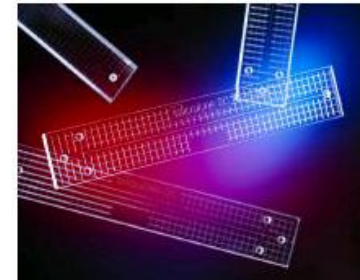
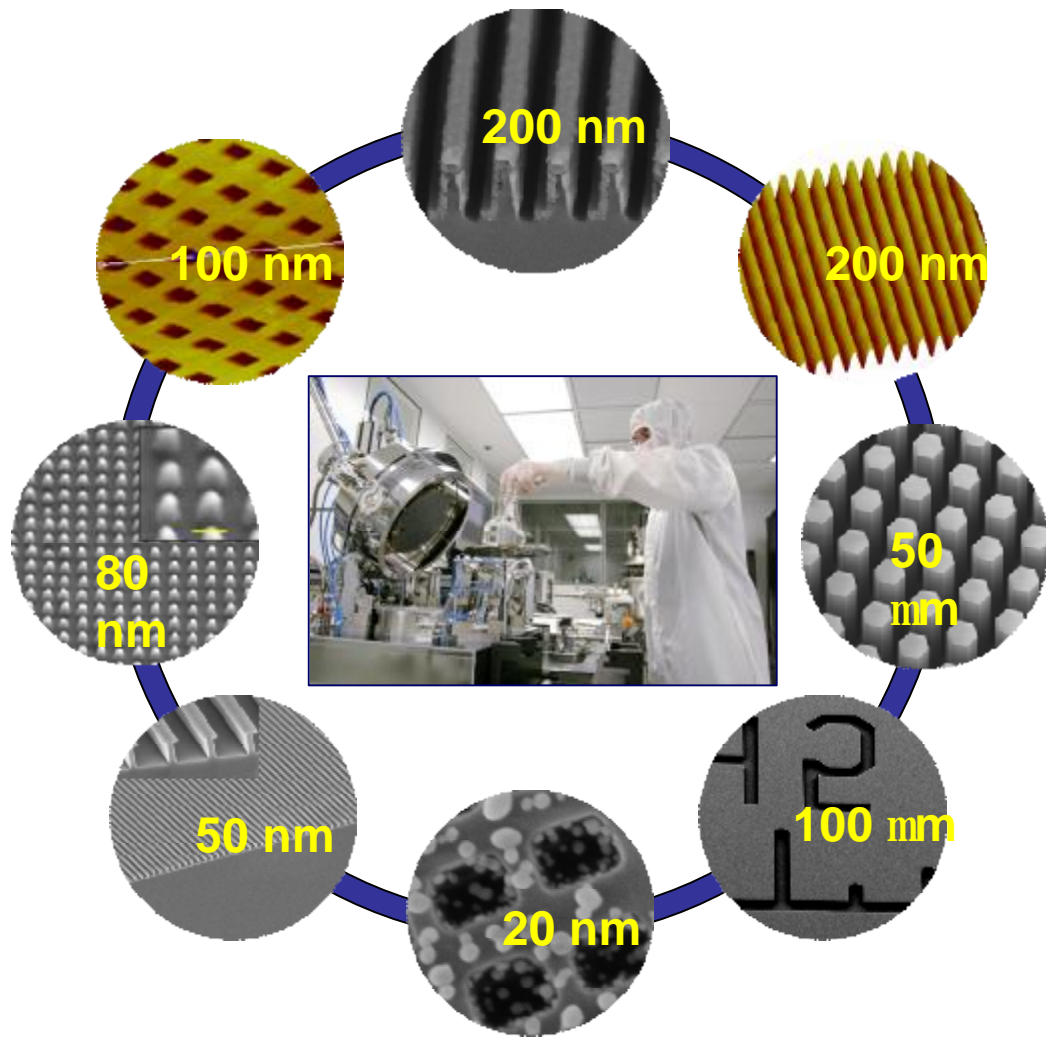
- established infrastructure
- qualified processes,
- leverage NIL synergies

NILCom devices use:

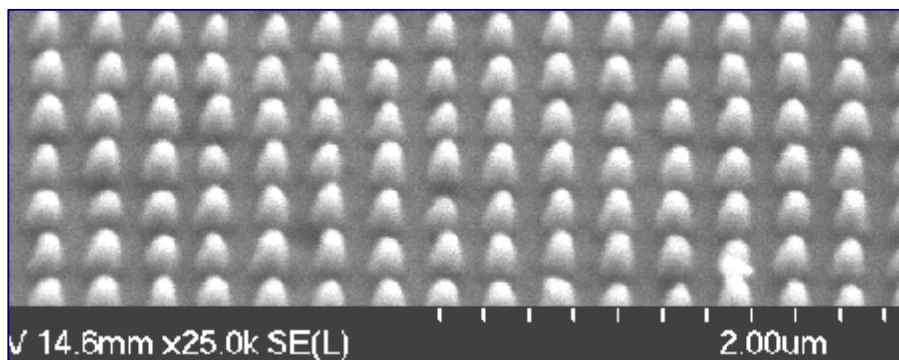
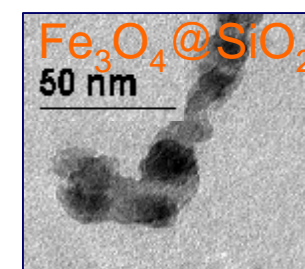
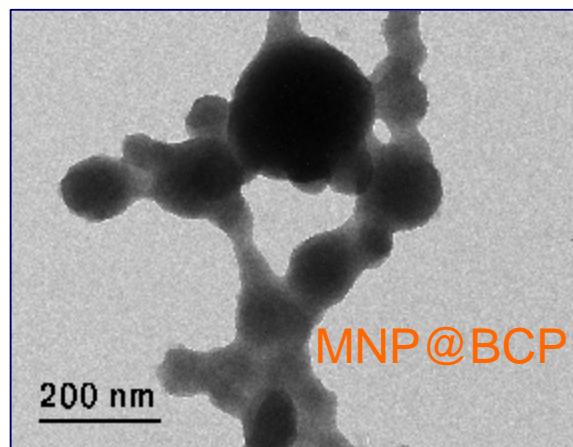
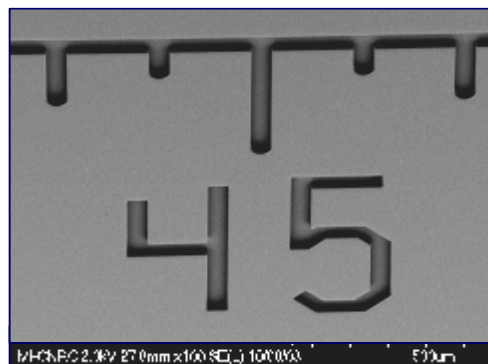
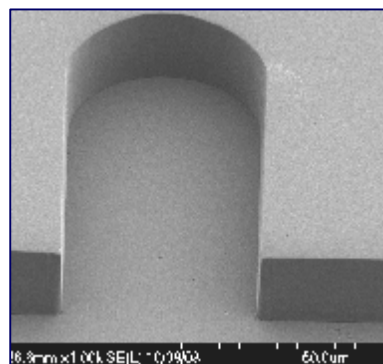
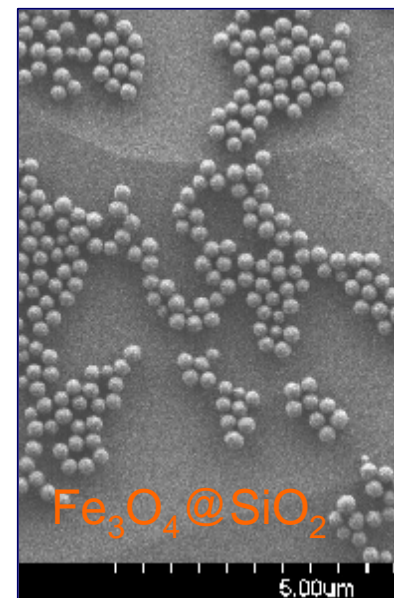
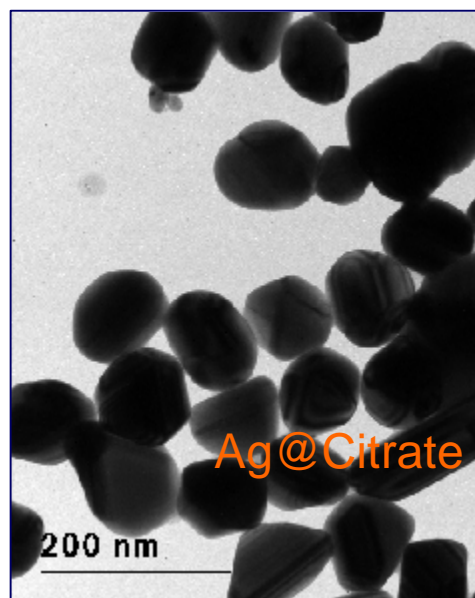
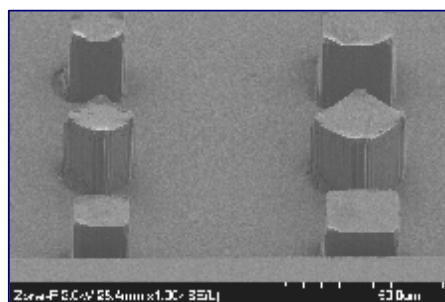
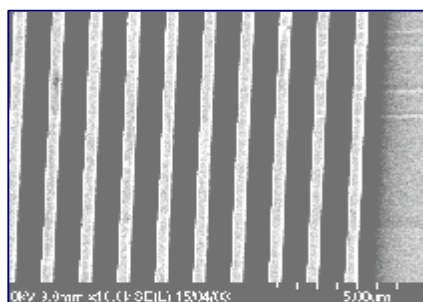
- the most advanced and cost efficient pattern replication methods
- an accelerated product commercialization path.



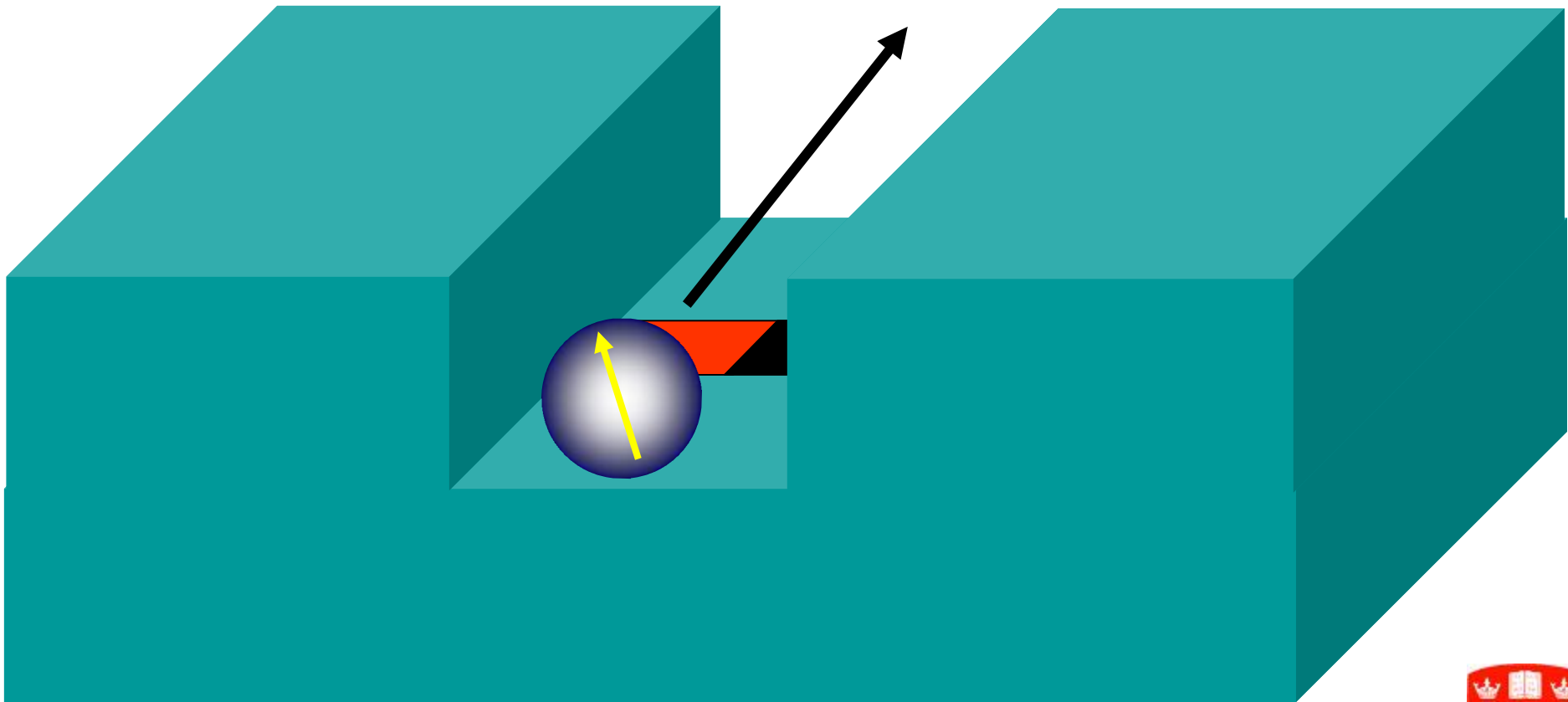
# HEL: nano- & micro- at IMI



# Top-down and bottom-up nanofab



# Integrating MEMS and Particles





# Outline

- Notions of size
- Fabrication cost?
- **Catalysis: is there a best of both worlds?**
- ...and the PV envelope?
- Conclusions and acknowledgments



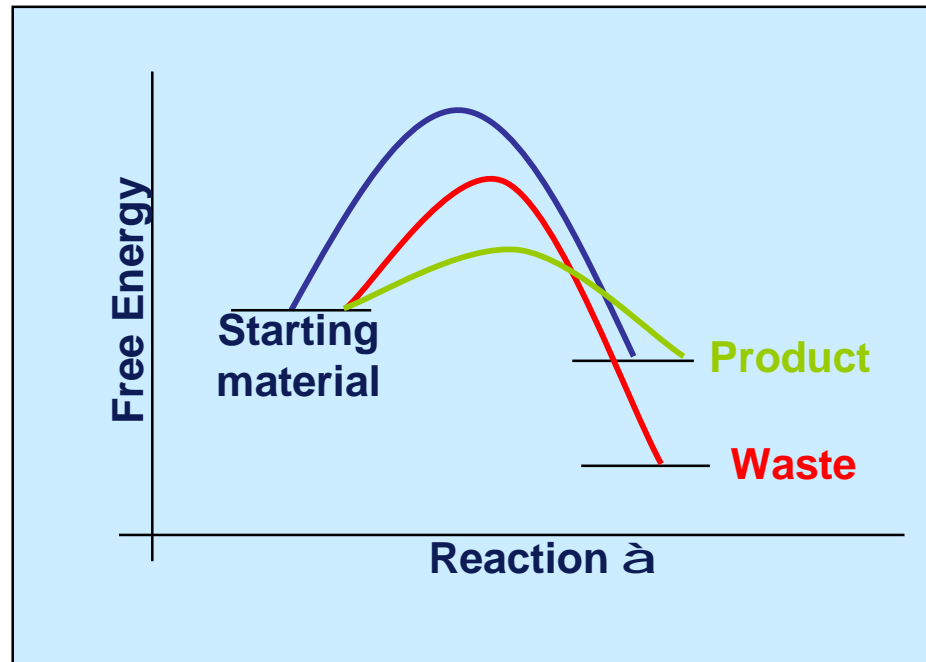
# What is a Catalyst ?

## Classical Definition:

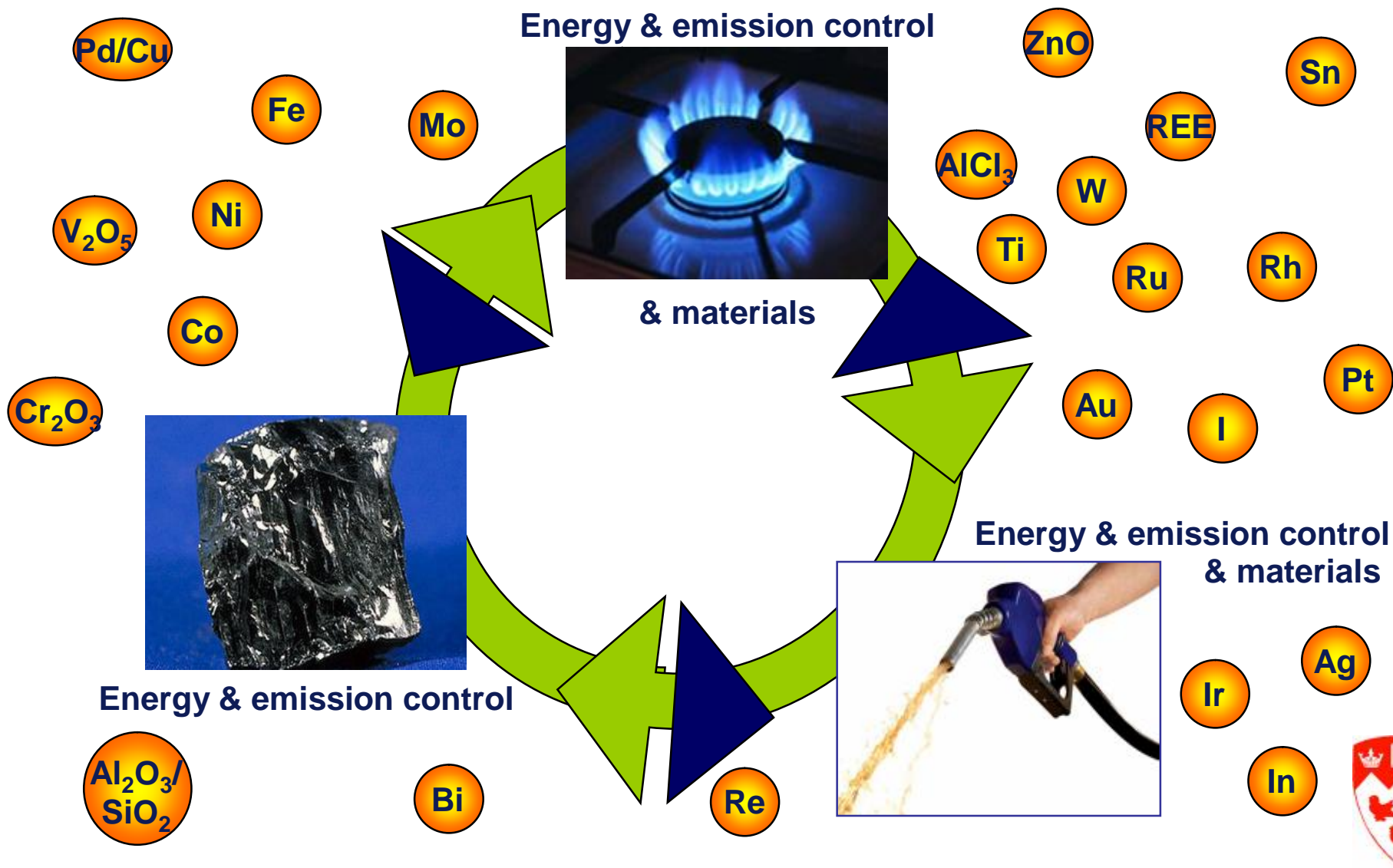
A catalyst is a substance that changes the rate of a chemical reaction without itself being consumed or changed in the reaction

## Functional purpose is to improve...

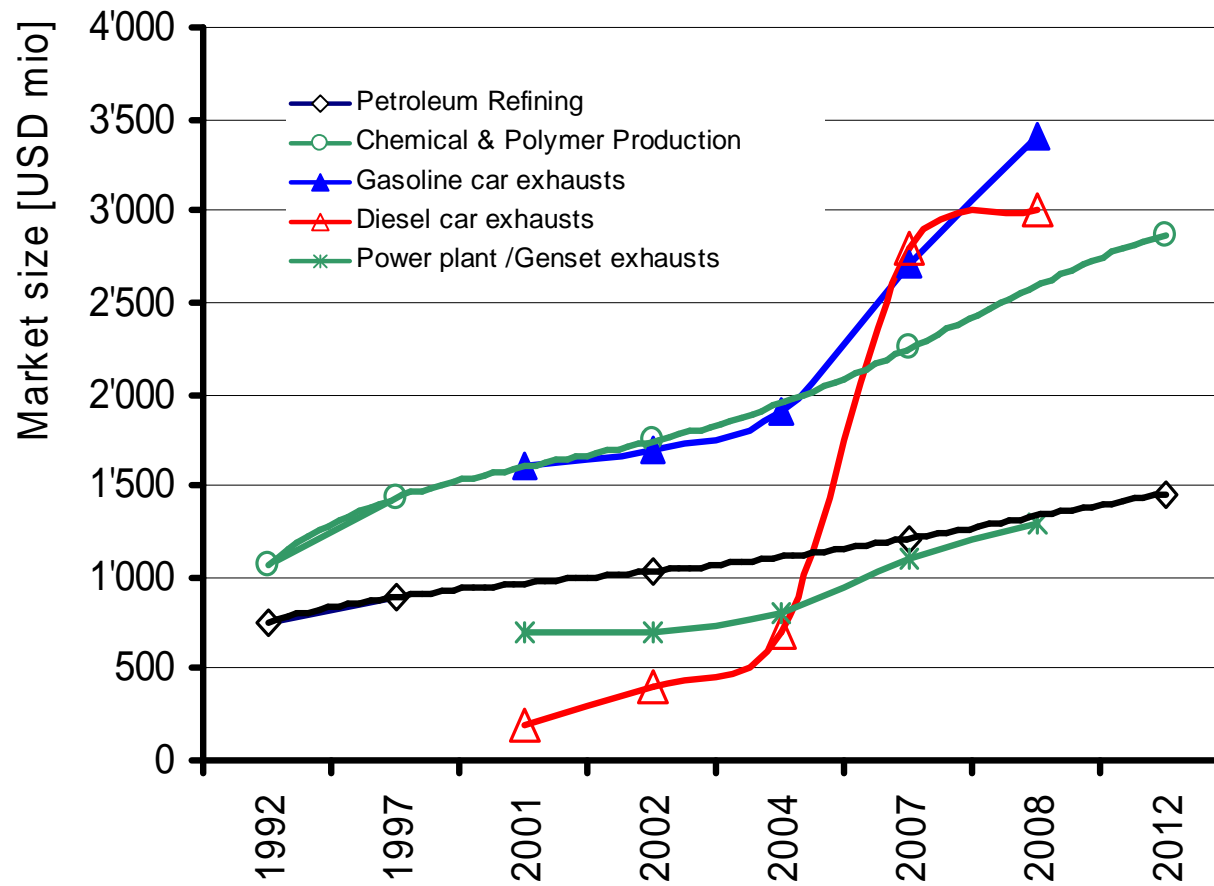
- Throughput
- Yield
- Selectivity
- Stability
- Cost



# A simplistic snapshot of the carbon catalysis universe



# Catalyst Market Size



Catalyst Group (2003); Freedonia Group (2003)



## Catalytic Market Share:

**Smalltech  
Catalysts ?**

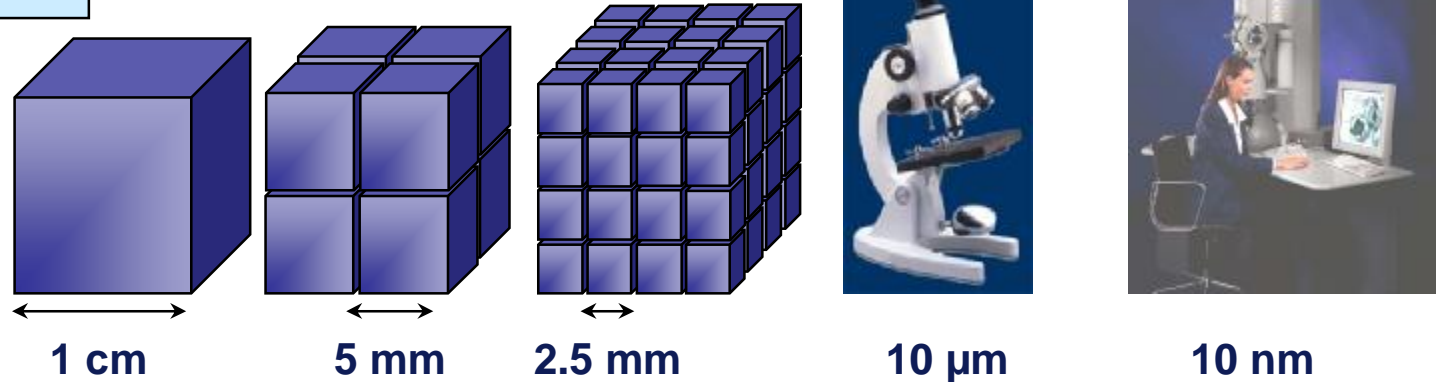
**Heterogenous  
Catalysts  
(Bulk &  
Supported)**

**Homogeneous  
Catalysts  
(acid/base,  
transition  
metals)**



# Efficient materials use: a case for small-tech

Metal	Cost per cm <sup>3</sup> (USD)
Rhodium	\$800
Platinum	\$610
Gold	\$400



Particle size:

1 cm

5 mm

2.5 mm

10 μm

10 nm

Total Volume:

1 cm<sup>3</sup>

1 cm<sup>3</sup>

1 cm<sup>3</sup>

● ● ●

1 cm<sup>3</sup>

1 cm<sup>3</sup>

Total Surface Area:

6 cm<sup>2</sup>

12 cm<sup>2</sup>

24 cm<sup>2</sup>

6 000 cm<sup>2</sup>

6 000 000 cm<sup>2</sup>

Rhodium cost  
per cm<sup>2</sup> (\$ US):

130

70

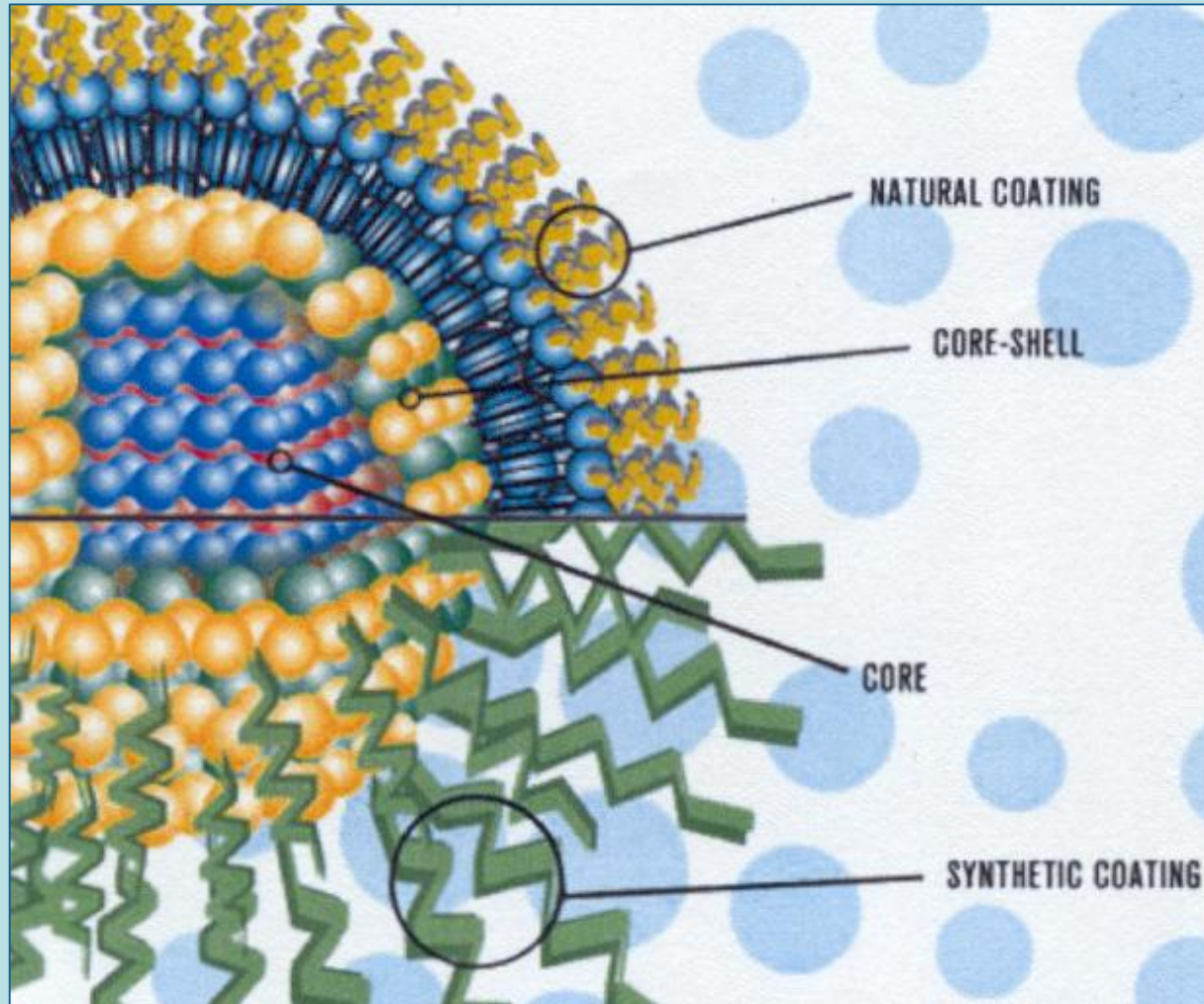
30

0.13

0.0001



# Multifunctional core-shell nanoparticles



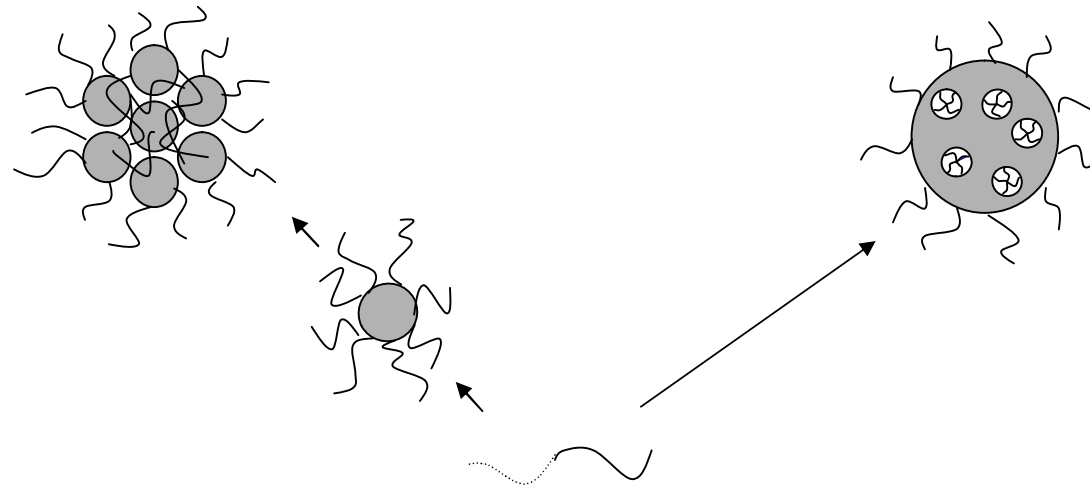
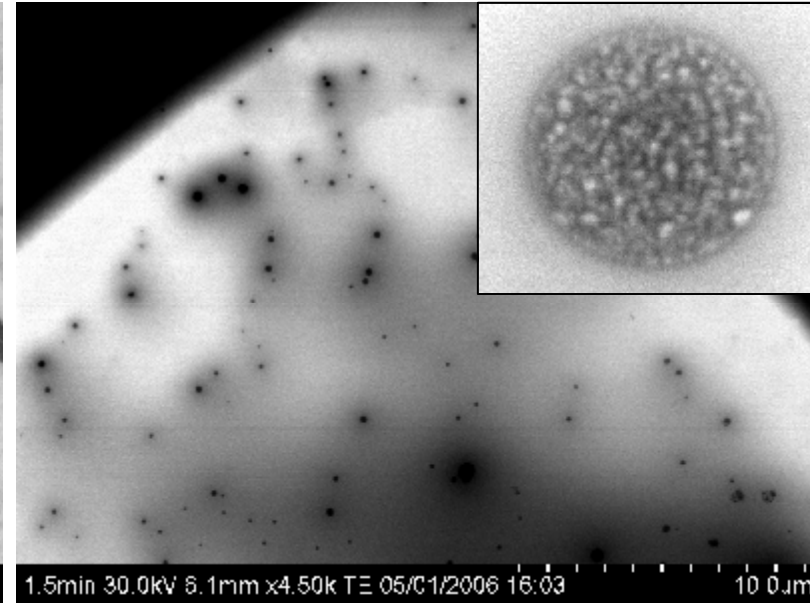
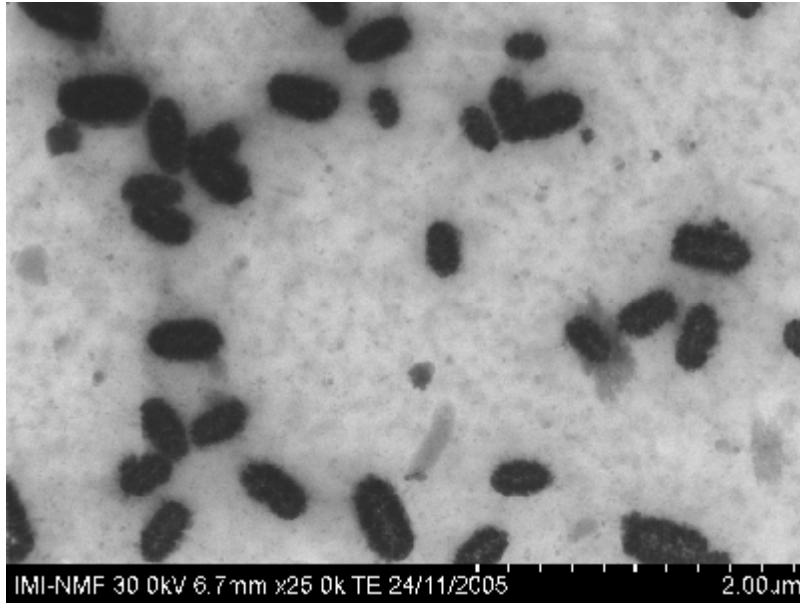
K. Heyman, *The Scientist* 2005 (19:9), 35; & [www.evidenttech.com](http://www.evidenttech.com)



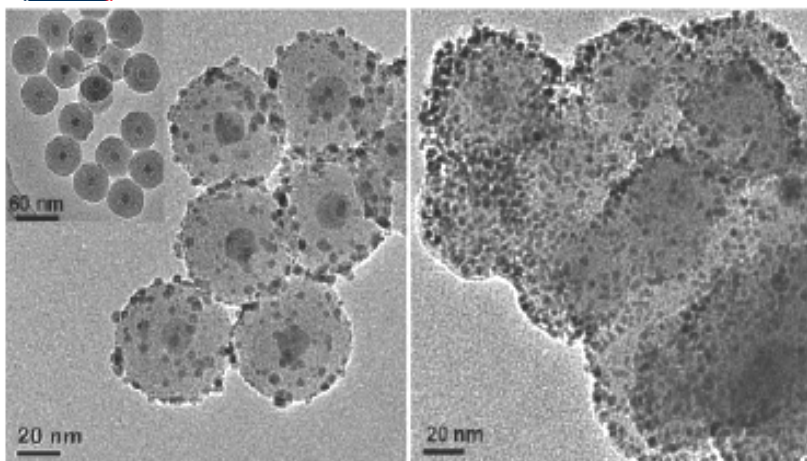
# Organoferrite response to an applied field



# Potential Catalyst Supports

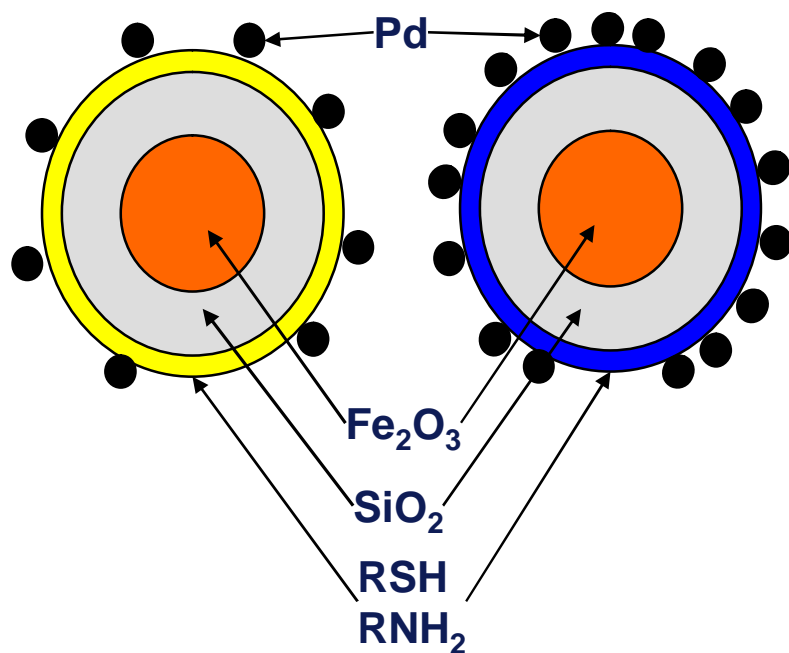


# Efficient materials use: very recent developments



Yi *et al*, *Chem. Mater.* 2006, 2459-2461.

- One of top three articles downloaded from *Chemistry of materials* last quarter
- Supported catalysis on nanostructured material
- *Best of both worlds approach: homogeneous catalyst integration with magnetic separation and recovery.*
- Moderate control over catalyst density
- Flexibility in catalyst component





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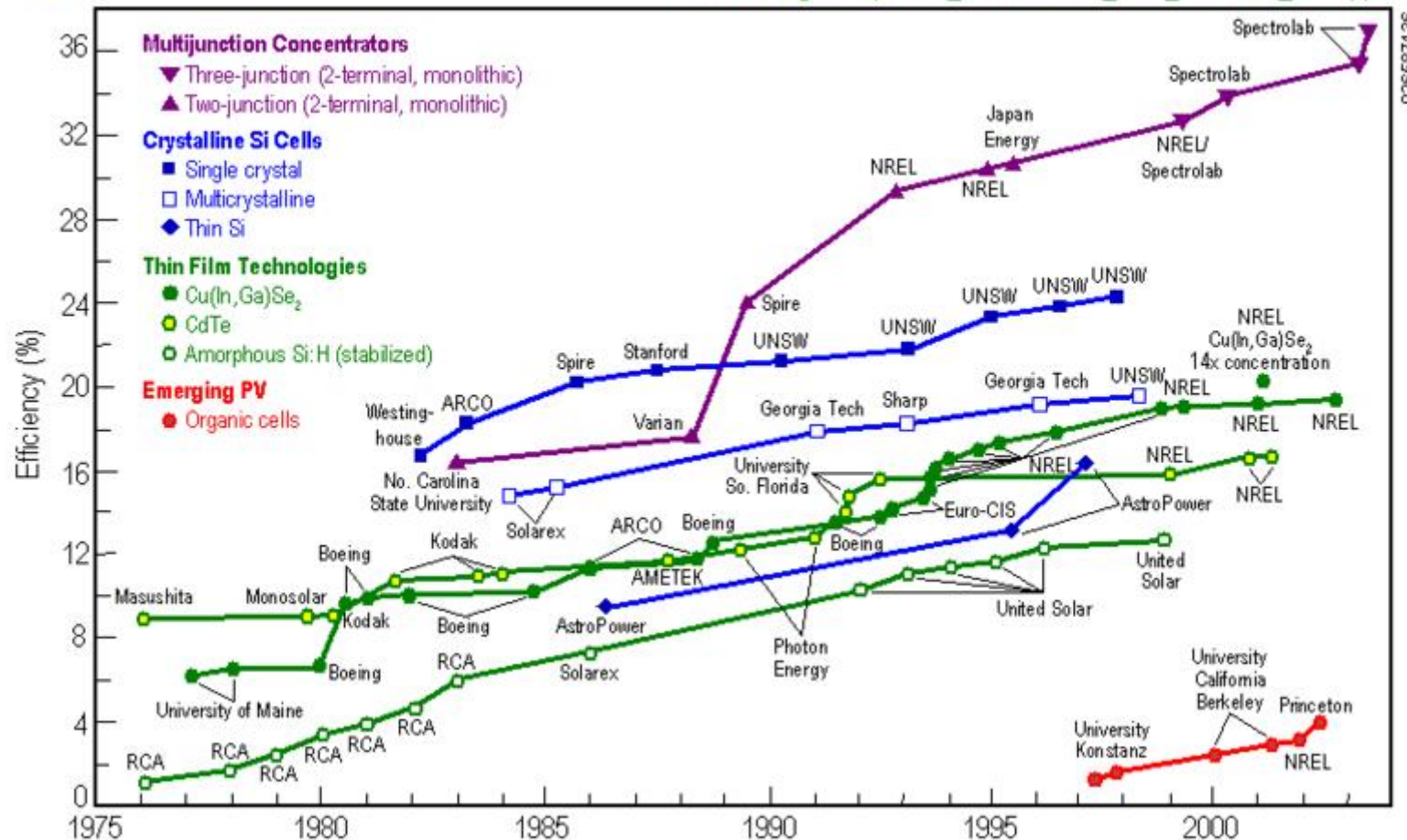


# Survey of Cell Efficiency

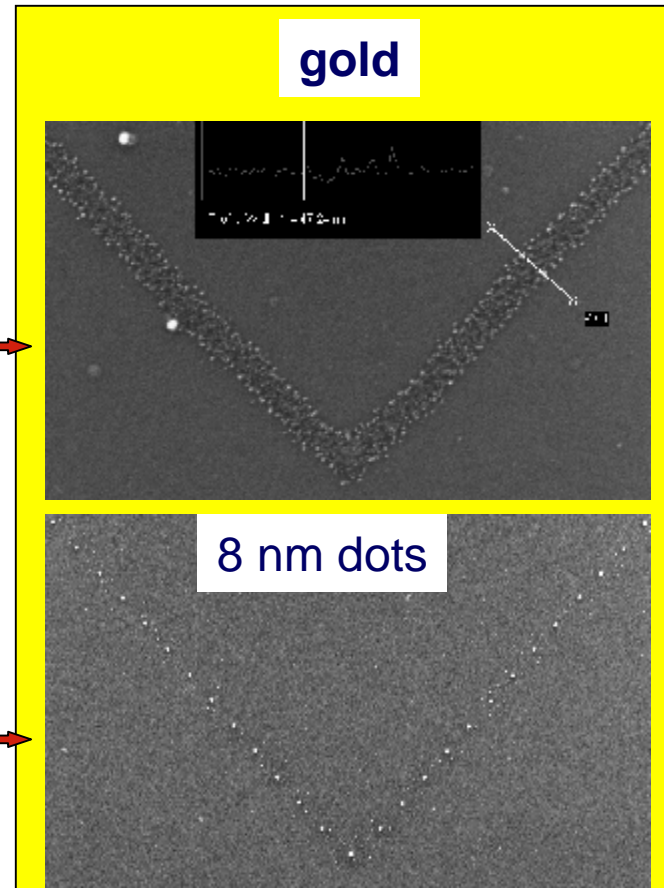
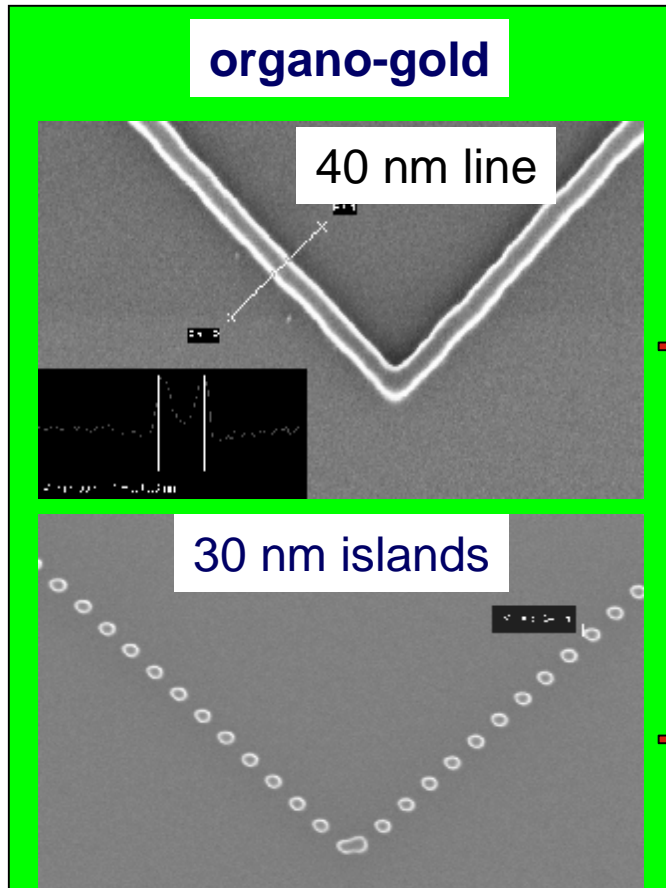
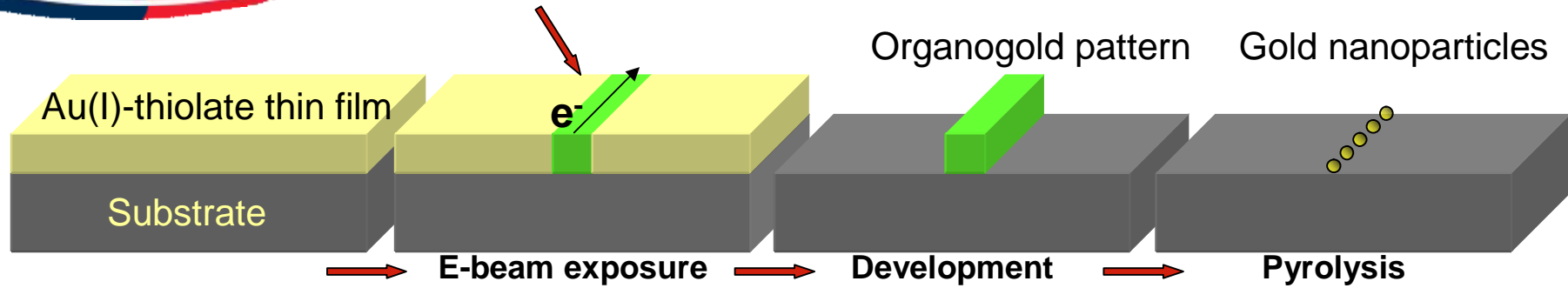


## Best Research-Cell Efficiencies

[www.nrel.gov/ncpv/thin\\_film/docs/kaz\\_best\\_research\\_cells.ppt](http://www.nrel.gov/ncpv/thin_film/docs/kaz_best_research_cells.ppt)



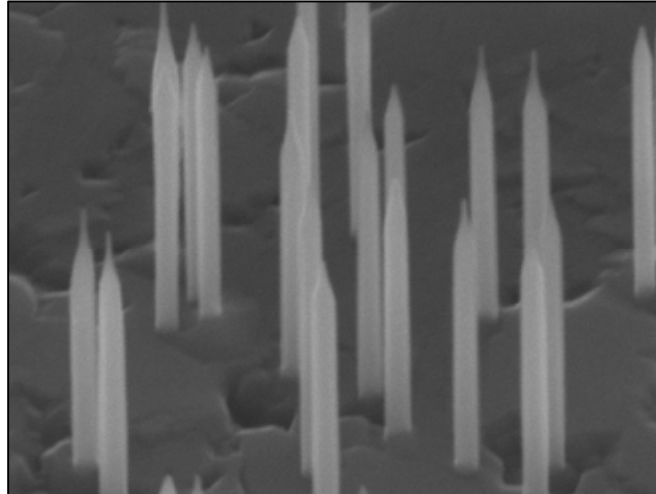
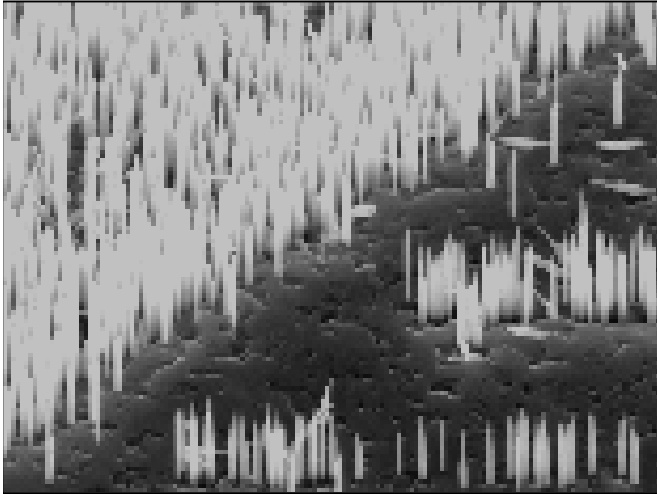
# Top-down fabrication



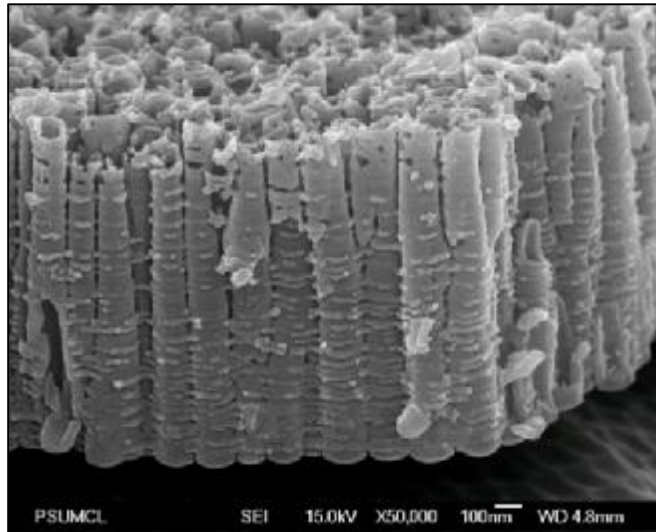
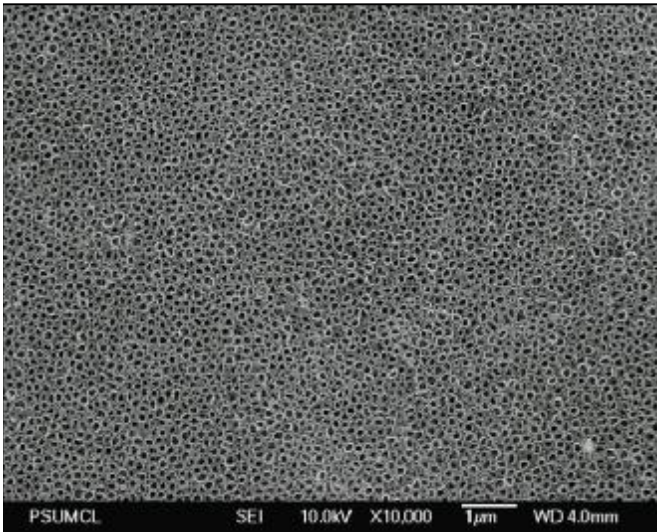
M. K. Corbierre, J. Beerens, J. Beauvais, and R. B. Lennox. *Chem. Mater.* **2006**, *18*, 2628-31.



# Cute results but where's the energy application?



GaAs nanowires:  
Corbierre & Lennox  
(McGill), Beerens &  
Beauvais (Sherbrooke)  
with Plante & LaPierre  
(MacMaster)



Metal-oxide nanotubes:  
Nikhil Koratkar *et al.*  
(Rensselaer)





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## So what does smalltech offer?

- Miniaturization of energy applications
  - fuel cells or PV for portable energy
- Maximization of material use
  - catalysis

### Smalltech Energy Ventures?

	2005 (Q1-Q4) mio, USD	2006 (Q1-Q2) Mio, USD
Clean Energytech (USA)	285	445
Clean Energytech (N. England)	14	88

**MONEY FLOWING TO NEW IDEAS IN ENERGY**

By Robert Weisman, *The Boston Globe*, September 1, 2006





# Merci!

FNM Group, especially Drs. Geissler & Ledrogoff (NRC-IMI)  
Dr. K. Robertson & Prof. T.S. Cameron (Dalhousie University)  
Prof. R.B. Lennox, Dr. Muriel Corbierre (McGill University)  
Prof. J. Beauvais, Dr. J. Beerens (Sherbrooke University)

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NSERC, FCAR, McConnell Foundation

CRTI

Genome Canada

...and thank **you** for your attention!

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