NANOMATERIALS FOR ENERGY APPLICATIONS

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Nov. 9, 2013

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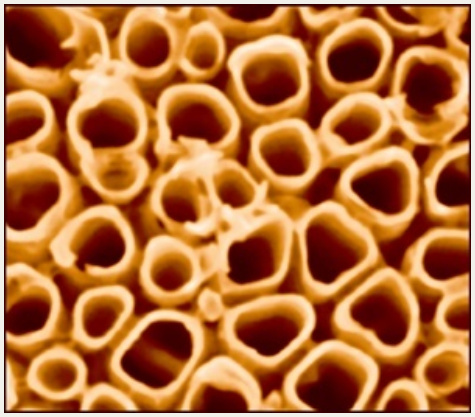
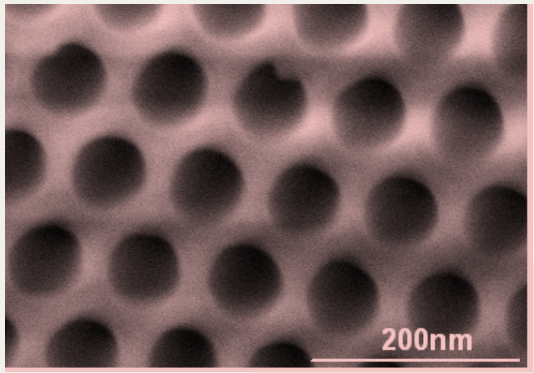
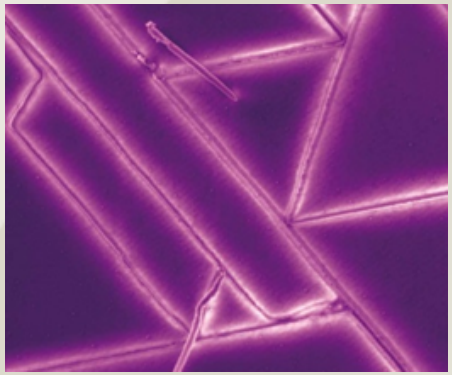


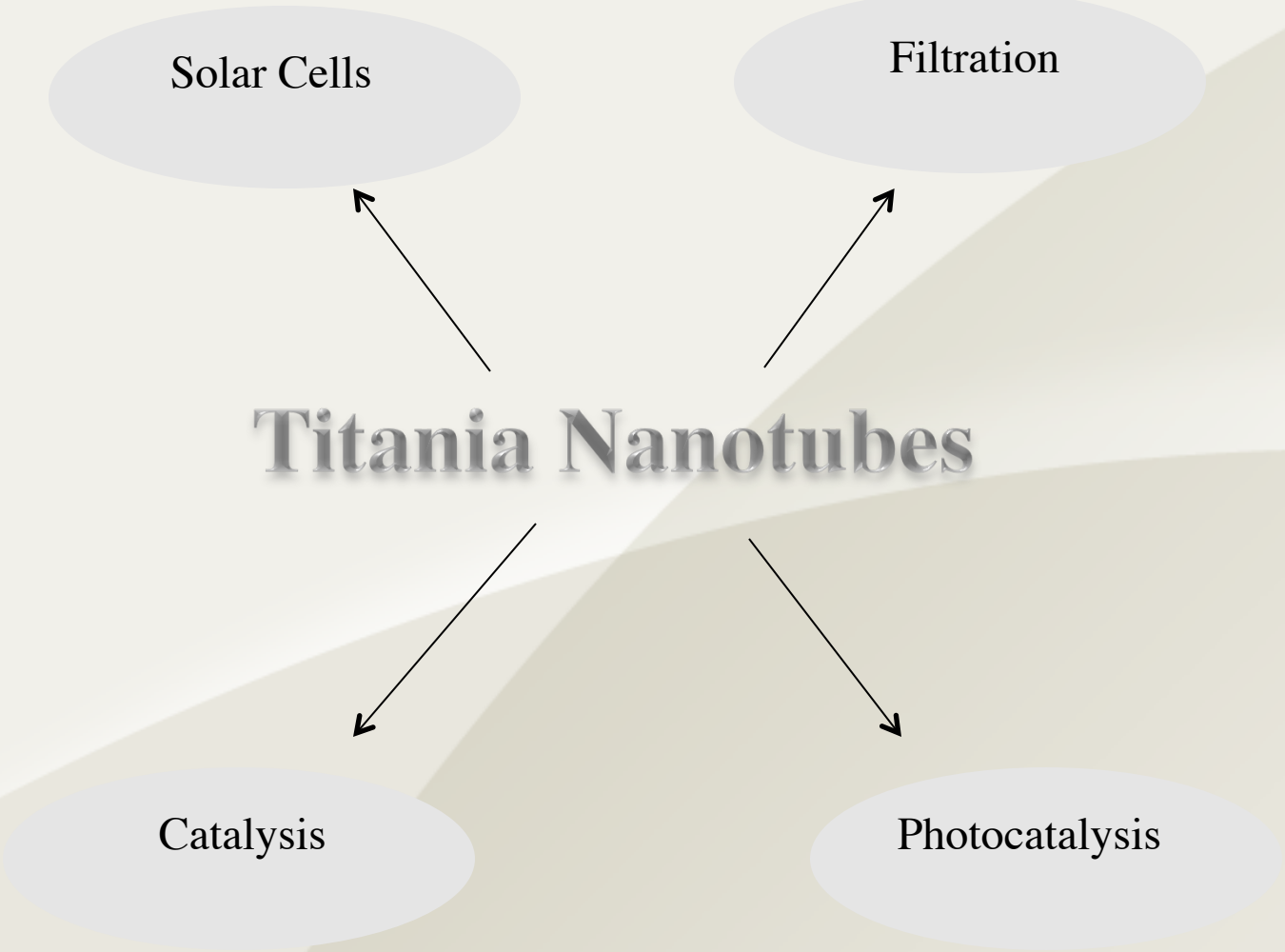
Titania Nanotubes

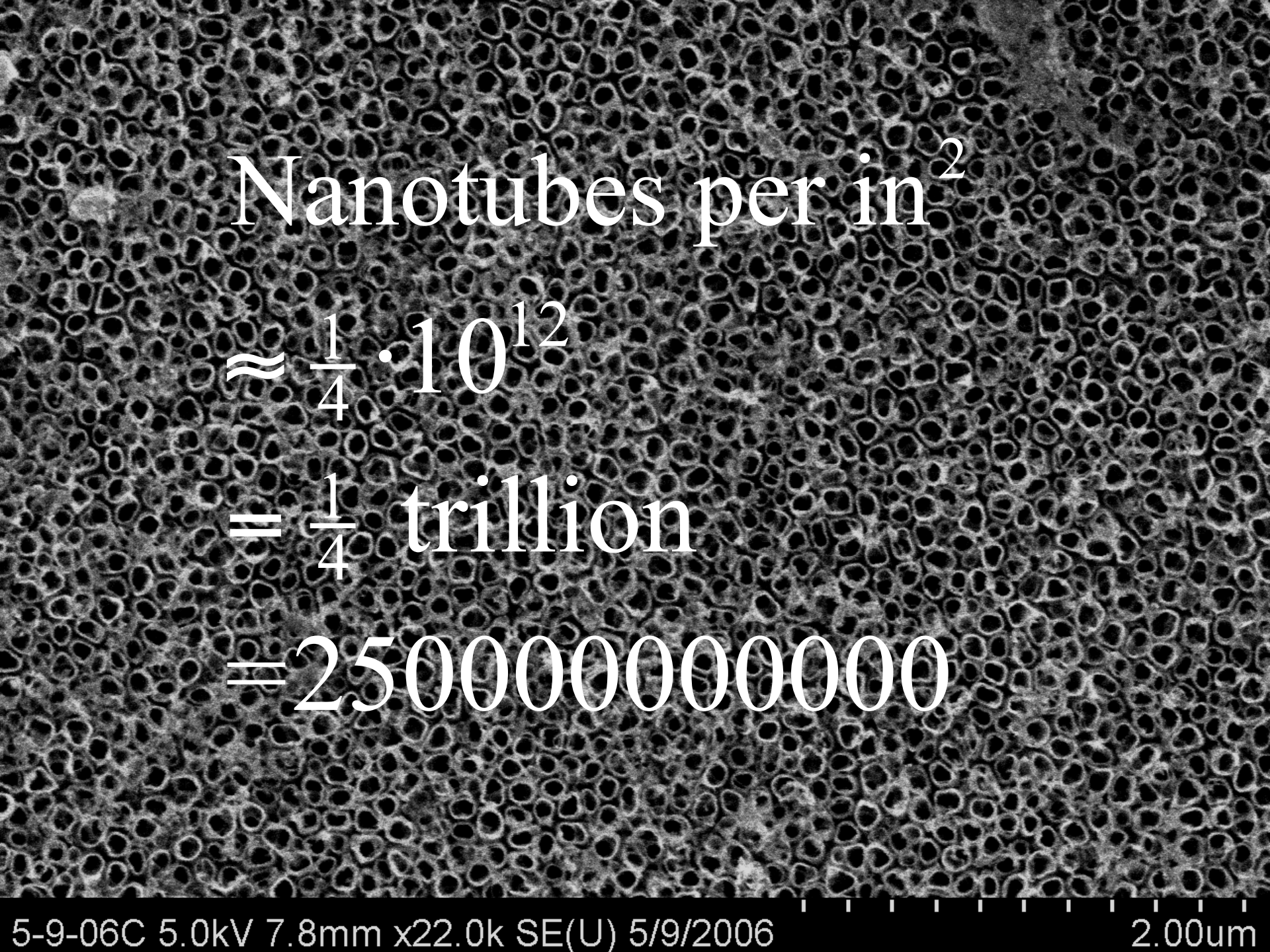


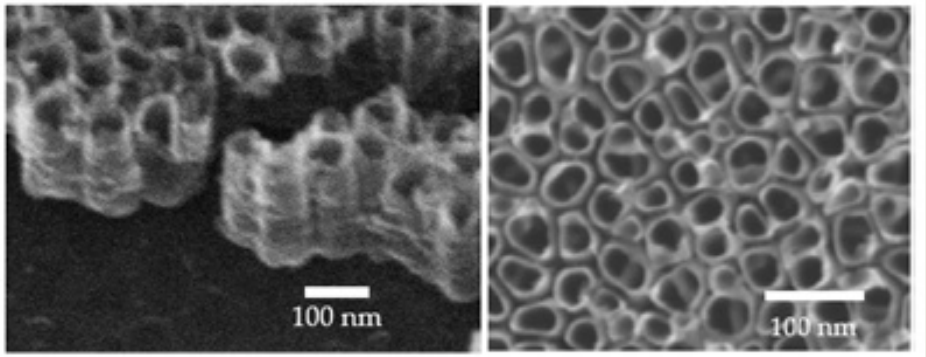
Nanoporous Alumina



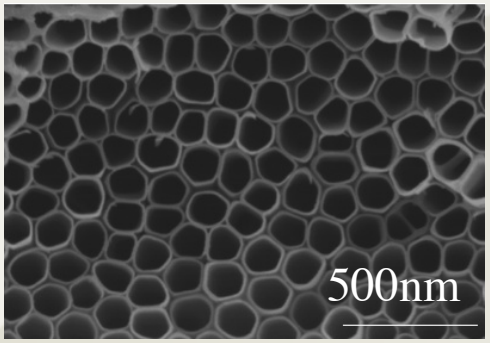
GaN Nanowires

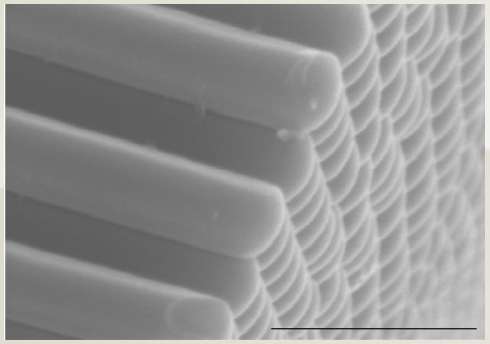

Solar Cells
Filtration
Titania Nanotubes
Catalysis
Photocatalysis


Nanotubes per in^2
$\approx \frac{1}{4} \cdot 10^{12}$
$= \frac{1}{4}$ trillion
$=250000000000$
5-9-06C 5.0kV 7.8mm x22.0k SE(U) 5/9/2006
2.00um

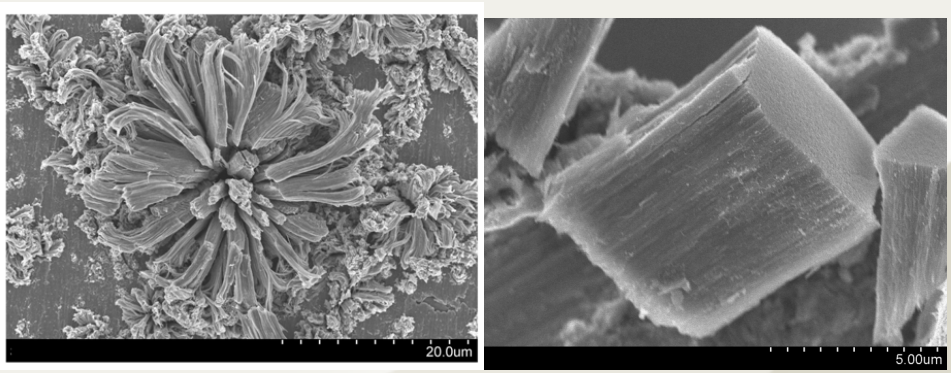


Short Nanotubes





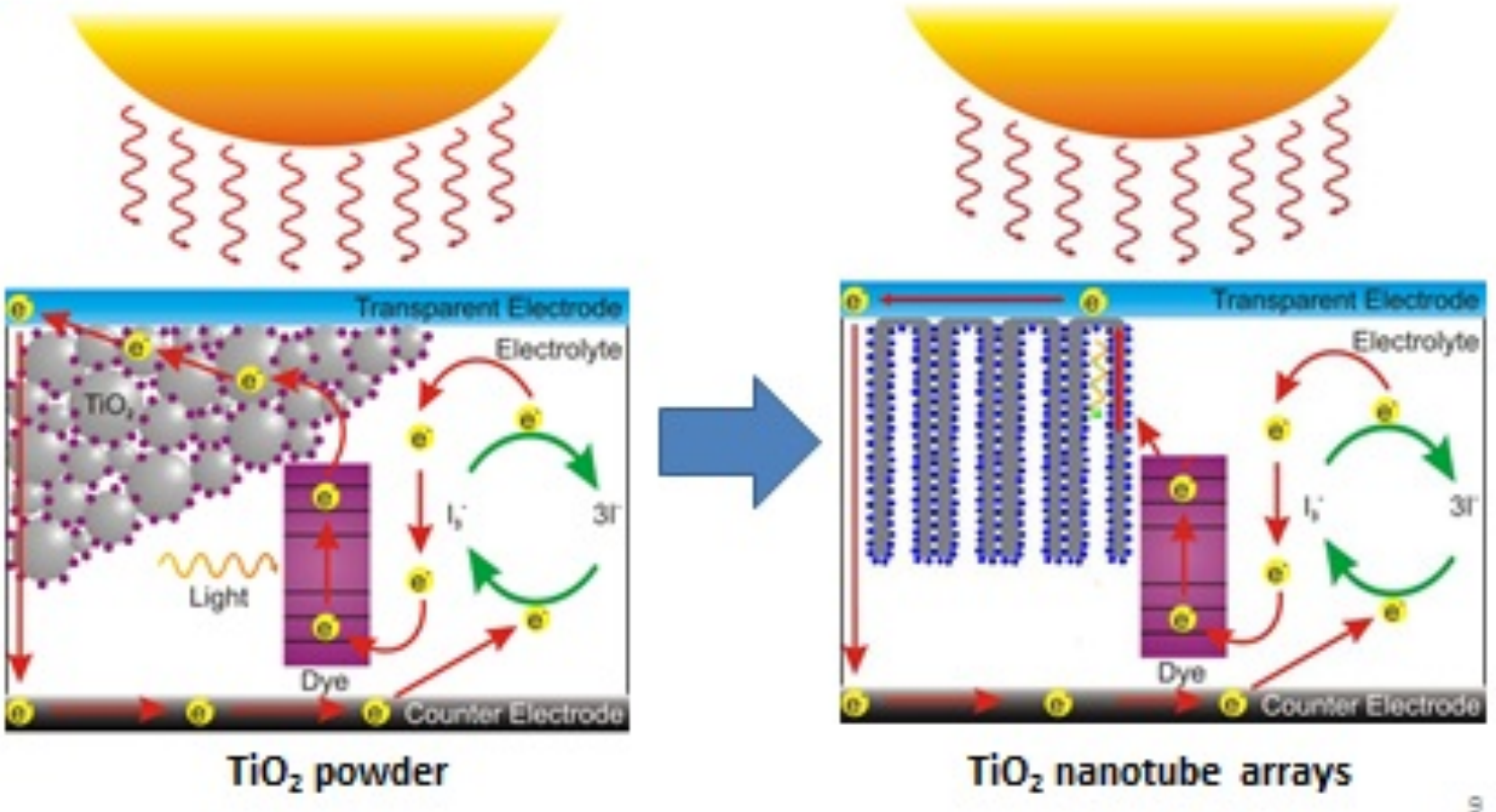
Quasi-Periodic Arrays



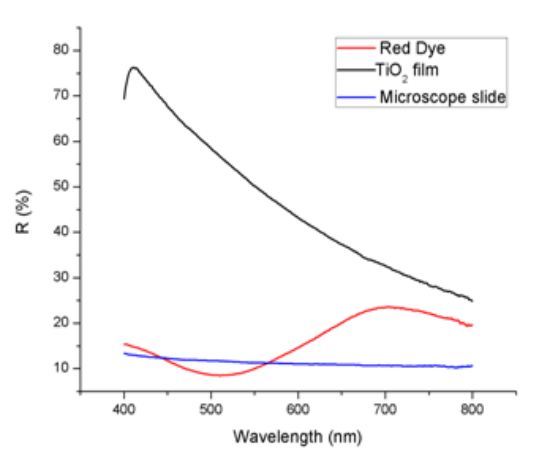
Ultra-high Aspect ratio tubes

Advanced Materials, 19, 946 (2007); JMR, 22, 1624 (2007); JES, 155, E7 (2008);

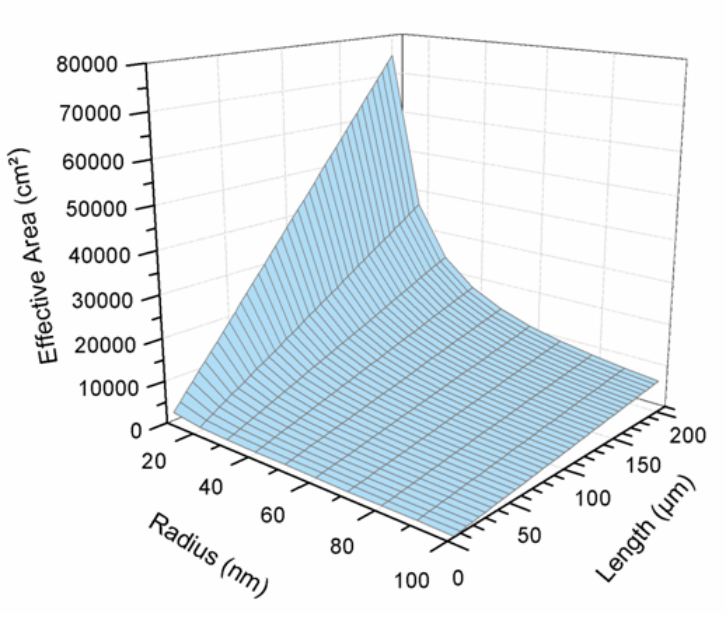
Patent# 20100024879



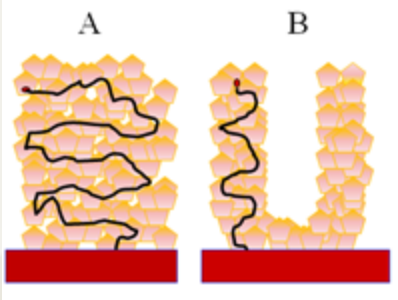
Dye-Sensitized Solar Cells



Increased light absorption

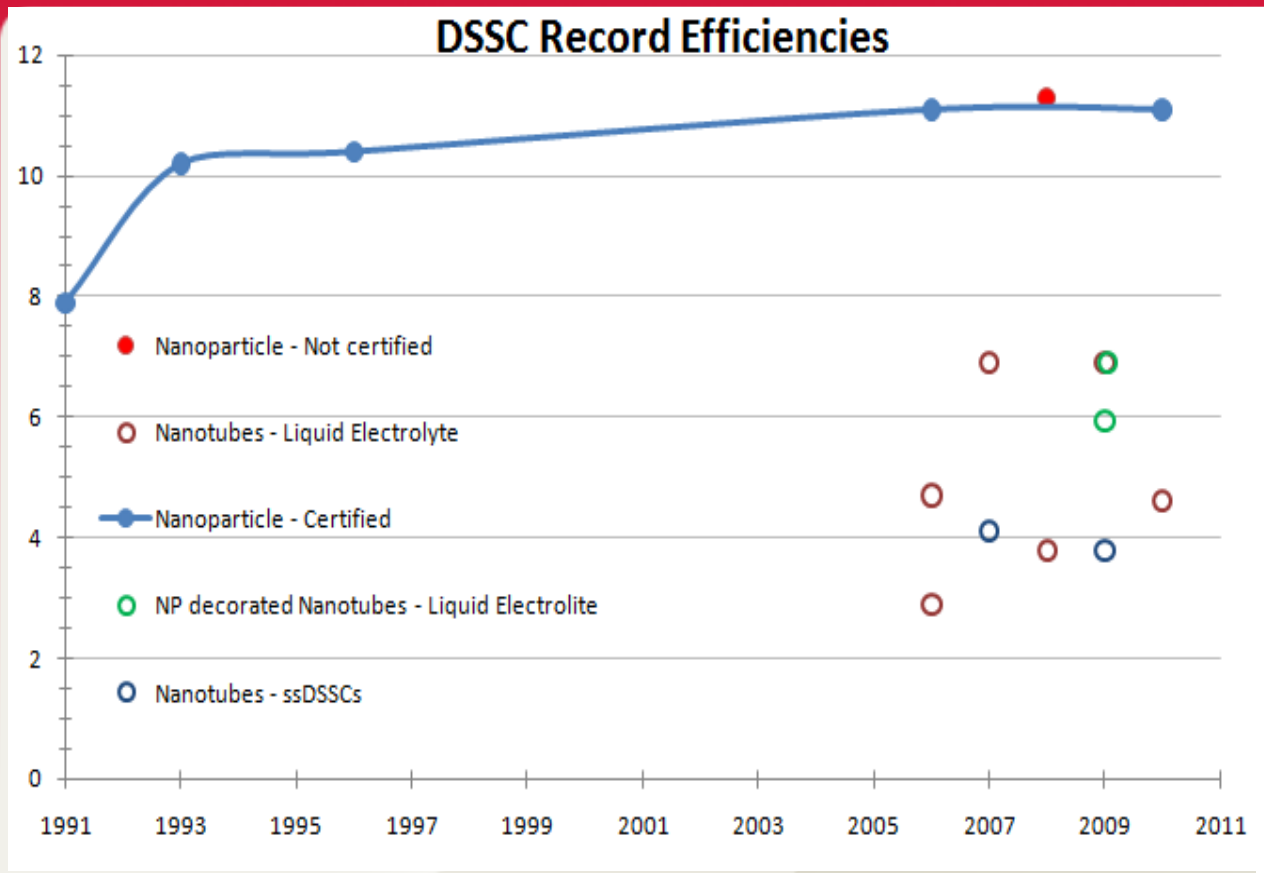


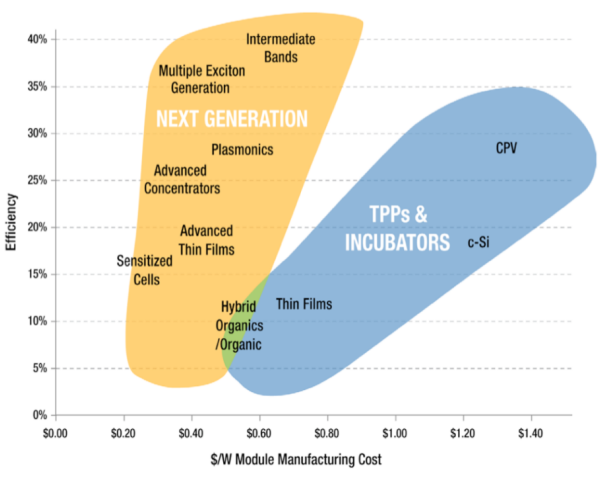
Increased surface area



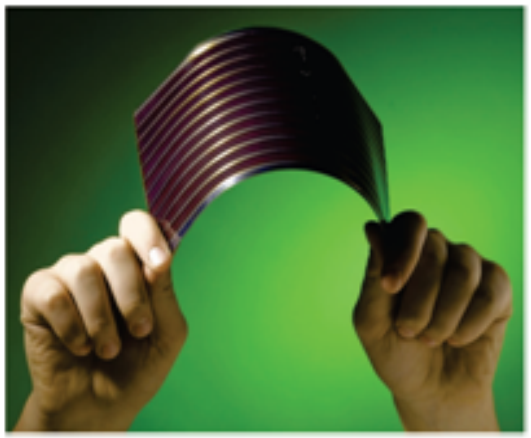
Lower resistance to carrier flow

Better Photoanodes


DSSC Record Efficiencies
12
10
8
6
4
2
0
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
Nanoparticle - Not certified
Nanotubes - Liquid Electrolyte
Nanoparticle - Certified
NP decorated Nanotubes - Liquid Electrolite
Nanotubes - ssDSSCs

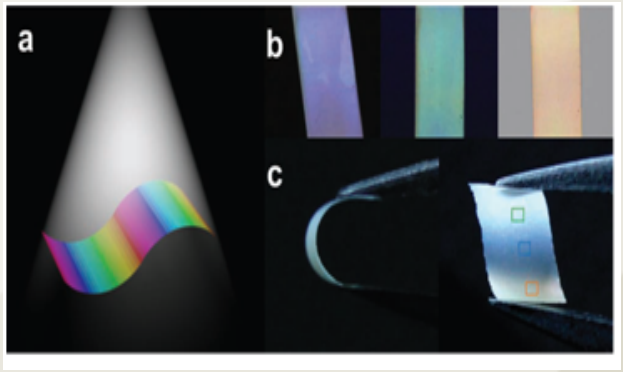

Efficiency
40%
35%
30%
25%
20%
15%
10%
5%
0%
$0.00
$0.20
$0.40
$0.60
$0.80
$1.00
$1.20
$1.40
$/W Module Manufacturing Cost
Intermediate Bands
Multiple Exciton Generation
NEXT GENERATION
Plasmonics
Advanced Concentrators
Advanced Thin Films
Sensitized Cells
Hybrid Organics /Organic
Thin Films
TPPs & INCUBATORS
CPV
c-Si

DOE

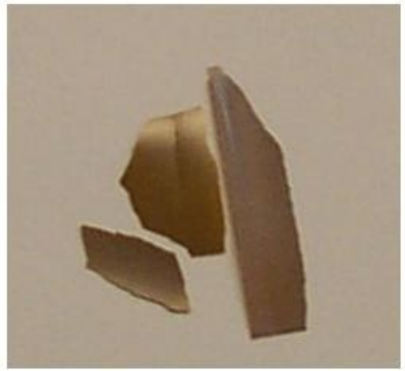


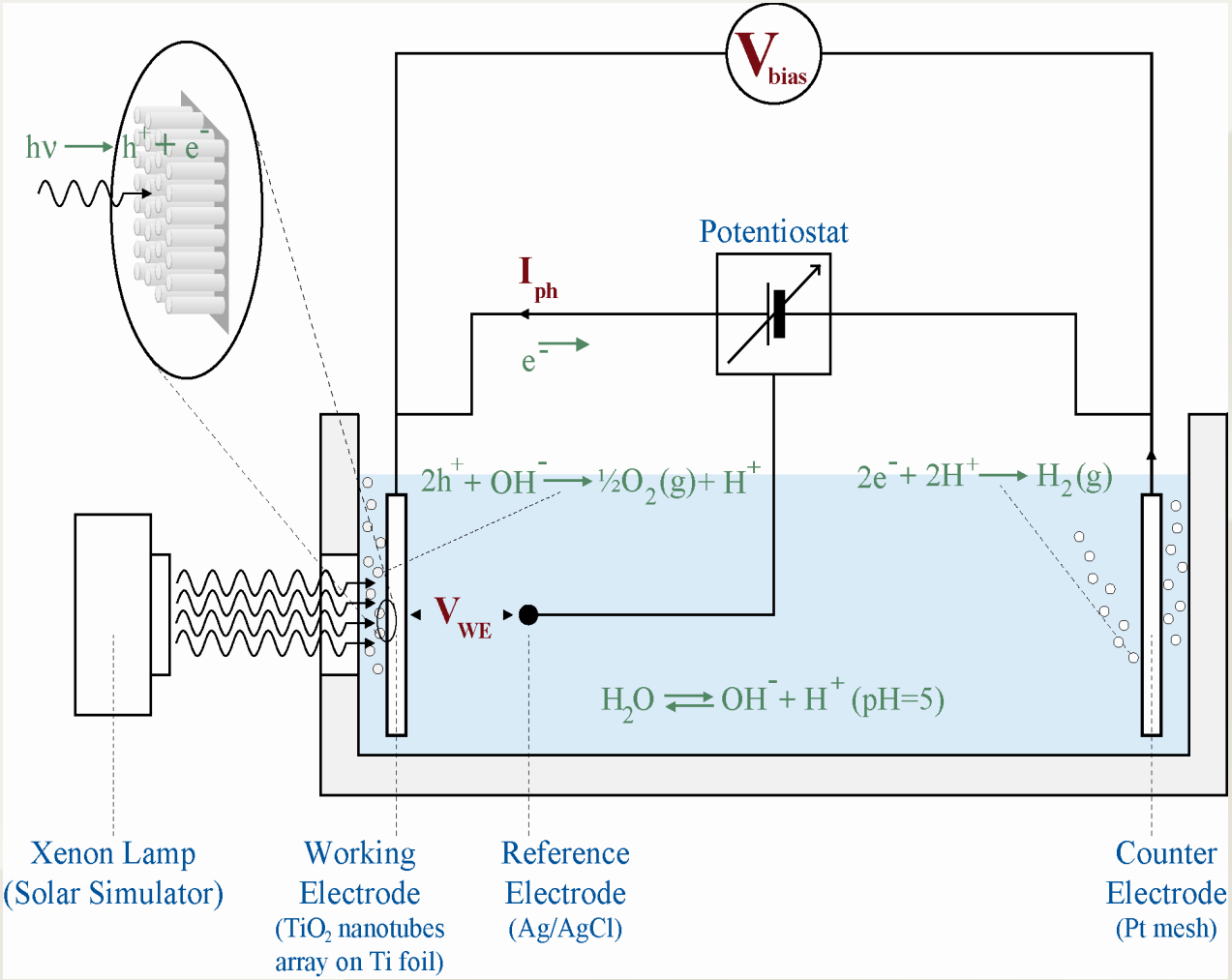
Flexible

AIPV/BIPV

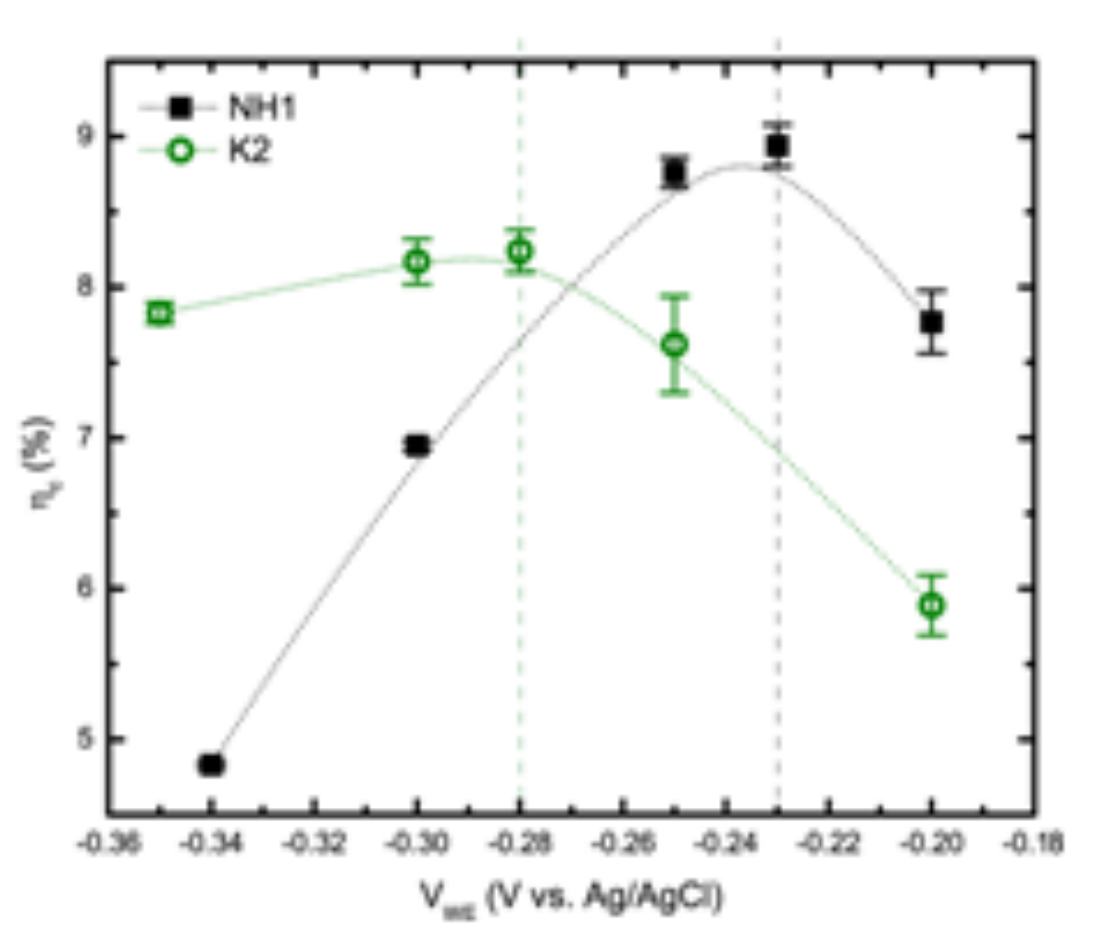


Lin et al. Small, 2011

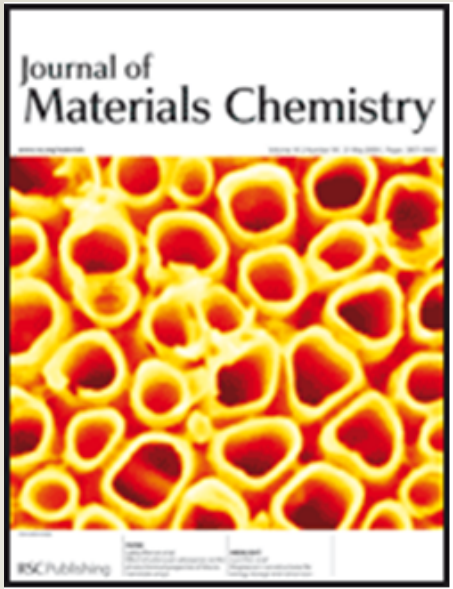




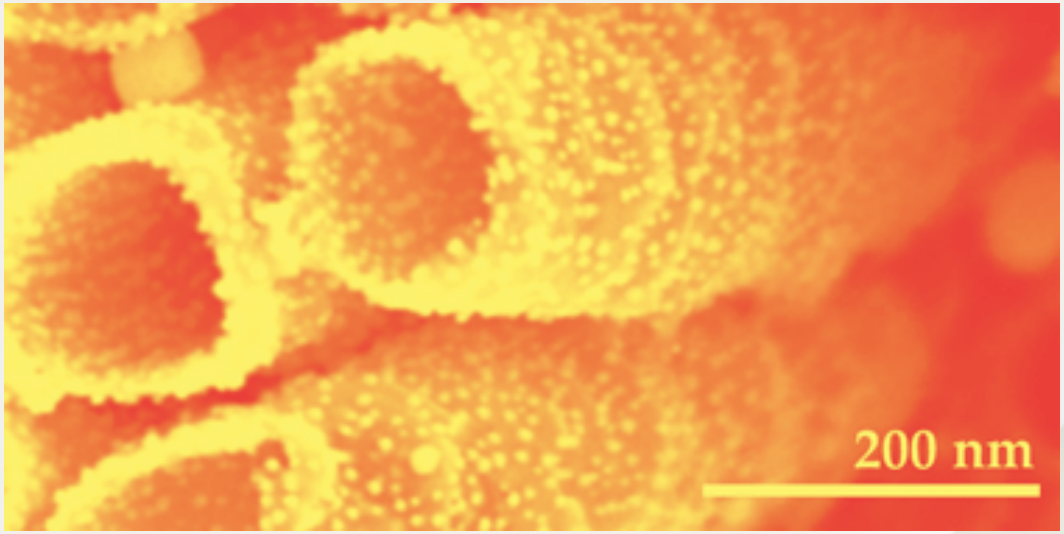
Photocatalytic Anodes for H_2 Generation

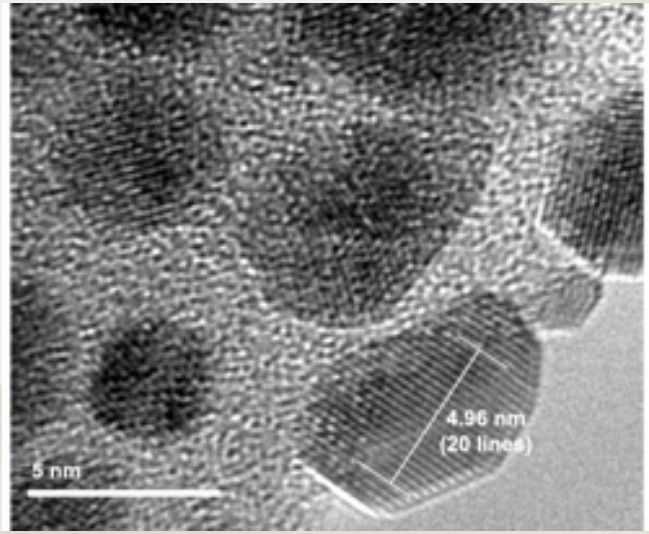


$$\eta_c = \frac{I_{ph}\left(1.23\text{V} - V_{\text{bias}}\right)}{I_0}$$



Energy and Environmental Science, 2010, 3, 427



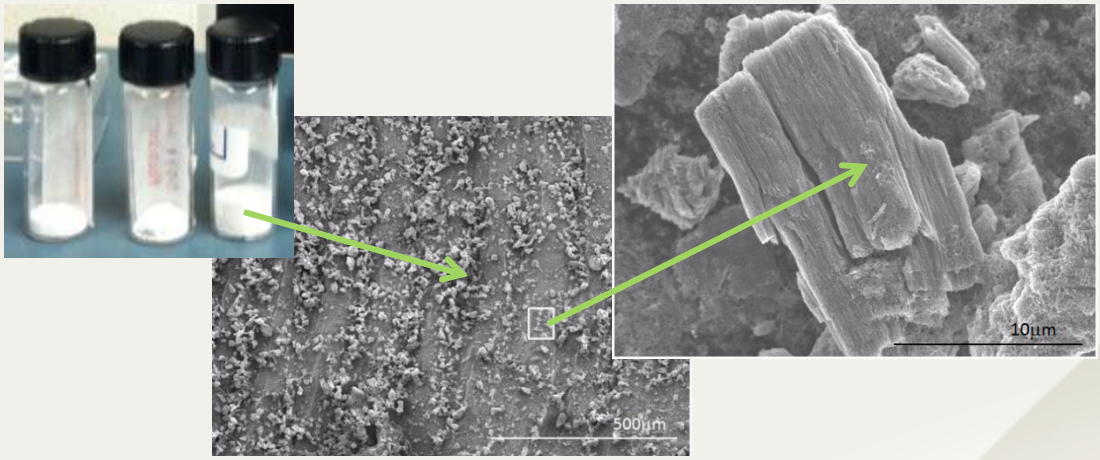


Au-nanoparticle attached Titania

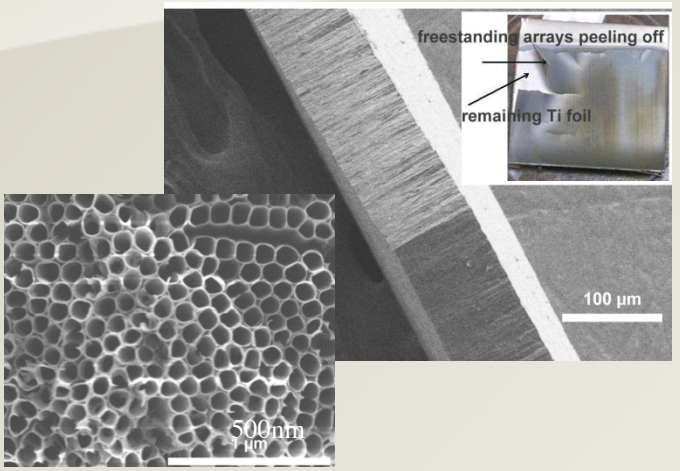
Catalysis

JMC, 19, 4483 (2009)

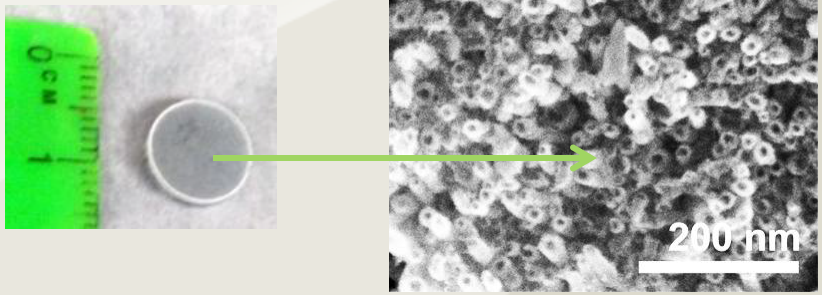
Nanotube Powders



Membranes



Filtration Pellets



Filtration Market: ~$8.9B (US 2010)

- Ultrafiltration Market: ~$1.2B
- Biological and Chemical Separation: ~$0.7B
- **Treatment of Produced Water: ~$0.86B**

Today's Needs for Clean Water:

- Shortage of Water Resources
- **Oil Contamination Due to Drilling and Fracking**
- Toxic Elements Removal (e.g. Arsenic)
- Antimicrobial Treatment

Produced Water Facts

- **15-20B Barrels/Year** in US (50B Worldwide)
- **Water-to-Oil Ratio** (WOR)
  7:1 US (3:1 Worldwide)
- Companies Pay **$3-$12/Barrel** of Produced Water

Filtration Industry Pain Points

High-Temperature Robustness

Non-Corrosive in Adverse pH Solutions

Less Susceptible to Fouling

Tight Size Control (<100nm)

Alleviate High Pressure Requirement

Our Material

Melting temperature: 1800°C

Strongly resistant in the 0-14 pH range

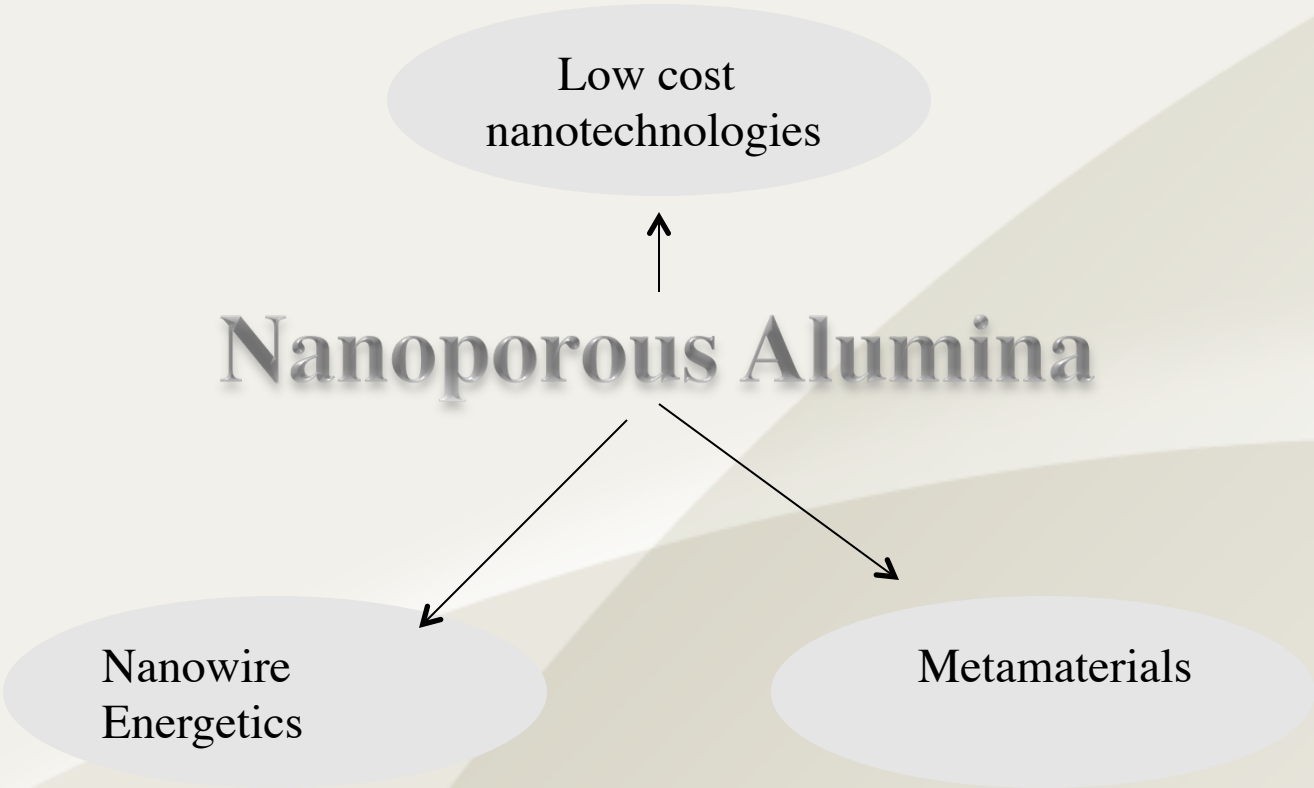
Capability for Selective Filtration

Tube diameter control down to 20 nm

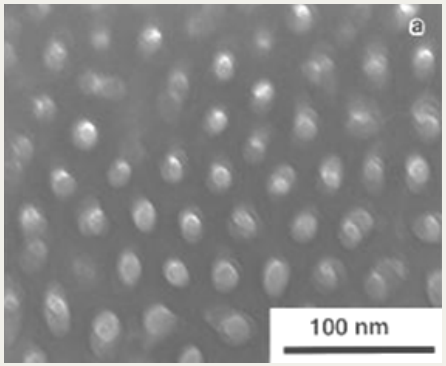
Naturally Porous Membrane (High Active Surface Area)

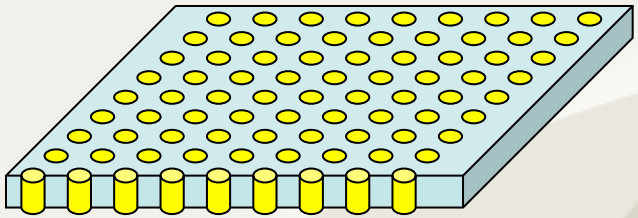
Very low production costs

	Commercial Silicon Carbide	Our Technology
Substrate Material	**SiC**	**No substrate**
Selective layer material	**SiC**	**TiO_2**
Porosity	**40%**	**60%, easy to control**
Permeability	High because of high porosity and hydrophilicity	High because of high porosity and hydrophilicity
Temperature Tolerance	Up to 800°C in atmospheric air	Melting point: 1800°C
Chemical resistance	Resistant in full pH range 0-14	Resistant in full pH range 0-14
Max Cl concentration	Unlimited	Most likely unlimited
Solvents	Completely Stable	Stable
Oxidizers	Any concentration	Already an oxide
Pore size	**0.04 – 3 µm**	**TBD (~ 0.1 µm)**
Flux Rate	**3 – 12 $m^3/(m^2h)$**	**1.2 $m^3/(m^2h)$**

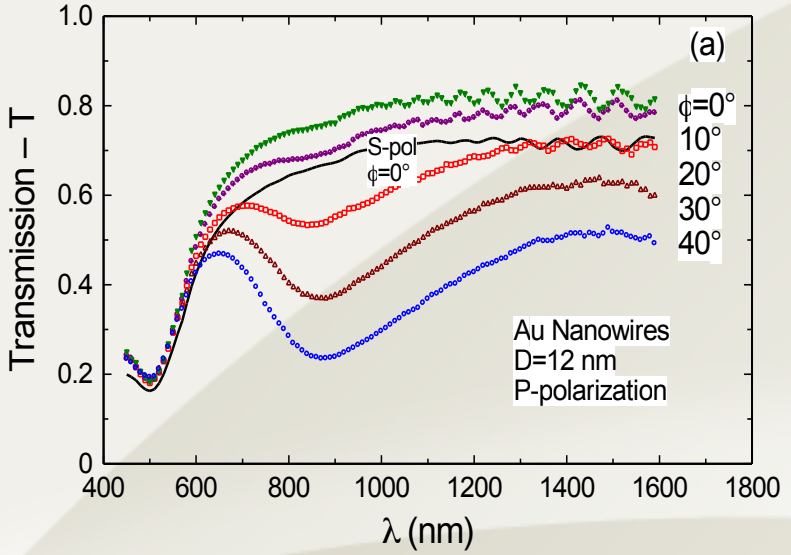

Low cost
nanotechnologies
Nanoporous Alumina
Nanowire
Energetics
Metamaterials

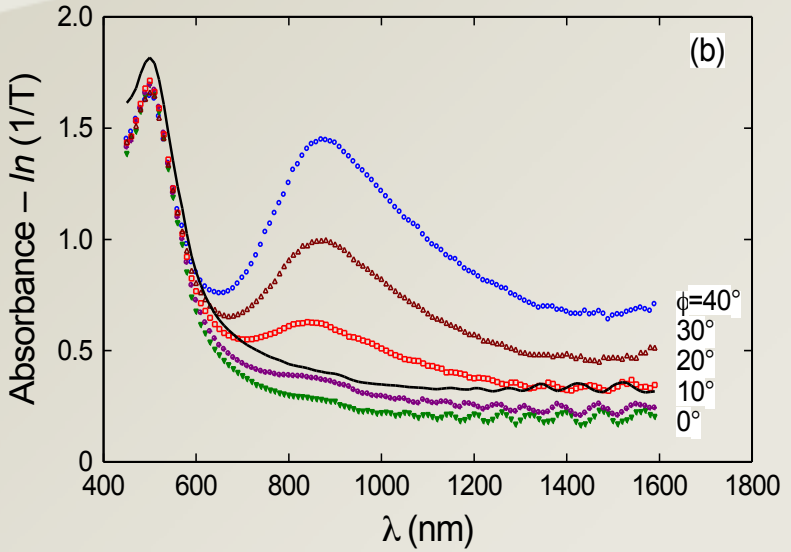
Metal-Dielectric Composites





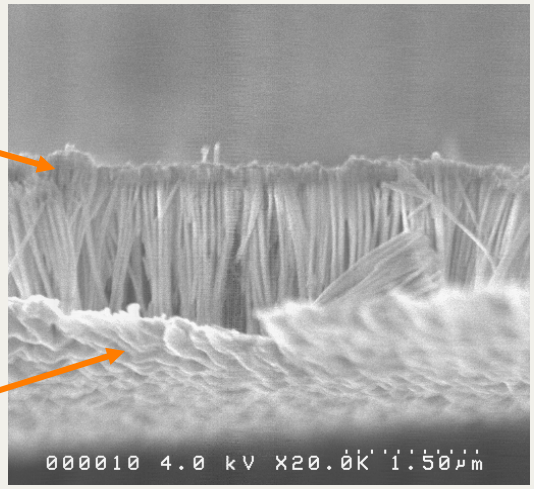
Improved Absorption Wavelength Selectivity



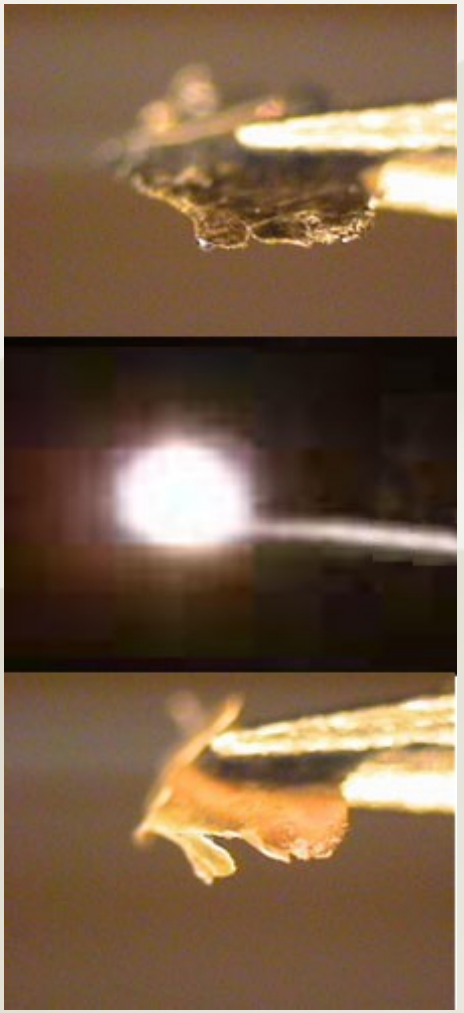


Optical Materials, 33, 1667 (2011); Applied Physics Letters, 93, 123117 (2008)

Fe_2O_3
Oxidizer



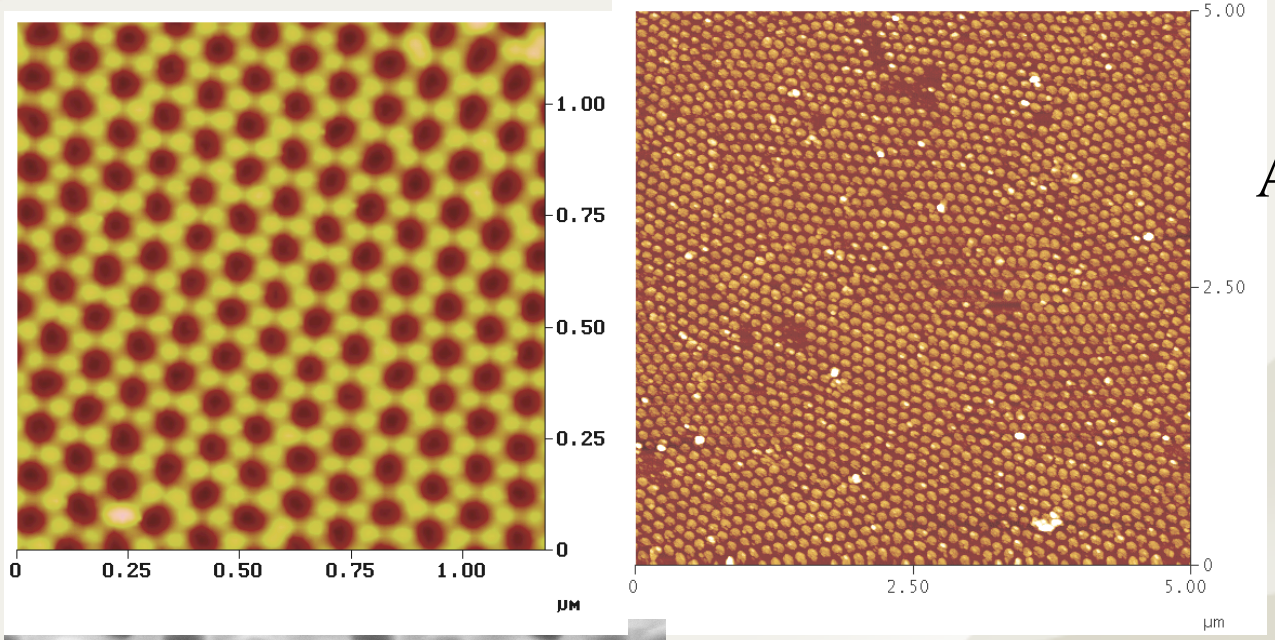
Al Fuel



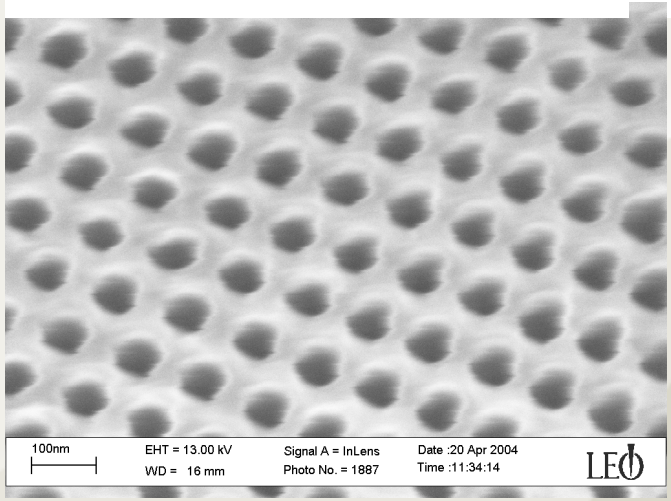
Ignition

Light-weight, single-use, MEMS-compatible energy sources

Applied Physics Letters 84, 4735 (2004)



Au Nanodots



Nanopores in Si

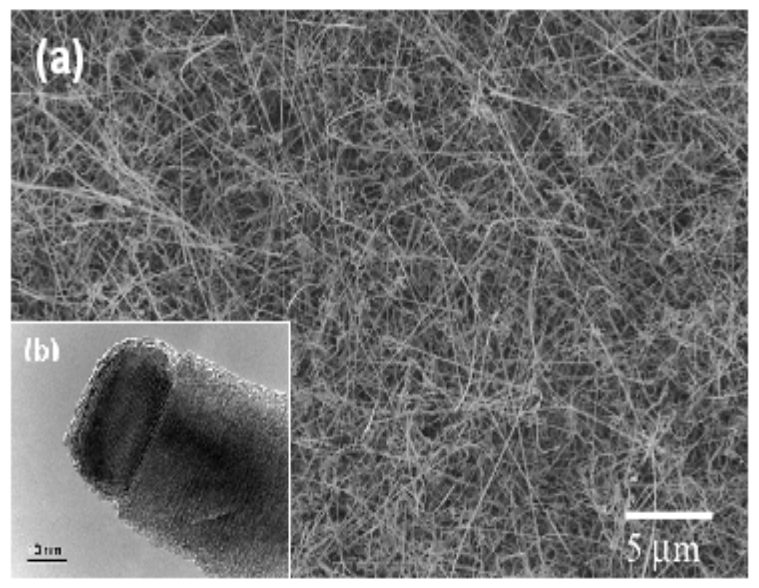
Low-Cost, Scalable Nanotechnology

JES, 151, C492 (2004)

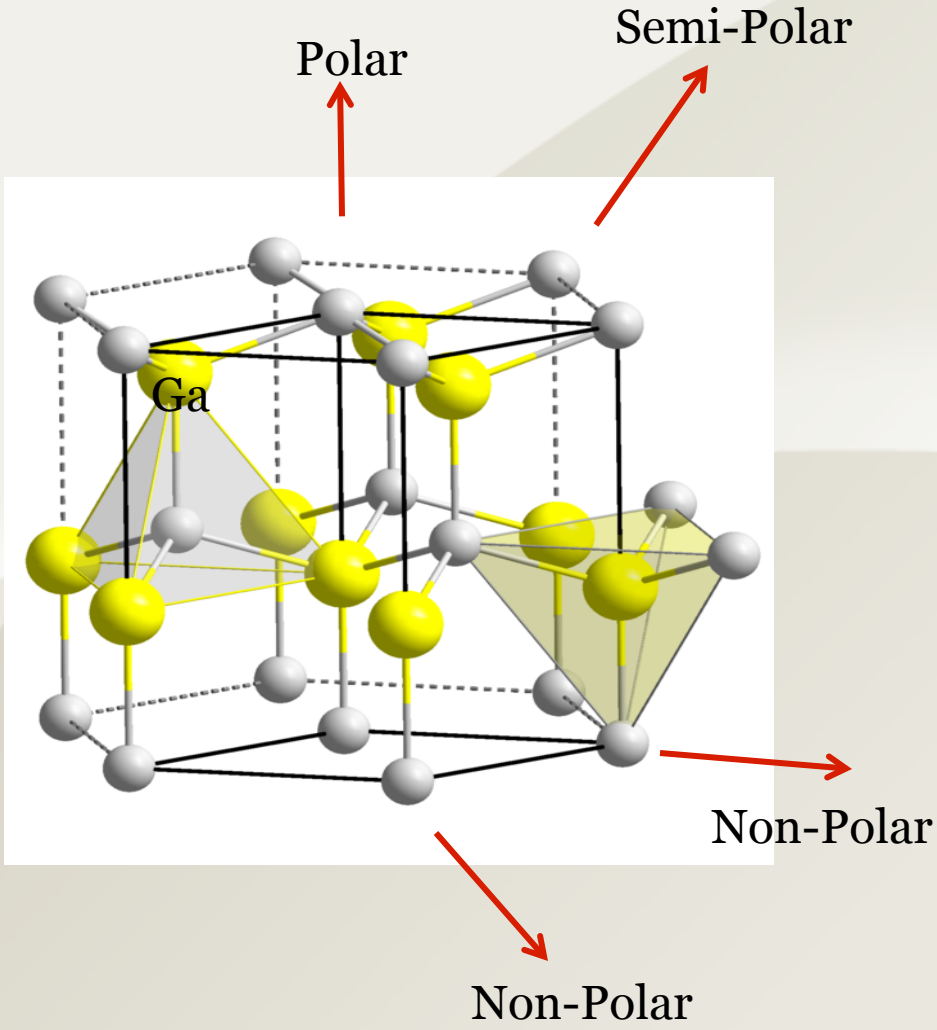
GaN Nanowires

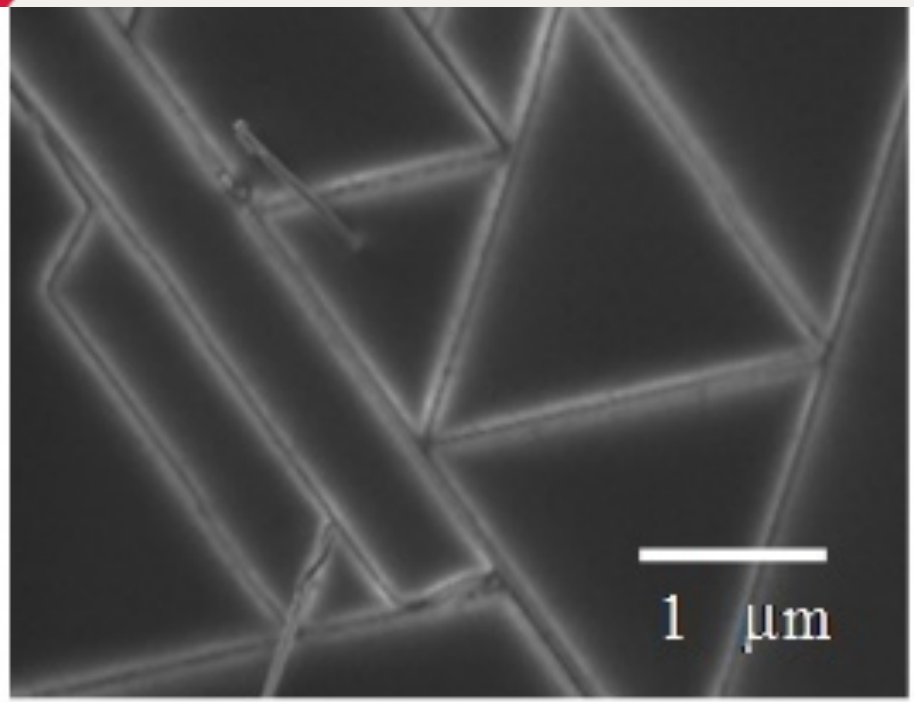
Multifunctional devices

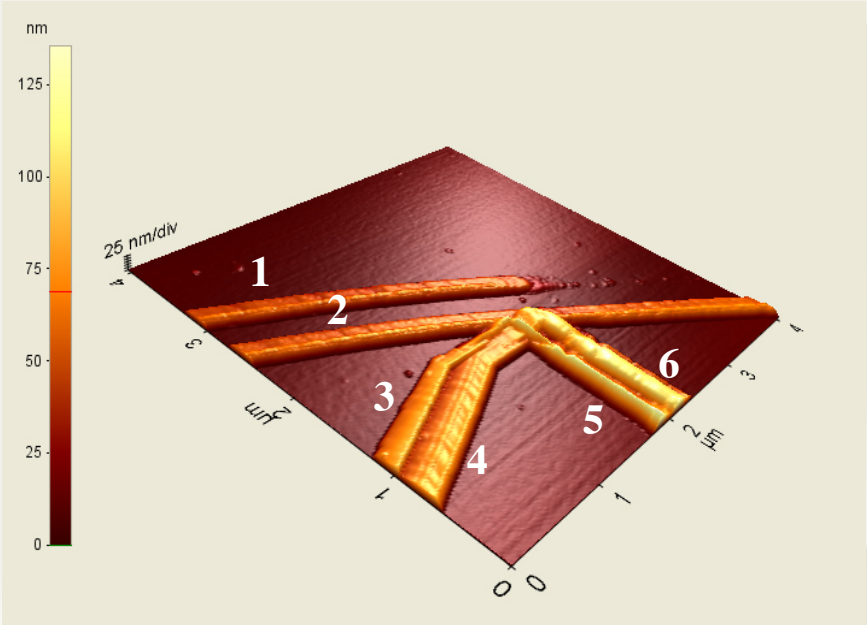
Solid State Lighting



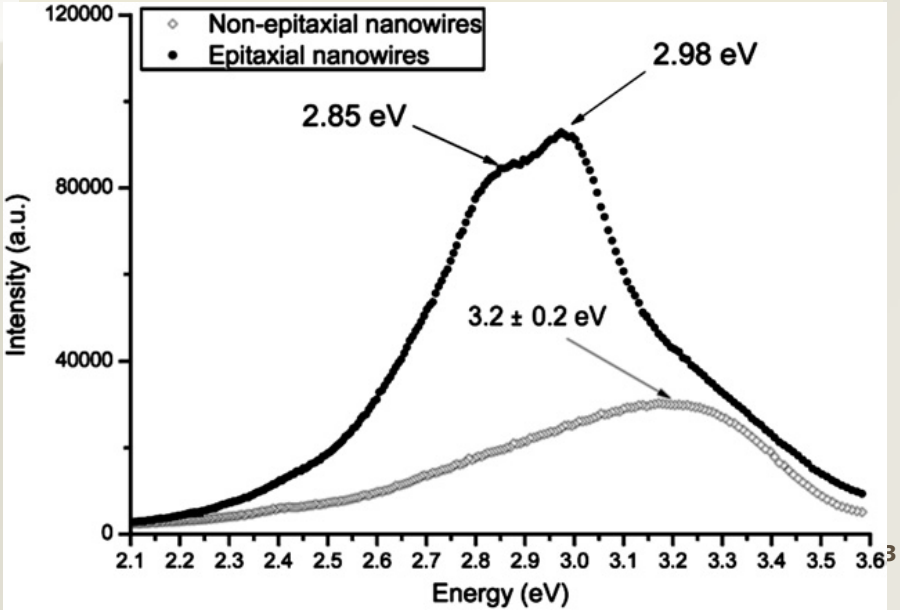
GaN Nanowires

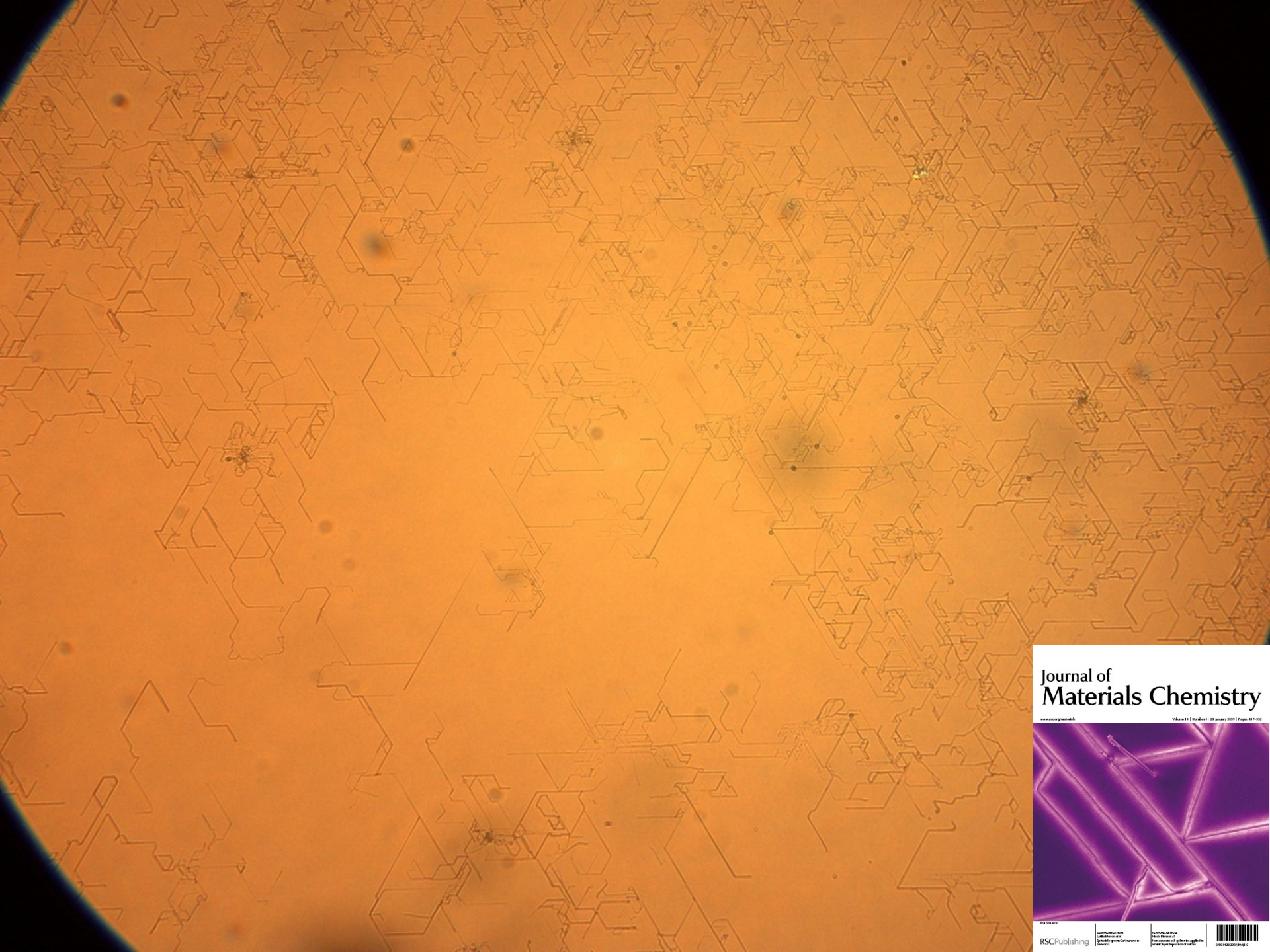


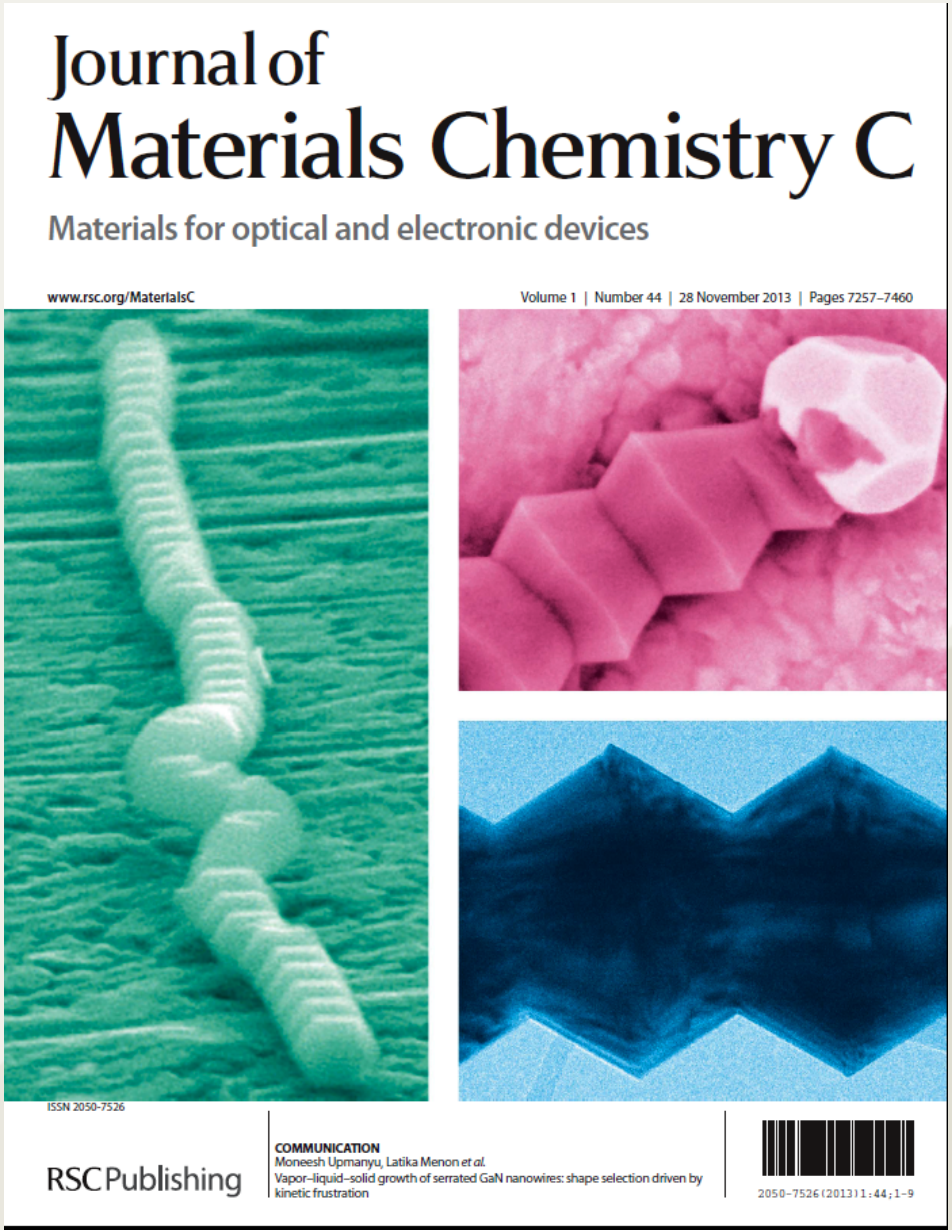


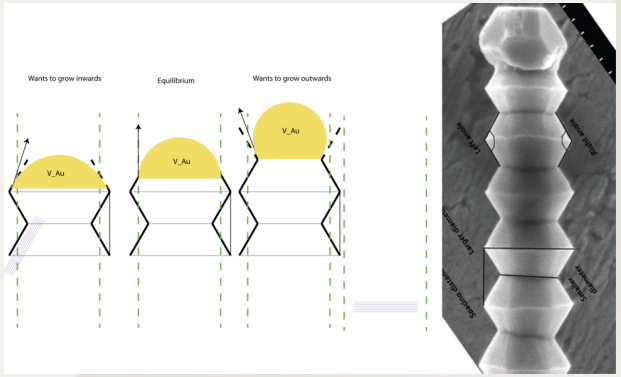


Epitaxial GaN




Journal of
Materials Chemistry
www.rsc.org/materials
Volume 19 | Number 4 | 28 January 2009 | Pages: 437–552
RSC Publishing
COMMUNICATION
FEATURE ARTICLE





Serrated GaN

Enhanced Surface Area

Northeastern University Research Funding

- NSF (CAREER, DMR, ECCS, I-CORPS)
- Airforce, Army, ONR

Lab Highlights

- Over 5M in funding to date
- Graduated 6PhDs and 4MS
- Over 40 papers on nanomaterials
- Outreach and mentoring

Menon Laboratories, Inc.

- Incorporated in March 2013
- MassCEC funding
- Oil and Gas Company funding