

# **Nanotube Fabrication by Anodic Aluminum Oxide, Self-Aligned Processing, and Atomic Layer Deposition Processing**

Rubloff Research Group Accomplishments

# Nanotube Fabrication by AAO-ALD

## Accomplishment

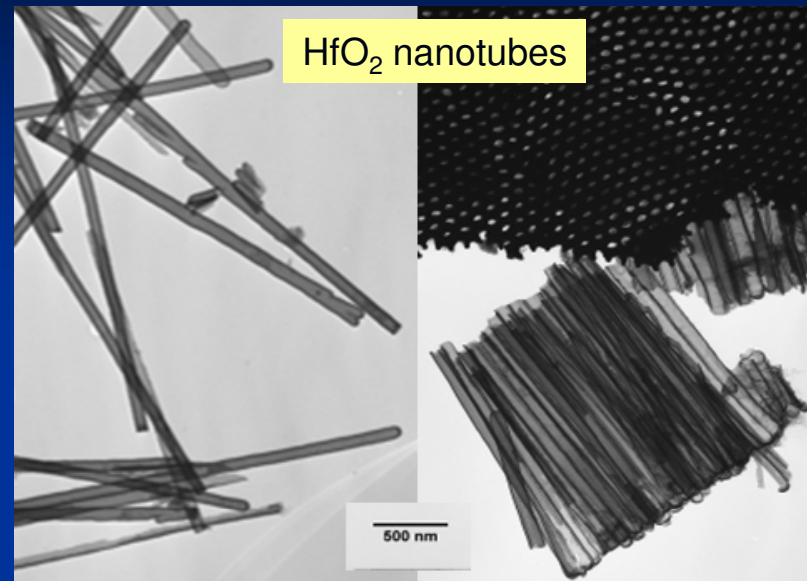
Nanotube fabrication achieved through self-regulating phenomena in materials science:

- Self-assembly of nanopores during anodic oxidation of aluminum (AAO)
- Self-aligned processes to form nanostructures
- Self-limiting chemical synthesis by atomic layer deposition (ALD)

## Significance

Realizing nanotechnology benefits requires new approaches to control materials, devices, and products at the nanoscale

Natural phenomena (self-assembly, self-alignment, self-limiting reaction) in chemical processes provide new pathways to nanomanufacturing



Materials Today 2007 Calendar

## Researchers involved

Israel Perez, Erin Robertson, Laurent Henn-Lecordier, Gary W. Rubloff  
Collaborations with Sang Bok Lee's group

## Links

[http://materialstoday.com/competition\\_images/2006/perez.htm](http://materialstoday.com/competition_images/2006/perez.htm)

# Nanotube Fabrication by AAO-ALD

We have combined anodic aluminum oxide (AAO) nanostructures with atomic layer deposition (ALD) to fabricate nanotube structures of HfO<sub>2</sub> high-K dielectric in size ranges 20-300nm diameter, a few nm wall thickness, and microns in length. Natural self-assembly during anodization causes arrays of nanopores with strikingly uniform dimensions and inter-pore spacing to be formed in Al films from submicron to 25 microns thick. The resulting nanotubes can be released by etching away the Al<sub>2</sub>O<sub>3</sub> nanotemplate, or alternatively used in place in the template, for applications ranging from drug delivery nanoparticles to high density energy storage structures. TEM images of these structures are shown in the figure for freed nanotubes (left) and nanotubes held together by leaving the top ALD film while removing the Al<sub>2</sub>O<sub>3</sub> template (right). These images, by UMD graduate student Israel Perez, have been chosen for inclusion in the MRS 2007 calendar.

# Self Assembly of Nanopores by AAO

## Self-assembly occurs in anodic oxidation of aluminum

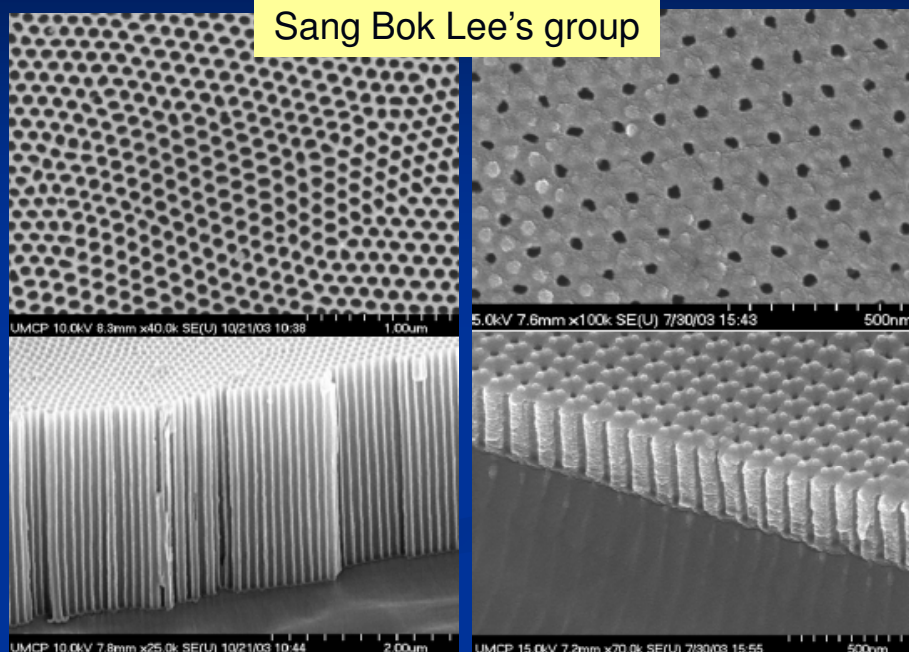
Produces highly uniform distributions of nanopores in the resulting  $\text{Al}_2\text{O}_3$ .

Nanopores are 20-300 nm in diameter and  $\mu\text{m}$ 's in thickness

Nanopores in anodic aluminum oxide (AAO) can be used as templates for nanotube or nanowire fabrication

Nanotubes/nanowires can be left in place in the AAO template or released by dissolving the AAO template.

Sang Bok Lee's group

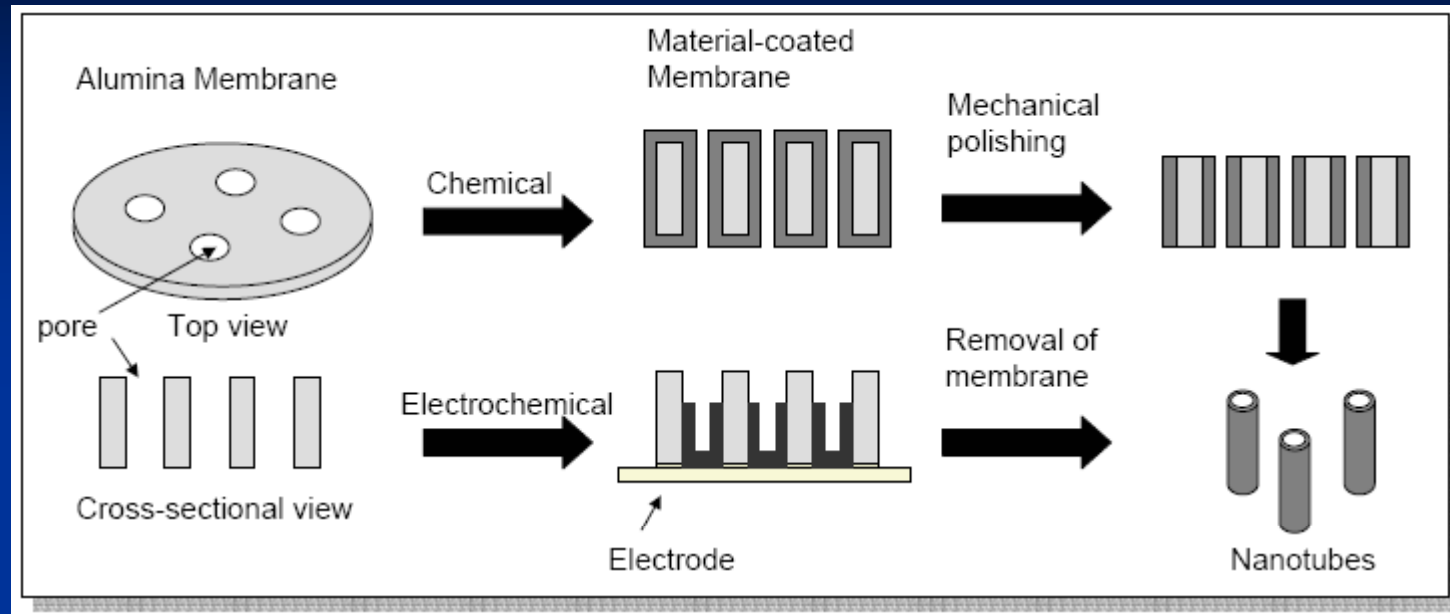


## Application examples

Released nanotubes for targeted drug delivery

High density devices for energy capture, storage, displays, ...

# Nanofabrication by Self-Aligned Processing



## *Self-alignment* of thin film structures in AAO nanopores

Etching of AAO template for pore widening as needed

Chemical or electrochemical deposition processes to form thin films on nanopore sidewalls

Mechanical polishing of top/bottom surfaces

Release of nanotubes/nanowires as needed for the application by etching away the AAO template

# Atomic Layer Deposition (ALD)

## Self-limiting deposition of ultrathin films in AAO nanopores

Atomic layer deposition (ALD): alternating exposures of reactant gases to cause self-limiting adsorption and reaction

Deposition controlled at atomic scale even in superhigh aspect ratios (e.g., nanoscale pores)

The ultimate in thin film deposition control to manufacture nanostructures from AAO templates

