ULTRA-HIGH SURFACE AREA SINGLE AND MULTI-WALLED CARBON NANOTUBE 3-DIMENSIONAL HYBRID STRUCTURE

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Carbon-based structures prove promising candidate materials in many applications including flexible electronic devices, membranes, sensors, and energy storage devices, the primary reason being their ability to achieve unprecedented surface areas at the nanoscale level. Here, we synthesize a unique high surface area 3-dimensional hybrid nanostructure by combining carbon nanotube growth on two templates, anodized aluminum oxide (AAO) and spherical silica nanoparticles. First, we fabricated a low-aspect ratio AAO template and applied chemical vapor deposition (CVD) to synthesize multi-layered graphitic structures known as nanocups. After the first growth, we inserted silica nanoparticles and conducted another round of CVD to generate a network of single-walled nanotubes (SWCNTs) inside the carbon nanocups. This novel hybrid carbon nanostructure demonstrates an enhanced conductive surface area that paves the way for many potential applications, including improved charge density on super-capacitors.

Ultra-High Surface Area Single and Multi-Walled Carbon Nanotube 3-Dimensional Hybrid Structure

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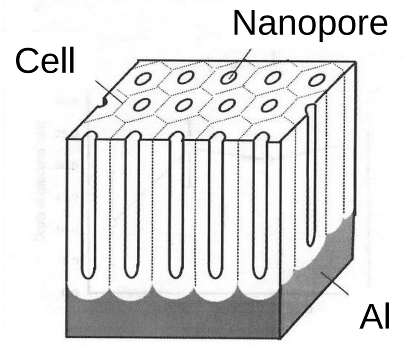
Purpose

To design a novel 3-D hybrid structure by growing a network of carbon nanotubes inside graphitic nanocups. Motivations are:

- Large conductive surface area
- Energy storage applications

Introduction

Anodized Aluminum Oxide (AAO)

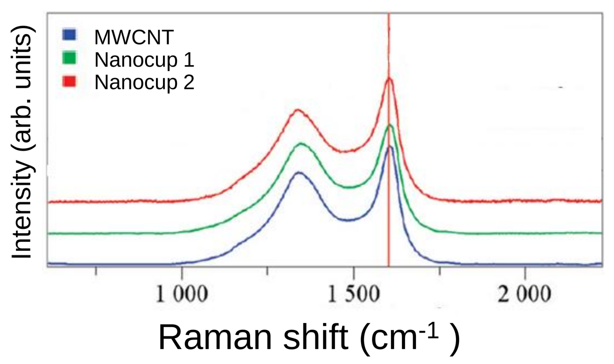


- Highly ordered nanopores in alumina template
- Easily controlled dimensions based on anodization conditions[1]

1. F. Li *et al.*, *Chem. Mater.* 1998, 10, 2470-2480

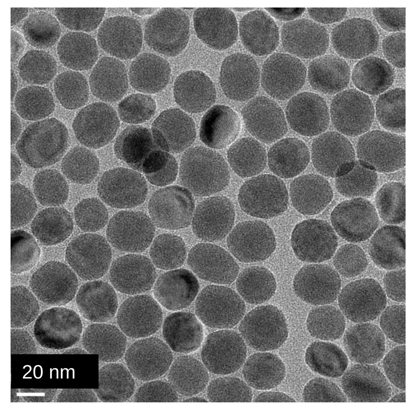
Nanocups

- 3-D graphitic structure grown directly on AAO template[2]
- Low length/diameter aspect ratio
- Similar structure to multi-walled carbon nanotubes (MWCNTs)



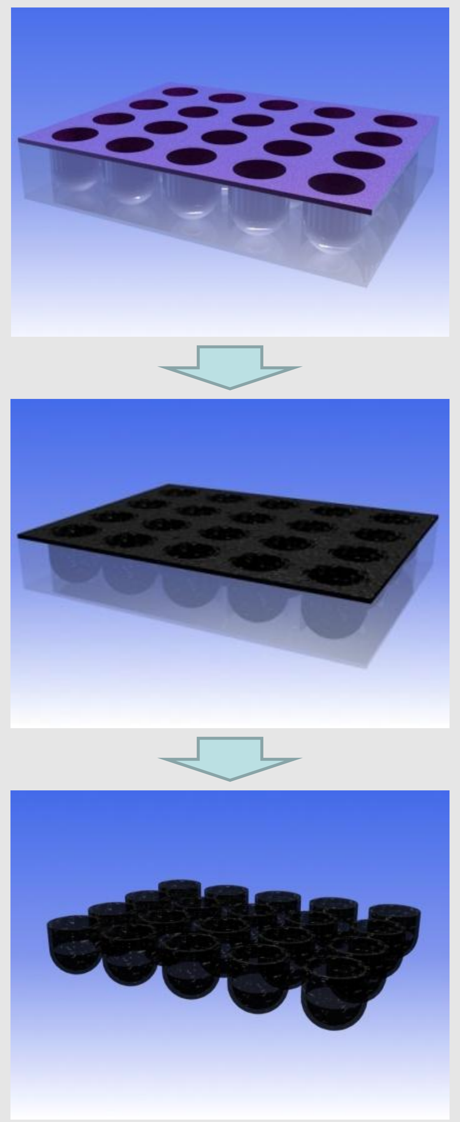
2. H. Chun, M. Hahm *et al.*, *ACS Nano*, 2009, 3 (5), pp 1274–1278

Magnetite Nanoparticles



- Iron is known catalyst for carbon nanotube growth
- Magnetic properties allow for simple manipulation of nanoparticles

Methods



1. AAO Synthesis**

Two step anodization in oxalic acid with chemical etching and widening steps

2. First Growth-Nanocups

Acetylene chemical vapor deposition (CVD) at 650ºC for MWCNT structure

3. Removal of Alumina Layer

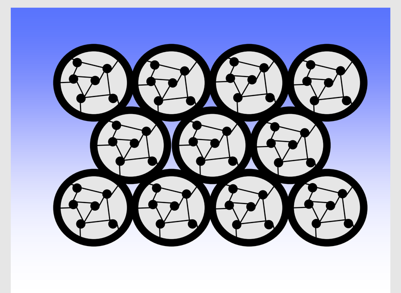
Hydrofluoric acid (HF) dissolves alumina layer but graphitic nanocups remain

4. Insertion of Nanoparticles

- Magnetite nanoparticle solution dripped over nanocups
- Magnet pulls particles towards base of cups

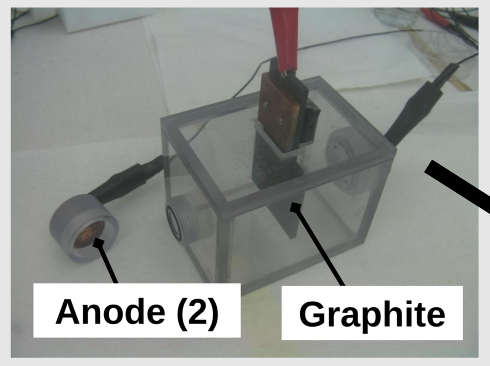
5. Second Growth-Nanotubes

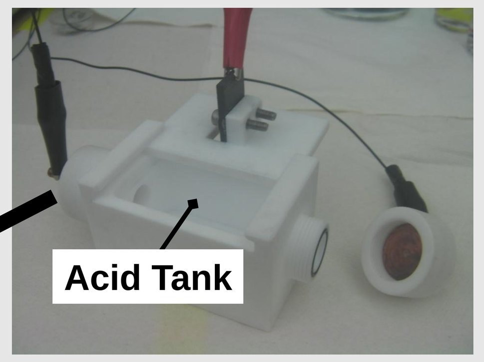
CVD to grow carbon nanotubes between nanoparticles within cups



****Custom anodization cells designed for AAO**

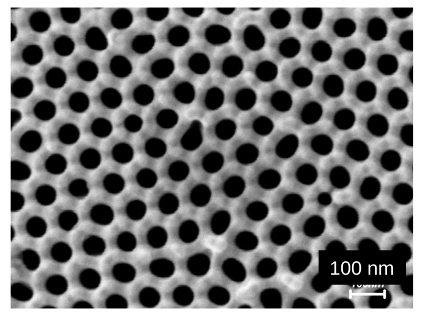
Two cells engineered for specific anodization requirements: polycarbonate (left) and Teflon (right)

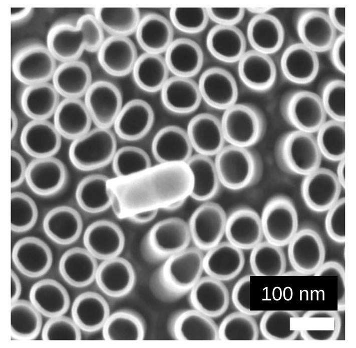




Results and Conclusions

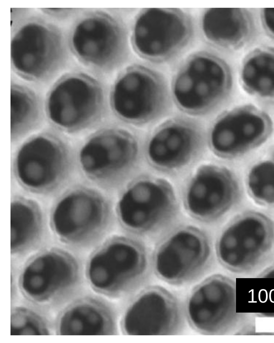
1) Able to achieve ordered nanopores in alumina template
- New cells effective to form AAO template





2) Nanocup growth with low aspect ratio
- Difficulty holding together upon treatment with HF

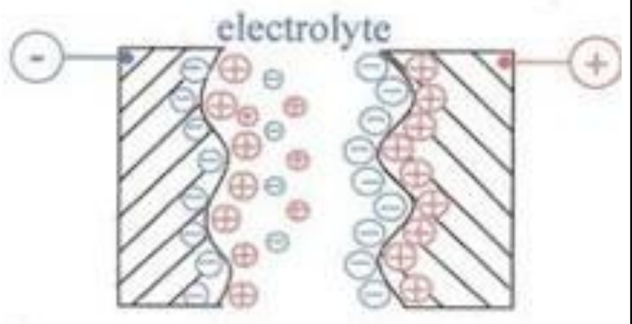
3) Nanoparticle insertion method based on published work*
- High resolution SEM needed to check particles



*H. Chun, M. Hahm *et al.*, *ACS Nano*, 2009, 3 (5), pp 1274–1278

Future Developments

- Nanoparticle retention in nanocups after HF treatment
  - Poly(methyl methacrylate) (PMMA) coating
- Second growth optimization
- Development as supercapacitor



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