Today

- Nanoparticles
- Manufacturing
  - Ball Milling
  - Plasma Arcing
  - CVD
  - Sol-Gels
  - Electrodeposition

Nanoparticles

- Nanoparticles are simply particles that have nanoscale dimensions
- They can be organic or inorganic
  - Combustion produces organic nanoparticles
  - Inorganic nanoparticles, e.g., Gold
- Basis for many interesting applications
- Different from bulk material mostly due to surface/volume ratio

Surface Area

N = total atoms; n = surface atoms
Nanoparticle Uses

- Basis for creating other more complex nanostructured materials
- High surface area/volume ratio
  - Insulators
  - Catalysts
  - Energy storage
- Coatings
  - Transparent
  - Flexible
- Encapsulators
- Additives to form composites

Ball Milling

- Mechanical crushing of solid into nanocrystallites
- Inexpensive (read “commercial process”)
- As product is made, one key is to keep it from reacting with itself
- Old process

Ball milling involves mechanical crushing of solid into nanocrystallites. It is an inexpensive process. As product is made, one key is to keep it from reacting with itself. Old process.

Plasma Arcing

- Create particles by vaporizing an electrode using a voltage difference (>20V) at a high current (> 50A).
- The atoms in electrode are ionized and leave the anode and are deposited on the cathode.
- The ions usually pass through an inert gas (e.g., helium or argon)
- Often the anode is doped with a catalyst

Plasma Arcing to make CNTs

Plasma arc evaporation is used to make carbon nanotubes. The process involves vaporizing the electrode using a voltage difference (>20V) at a high current (> 50A). The atoms in the electrode are ionized and leave the anode and are deposited on the cathode. The ions usually pass through an inert gas (e.g., helium or argon). Often, the anode is doped with a catalyst.
Plasma Arcing Parameters

- Anode catalyst
- Pressure
- Kind of gas
- Anode-to-cathode distance
- Current, voltage
- Kind of metal
- Geometry

Related to Plasma Arcing

- Rotating Electrode System
  - Increase pressure
  - Evenly distributes discharges

- Flame Ionization
  - Spray material into flame
  - Ions produced

Laser Ablation

- Used by Smalley et al to make CNTs
- Laser vaporizes graphite target @ 1200°C
- As carbon vapor cools -> clusters are formed.
- Catalysts help to form open structures

Chemical Vapor Deposition (CVD)

- Deposit a material (chemical precursor) in gas phase onto a solid surface
Metal-Organic-CVD

- MOCVD uses a precursor that is a metal surrounded by organic ligands
- E.g., Pt(hfac)2 complex, or bis(hexafluoroacetylacetonate) platinum.

Why MO?

- Metal generally solid at room temp
- However, the non-polar organic ligands greatly reduce the intermolecular forces -> easier to vaporize
- Also, readily decomposes on substrate - in this case SiO₂

Example CVD Process

- Precursor is +2. must be reduced
- Produces neutral ligands
- Pt is deposited on surface
Example CVD Process

- Precursor is +2. must be reduced
- Produces neutral ligands
- Pt is deposited on surface
- And more arrives

CVD grown Platinum-film

SiO$_2$

Enhanced CVD

- Other CVD methods
  - Laser assisted CVD
  - Plasma enhanced CVD
  - Thermal CVD
  - Etc.

PECVD

NANO LETTERS 2004 Vol. 4, No. 5 921-926
CVD & Spin-on in Chip Fab

- Used to create thin film, e.g., for use as a dielectric
- CVD used for many layers

http://www.spectrum.ieee.org/WEBONLY/publicfeature/feb03/filmf3.html

CVD Parameters

- Volatility of precursor
- Ease of decomposition & volatility of fragments
- Relative concentration
- Catalyst on target surface
- Arrangement of surface
- Temperature
- Pressure

Sol-Gels

- Start with precursor
- Form Solution (e.g., hydrolysis)
- Form Gel (e.g., dehydration)
- Then form final product
  - Aerogel (rapid drying)
  - Thin-films (spin/dip)

Sol of Sol-Gel

- Suspension (By brownian motion and/or charge) of solid particles in a solution
- Form Sol from a precursor (e.g., TMOS or TEOS)
- Add: water, cosolvent, acid catalyst
- Hydrolysis occurs
- Condensation occurs resulting in a sol with different polymeric structures
  - Linear, clusters, colloids, chains
Gel of Sol-Gel

- Gel is a solid network containing liquid components
- Sol becomes gel
- Gel can be molded, etc.
- Remove solution to create final product
  - Spinning
  - Drying
  - Mold
  - electrophoresis

Parameters to Sol-Gel

- Materials
- Relative Concentrations
- Ph
- Temperature
- Time of reaction
  - ...

Electrodeposition

- Or, electroplating

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Nanowires

JACS 2002, 124, 4020-4026
Terms For Natural Particles

- Surfactants: A substance that lowers the surface tension of a solvent (e.g., soap on water)
  - Usually amphiphilic linear molecule (e.g., with hydrophobic/phillic ends)
- Micelles: aggregate formed by, e.g., amphiphilic molecules in aqueous environment.

Next Time

- Today
  - Bottom-up manufacturing of particles
- Next Time
  - Nanomolding fab
  - Making synthetic gecko hair
    - Read paper on web
    - Write ~1/2 page summary
    - Email to me