15-398 Introduction to Nanotechnology

## Making Nanoparticles

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## Today

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

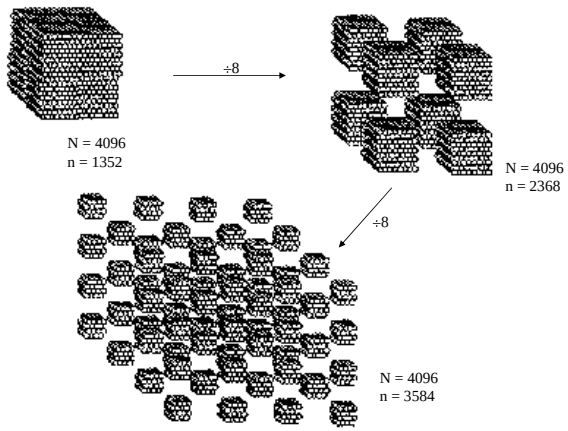
  

## Nanoparticles

- 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




augustus.scs.uiuc.edu/nuzzogroup/PPT/nano.ppt

## Nanoparticle Uses

- Basis for creating other more complex nanostructured materials
- High surface area/volume ratio
  - Insulators
  - Catalysts
  - Energy storage
- Coatings
  - Transparant
  - 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

Figure 3: A ball mill being used as part of a gold mining operation in Arequipa, Peru

http://www.itdg.org/html/technical_enquiries/docs/mineral_processing_milling.pdf

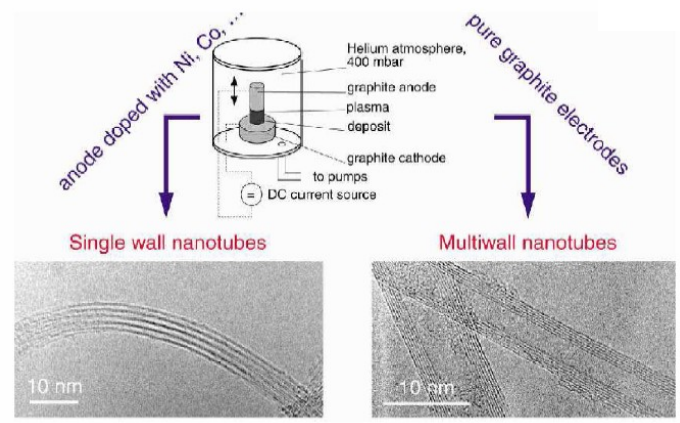
  

## Plasma Arcing

- 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



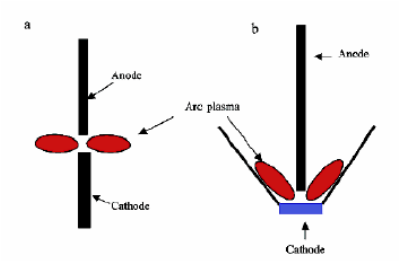

The Wondrous World of Carbon Nanotubes

## Plasma Arcing Parameters

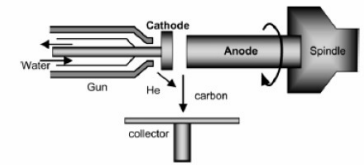
- Anode catalyst
- Pressure
- Kind of gas
- Anode-to-cathode distance
- Current, voltage
- Kind of metal
- geometery






## Related to Plasma Arcing

- Rotating Electrode System
  - Increase pressure
  - Evenly distributes discharges

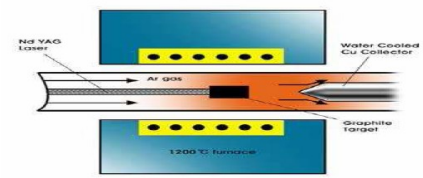



- Flame Ionization
  - Spray material into flame
  - Ions produced



## Laser Ablation

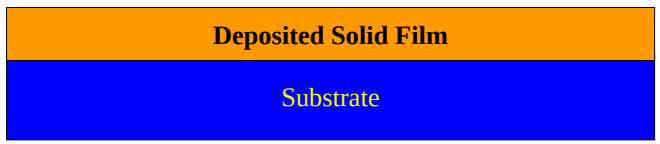
- Used by Smalley et al to make CNTs
- Laser vaporizes graphite target @ 1200°C
- As carbon vapor cools -> clusters are formed.
- Catalysts help to form open structures






## Chemical Vapor Deposition (CVD)

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



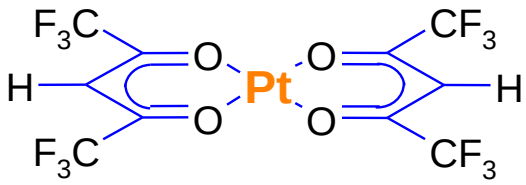

Slides adapted from Nuzzo, www.scs.uiuc.edu/chem/nuzzo.htm



## 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.





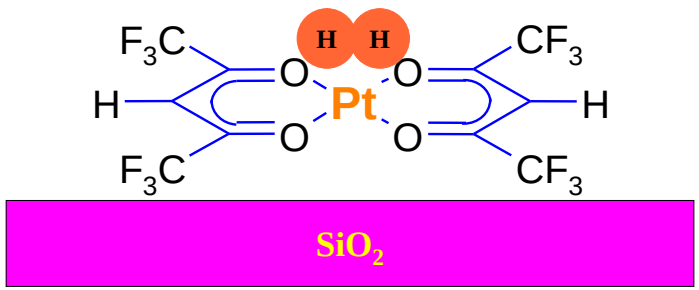

## Why MO?

- 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 $SiO_2$



## Example CVD Process

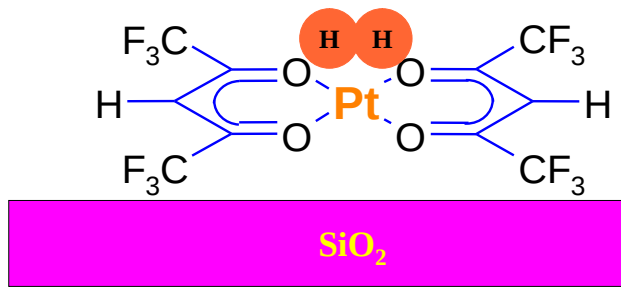
- Precursor is +2. must be reduced





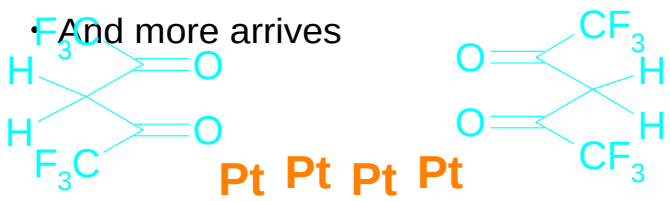

## Example CVD Process

- Precursor is +2. must be reduced
- Produces nuetral ligands
- Pt is deposited on surface



## Example CVD Process

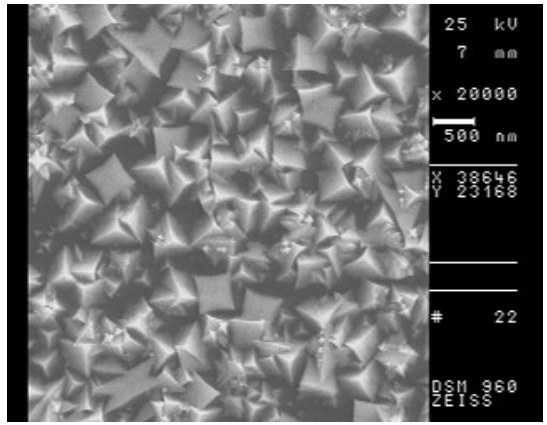
- Precursor is +2. must be reduced
- Produces nuetral ligands
- Pt is deposited on surface
- And more arrives




$SiO_2$



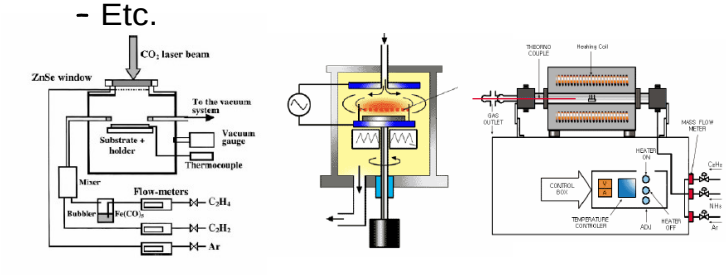
## CVD grown Platinum-film





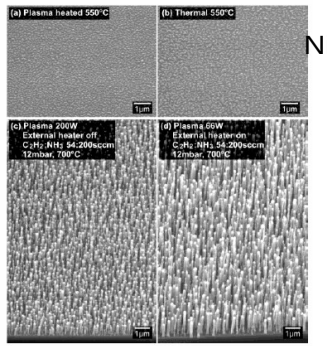

## Enhanced CVD

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

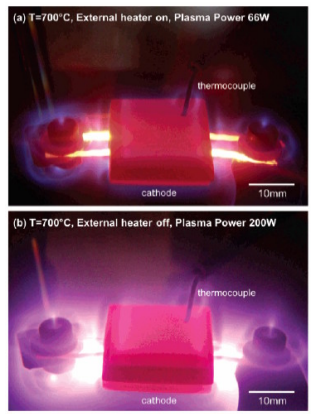





## PECVD



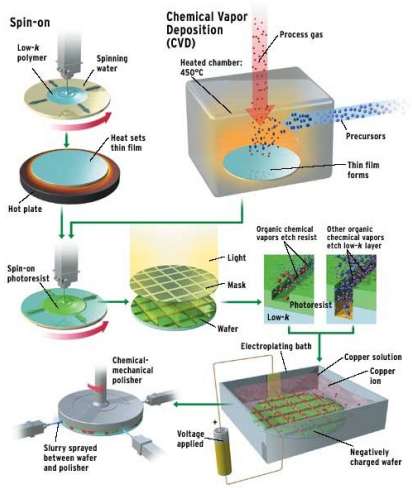

Ni




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

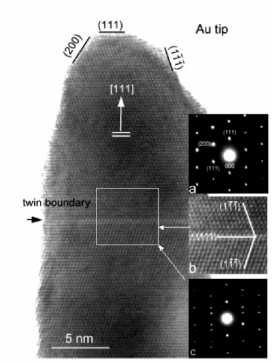
## Parameters to Sol-Gel

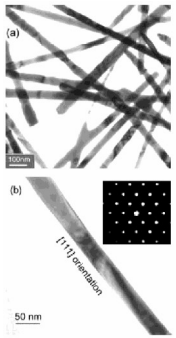
- Materials
- Relative Concentrations
- Ph
- Temperature
- Time of reaction
- …

## Electrodeposition

- Or, electroplating

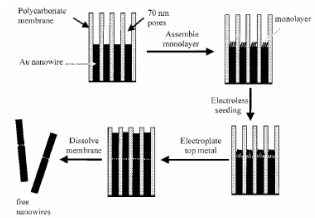


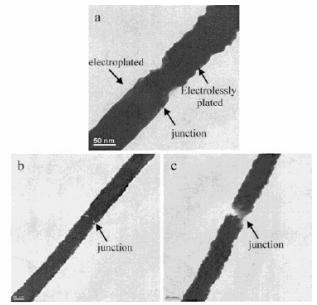




Nano Let, Vol 3, No 7, 920

## Nanowires



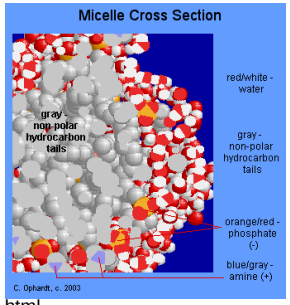

JACS 2002, 124, 4020-4026

## 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.




http://www.elmhurst.edu/~chm/vchembook/558micelle.html



## 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

