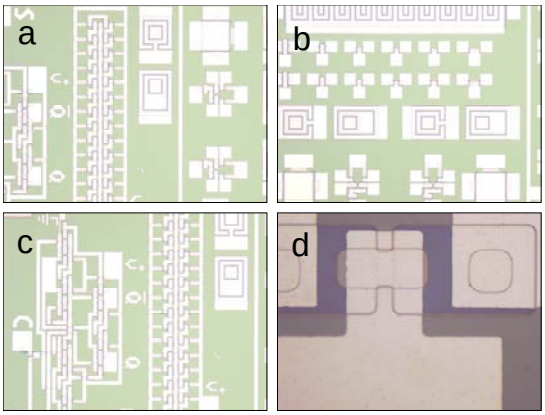
Laboratory Skills / Scientific Instrumentation

1. **Clean Room:** Clean-Room user (EE, Penn State), Photolithography, Reactive Ion Etching (RIE), Device Fabrication

Clean Room

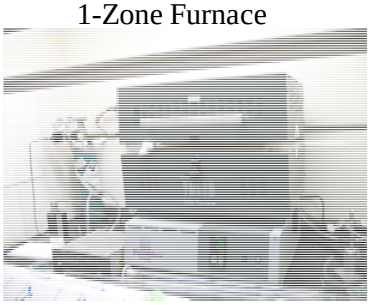


Standard Photo-Lithography

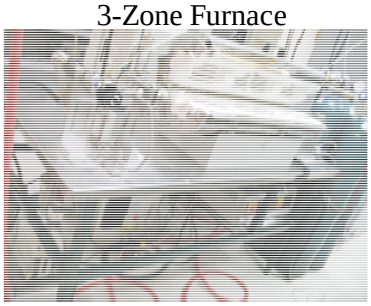
(a) Flip-Flop (b) Discrete MOSFETs (c) Ring Oscillators (d) Single MOSFET made by standard Photolithography

2. **Chemical Vapor Deposition (CVD):** Growth of nanostructures (SWNTs, MWNTs, Nanowires etc.), Annealing of material in controlled environment. Involves: Chemicals (gas, liquids), Furnace, Vacuum Pumps, Mass Flow Controllers etc.

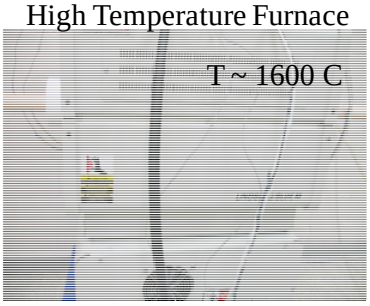
1-Zone Furnace

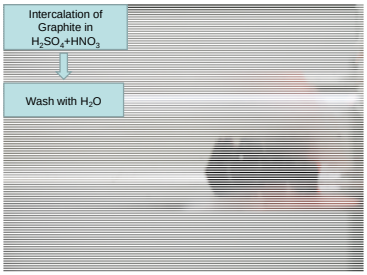


3-Zone Furnace

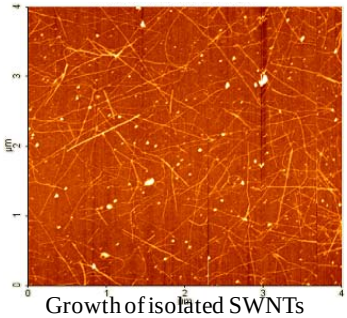


High Temperature Furnace

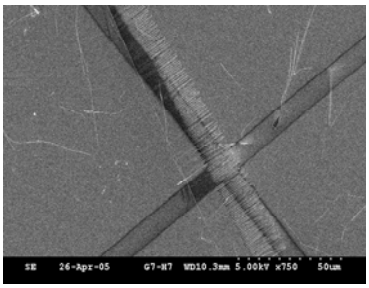




Exfoliation of intercalated graphite



Growth of isolated SWNTs

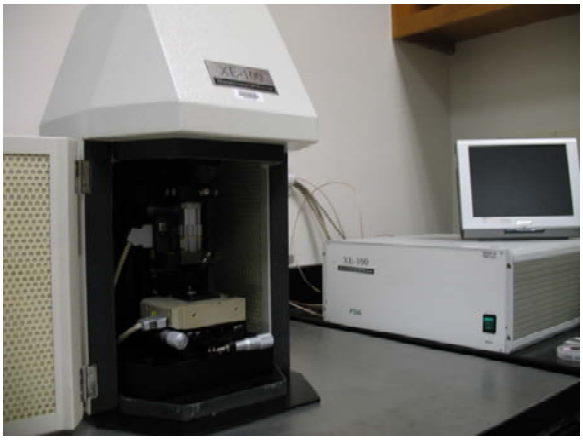


Growth of ZnO nanostructures

3. **Deposition Techniques** : E-beam evaporation, Thermal evaporation, sputtering, Electroplating

PVD 75 (Kurt J. Lesker):
E-beam, Thermal Evaporator

4. **Scanning Probe Microscopy:** Atomic Force Microscopy[AFM] (Non-Contact mode, Contact mode), MFM (Magnetic), EFM (Electric), Scanning Tunneling Microscopy (STM), Force-Distance microscopy.



PSIA-XE100

Asylum Research

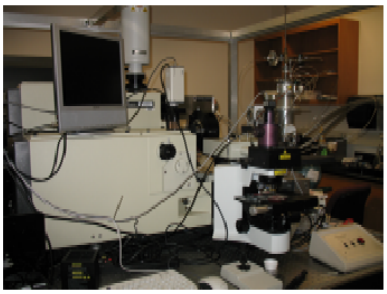
5. Raman Spectroscopy and Photoluminescence :

Renishaw: Single Grating micro Raman, Air Cooled CCD, Laser: 514, 647, 785 nm, Temperature attachment

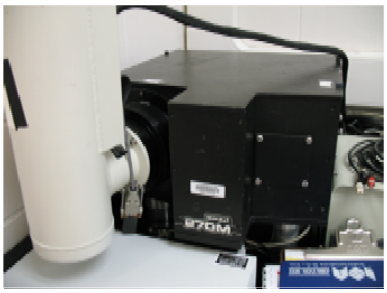
T-64000: Single/Triple Grating (additive & subtractive), L-N2 Cooled CCD, PMT, Laser: Any wavelength, Micro/Macro, Temperature attachments (micro and macro), Gas-cell, high pressure attachment

Renishaw inVia

JY-T64000



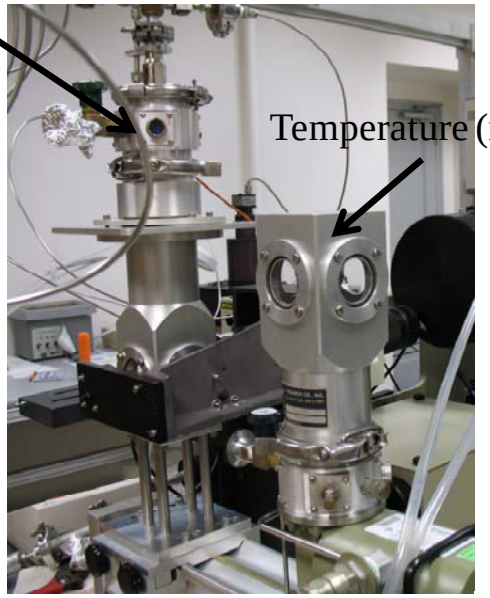
JY-270 M



Microscope Attachements:

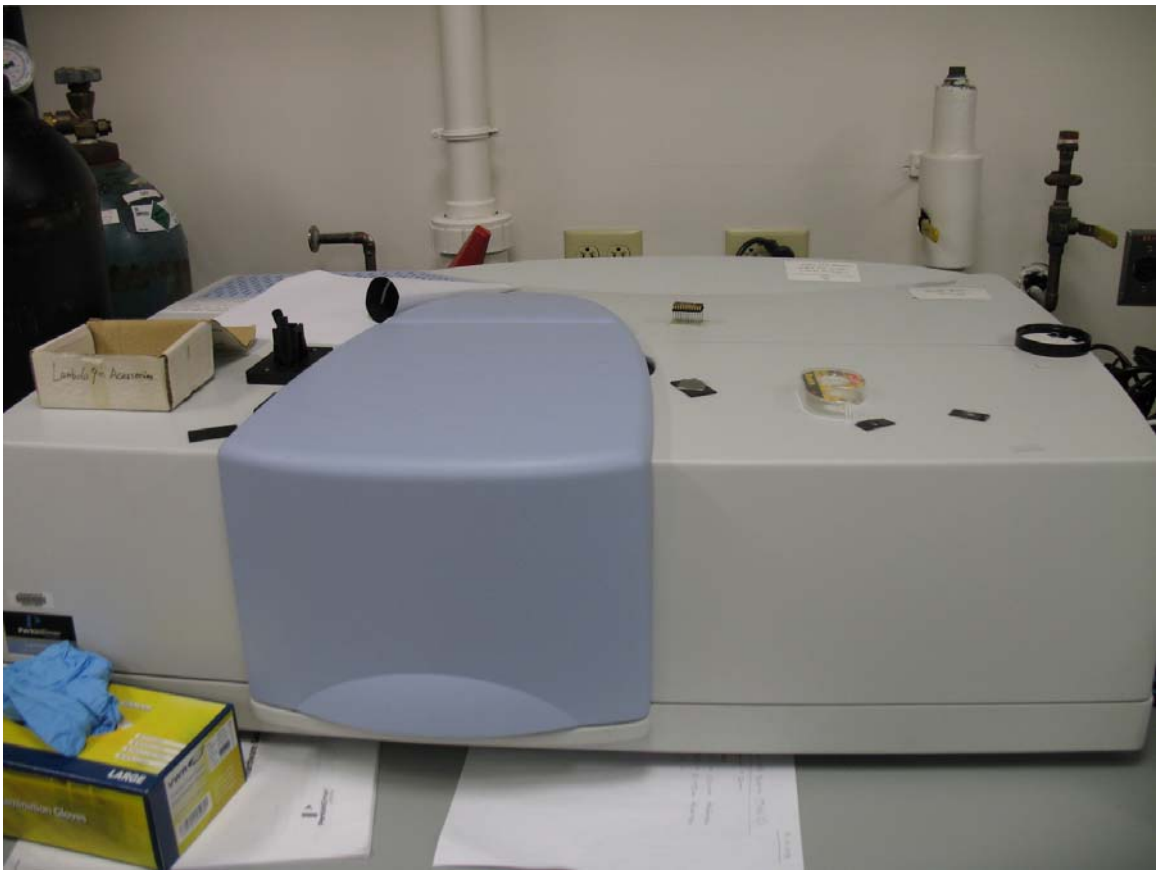
(Pressure, Temperature, Gas, Macro)

Temperature (micro)



Temperature (macro)

6. Optical absorption/transmission:



Lamda 950 (US-vis)

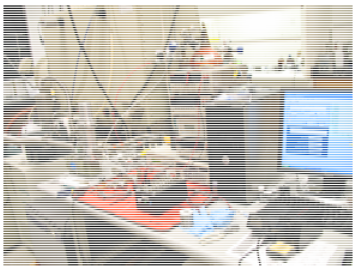
7. FTIR (Fourier Transformed Infrared spectroscopy)

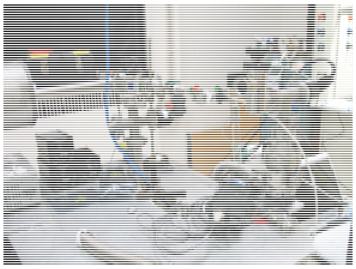
8. TGA

TA instrument's : TGA5000

9. Electrical Measurements:

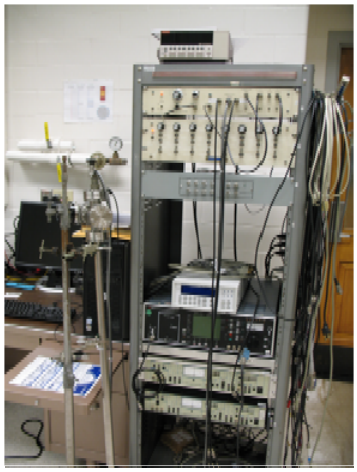
Low T, Vacuum





High T, Vacuum, Controlled Environment

Low T, High T, Vacuum, Gas, TEP



10. Scanning Electron Microscopy:

Jeol FESEM, Focused Ion Beam, Environmental Scanning Electron Microscopy (ESEM), SEM (Hitachi 3000)

Dual beam (electron, ion) FIB