



# Synthesis and Characterization of Nanocarbon using the UCSC MACS Facility at NASA Ames

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NSF Principal Investigator*

**Michael Oye**

*UCSC Electrical Engineering Professor  
Director, MACS Facility  
UCSC Associate Co-Director, ASL*

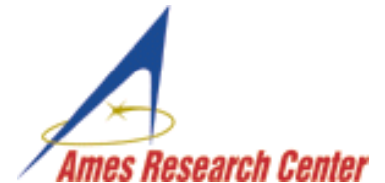
**UCSC/NASA-ARC Advanced Studies Laboratories (ASL),  
NASA Ames Research Center,  
Moffett Field, CA 94035**

*ASL is a strategic alliance between NASA Ames Research Center and  
the University of California Santa Cruz to foster collaboration between  
Academia, Government, and Industry*



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**MATERIALS ANALYSIS FOR COLLABORATIVE SCIENCE**  
AT AMES RESEARCH CENTER IN SILICON VALLEY





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## Outline:

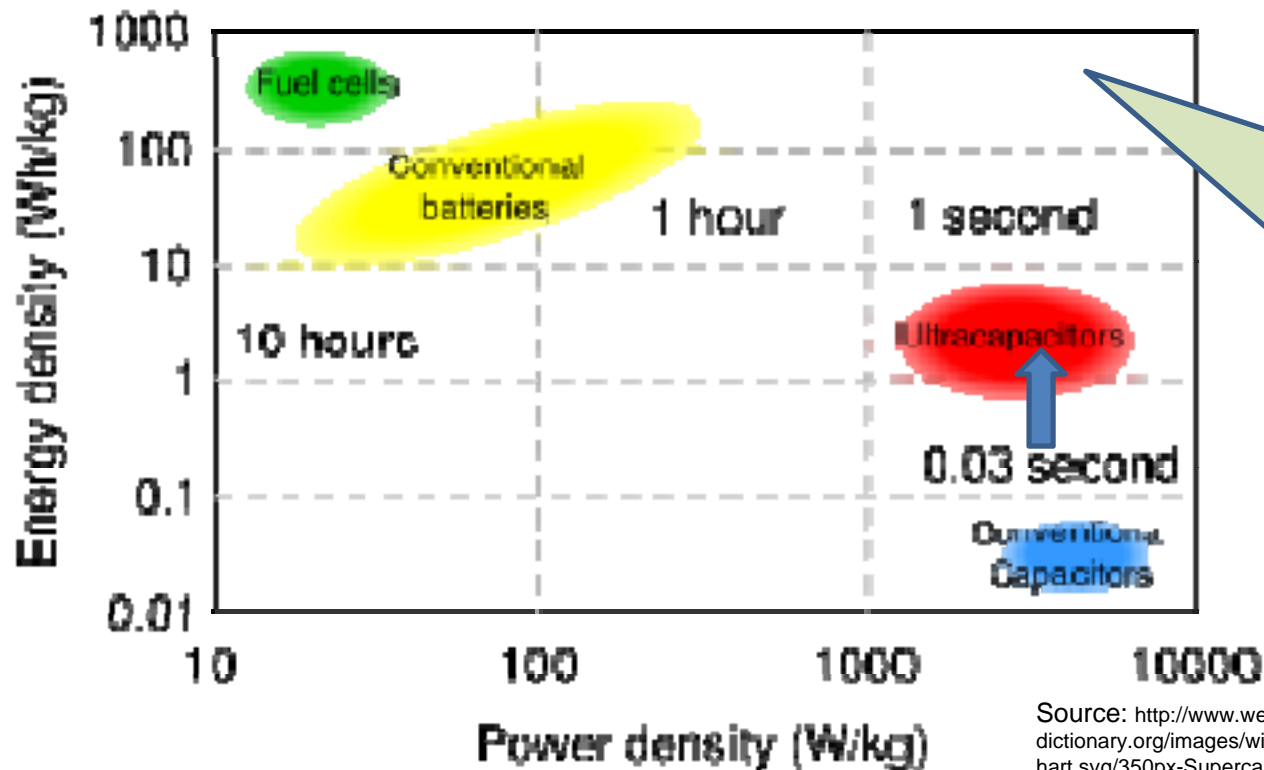
- **Why Nanocarbon materials for Energy Storage? → Ultracapacitors**
  - **What is Nanocarbon?**
- **What is UCSC MACS Facility (and ASL)?**
- **Synthesis**
- **Characterization**
- **NSF-funded training program for Synthesis & Characterization of Energy Storage materials for the Silicon Valley workforce**



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## Nanocarbon Materials For Energy Storage:



Want  
High Energy  
Density and  
High Power  
Density;  
Ultracapacitors  
bring you closer

Source: [http://www.websters-online-dictionary.org/images/wiki/wikipedia/commons/thumb/6/6b/Supercapacitors\\_chart.svg/350px-Supercapacitors\\_chart.svg.png](http://www.websters-online-dictionary.org/images/wiki/wikipedia/commons/thumb/6/6b/Supercapacitors_chart.svg/350px-Supercapacitors_chart.svg.png)



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- **Capacitor**

- Two plates that store electrical charge

- **Ultracapacitor**

- Increase charge storage density through nanoporous material

- **Activated carbon is most commonly used**

- High surface-to-volume ratio
- Relative low cost

- **Other types of carbon**

- Nanocarbons:

- Carbon Nanotubes
- Graphene
- Nano-onions

- Others (Polymers, metal carbide  $M_xC_y$ , aerogels, and others)
- 



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<http://macs.advancedstudieslabs.org>

Characterization instruments available in UCSC  
MACS Facility at NASA Ames Research Center  
in the Silicon Valley for Thin Film Users

**SEM, with EDS**  
(~1 nm resolution)



**TEM, with EDS**  
(~0.1 nm resolution)



*XPS, QE/ICPE, metal & dielectric  
sputtering, and others tools.*

- On-site Technical Staff
- Do-it-yourself, drop off samples, or mail in samples
- On-line scheduling for reservations and readily available instruments

**See website for  
additional info**



<http://macs.advancedstudieslabs.org>

moye@ucsc.edu

**Rates/hr for\*:**

**Non-profit**

**Commercial**

\*Training rates are also available on the website

|                     |   |       |       |
|---------------------|---|-------|-------|
| <b>TEM</b>          | <a href="#">Hitachi H9500 Transmission Electron Microscope</a>                | \$129 | \$185 |
| <b>SEM</b>          | <a href="#">Hitachi S4800 Field Emission Scanning Electron Microscope</a>     | \$83  | \$95  |
| <b>Tabletop SEM</b> | <a href="#">Hitachi TM1000 Tabletop Scanning Electron Microscope</a>          | \$18  | \$30  |
| <b>QE/IPCE</b>      | <a href="#">Newport Oriel QE/IPCE Measuring Kit</a>                           | \$18  | \$62  |
| <b>XPS</b>          | <a href="#">Perkin-Elmer 5100 X-ray Photoelectron Spectroscopy (XPS) Unit</a> | \$61  | \$90  |
|                     | Technical Staff time  | \$152 | \$200 |



# Synthesis and Characterization of Nanocarbon using the UCSC MACS Facility at NASA Ames

## What is ASL?

*Bringing Government, Academia, and Industry together to solve problems through partnership*



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- Why Nanocarbon materials for Energy Storage? → Ultracapacitors
  - What is Nanocarbon?
- What is UCSC MACS Facility (and ASL)?
- **Synthesis** ←
- Characterization
- NSF-funded training program for Synthesis & Characterization of Energy Storage materials for the Silicon Valley workforce



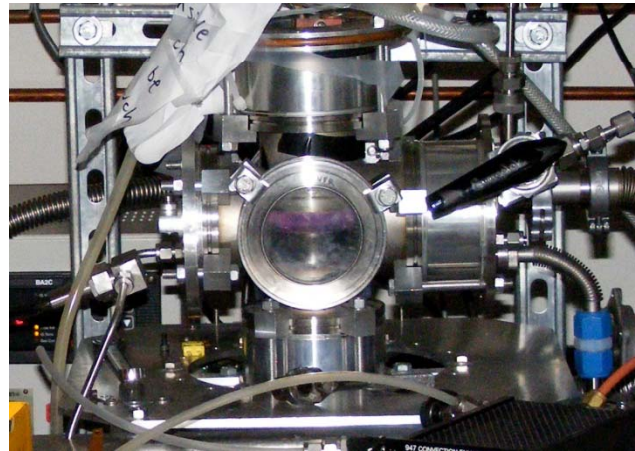
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## Nanocarbon Synthesis



**Rods:**  
Carbon nanotubes using  
Chemical Vapor Deposition  
(CVD) Furnace reactors



**Sheets:**  
Plasma-enhanced  
CVD of vertical  
Graphene



**Spheres:**  
**GRAFEX™**  
Manufactured commercially  
by Clean Technology  
International Corp. (CTIC);  
characterized in UCSC MACS  
Facility at NASA Ames  
<http://cticgroup.com/>



# Synthesis and Characterization of Nanocarbon using the UCSC MACS Facility at NASA Ames

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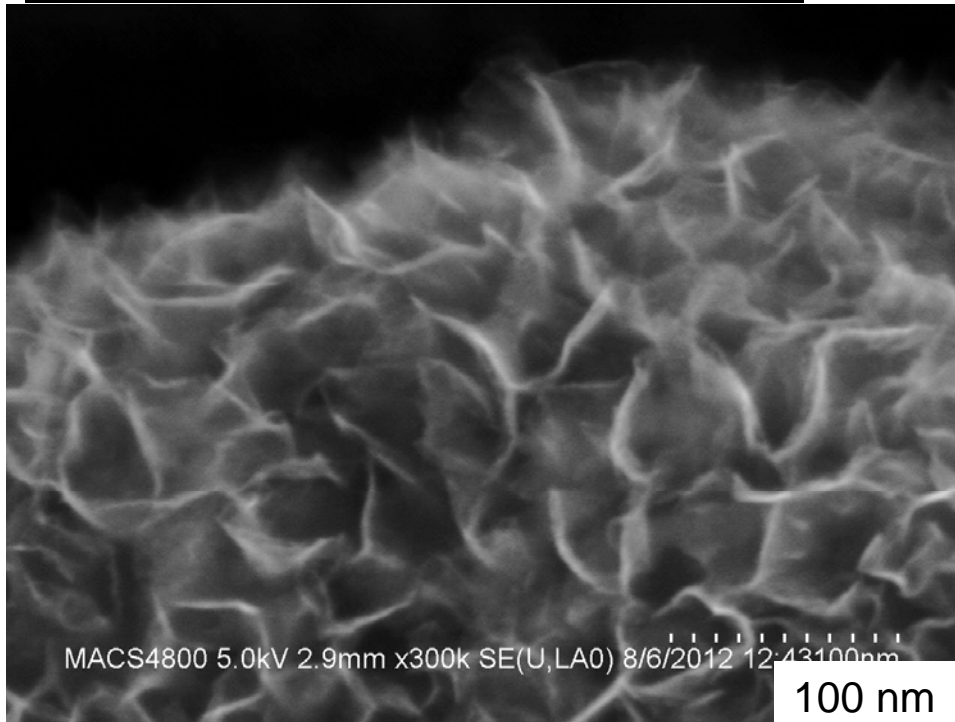
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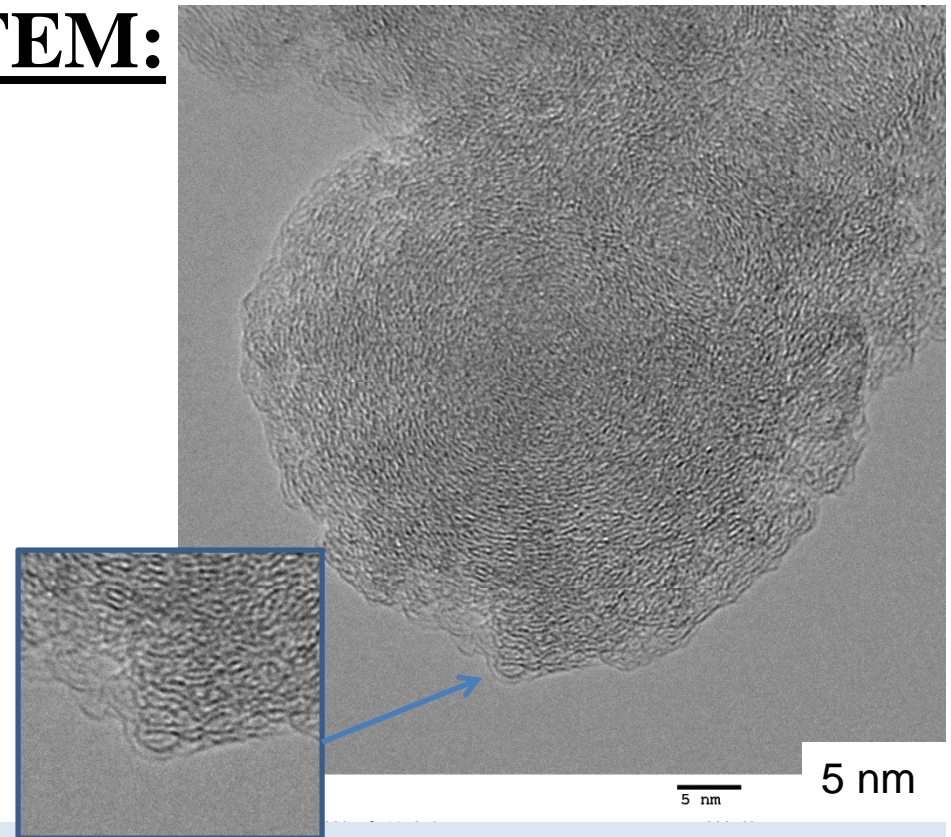
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## SEM (Hitachi S-4800):



## TEM:



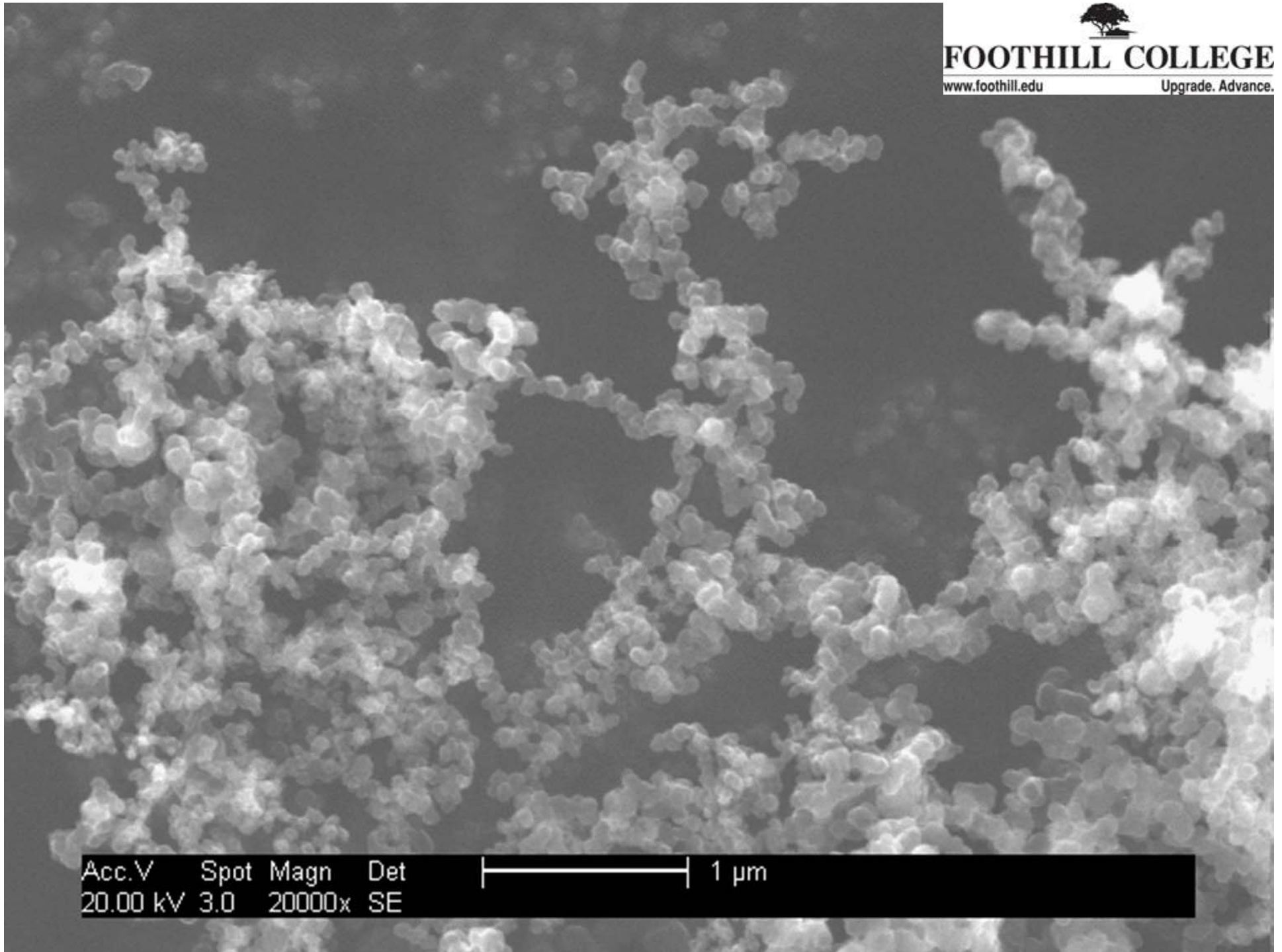
*Electron Microscope images taken by J. Varelas, on-site Technical Staff and Electron Microscopist*



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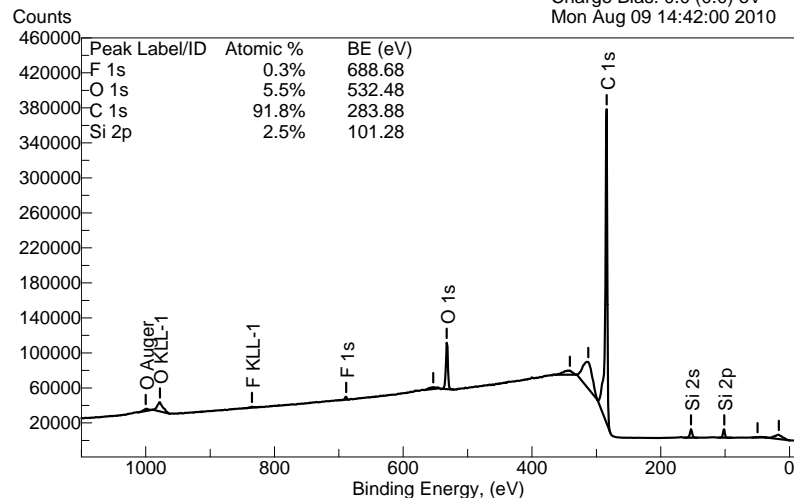


1  $\mu$ m

# Graphite XPS Spectra

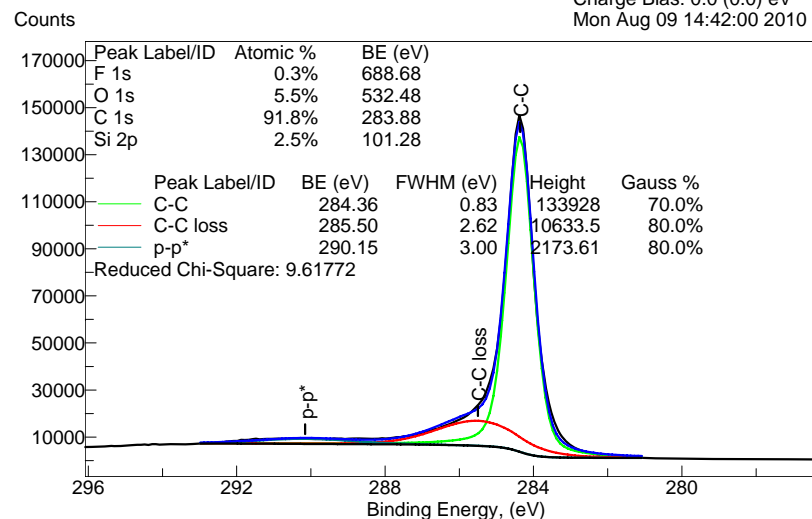
HOPG disk

System Name: XY ASCII  
Pass Energy: 100.00 eV  
Charge Bias: 0.0 (0.0) eV  
Mon Aug 09 14:42:00 2010



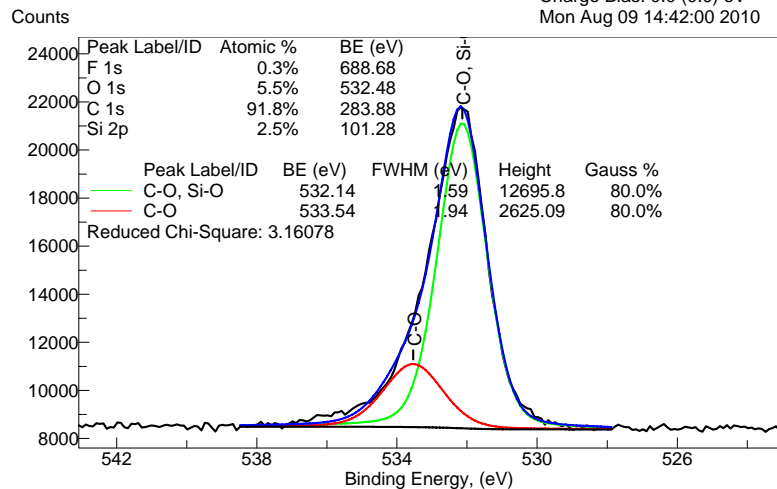
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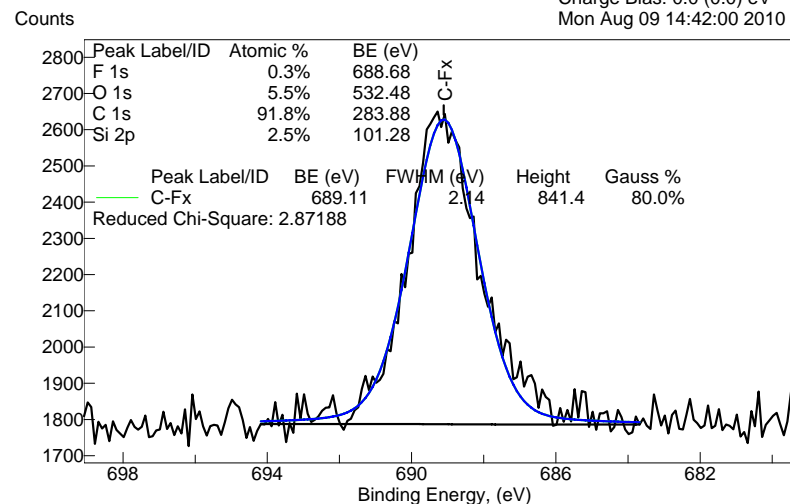
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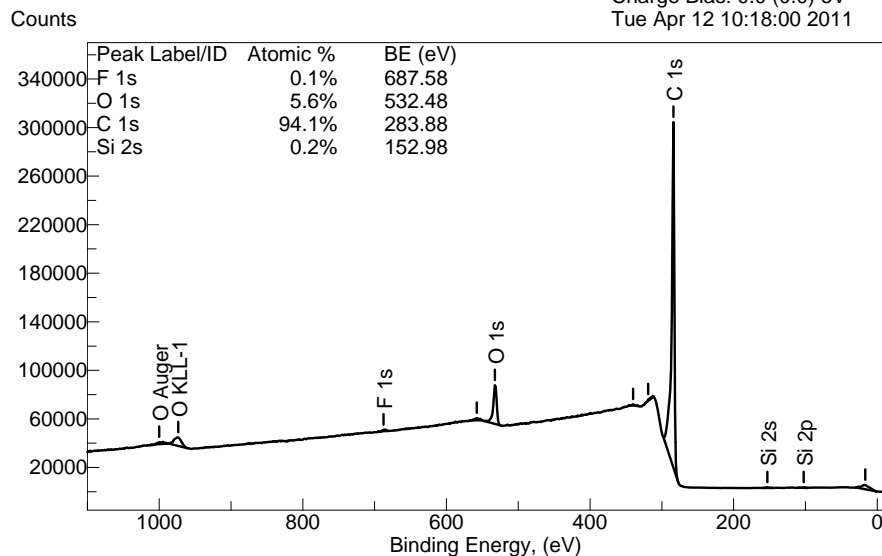
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Charge Bias: 0.0 (0.0) eV  
Mon Aug 09 14:42:00 2010





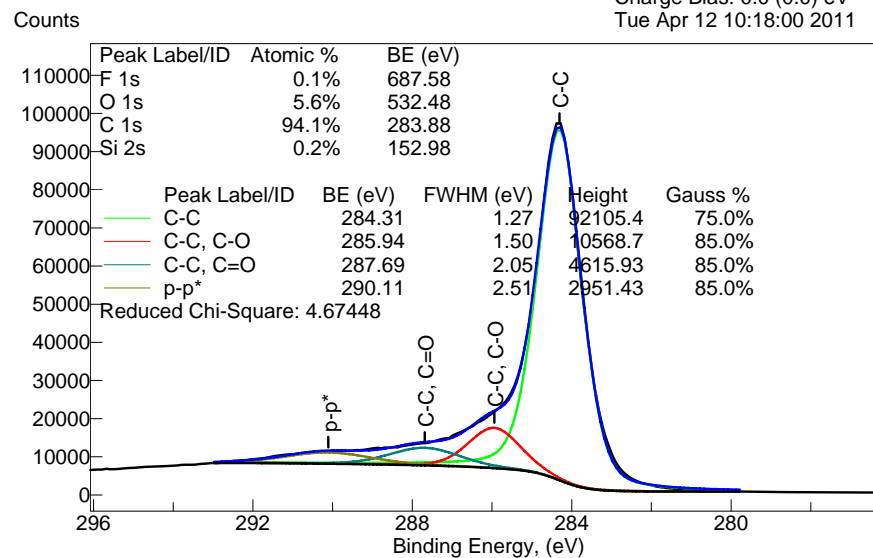
nanocarbon grade 1

System Name: XY ASCII  
Pass Energy: 100.00 eV  
Charge Bias: 0.0 (0.0) eV  
Tue Apr 12 10:18:00 2011



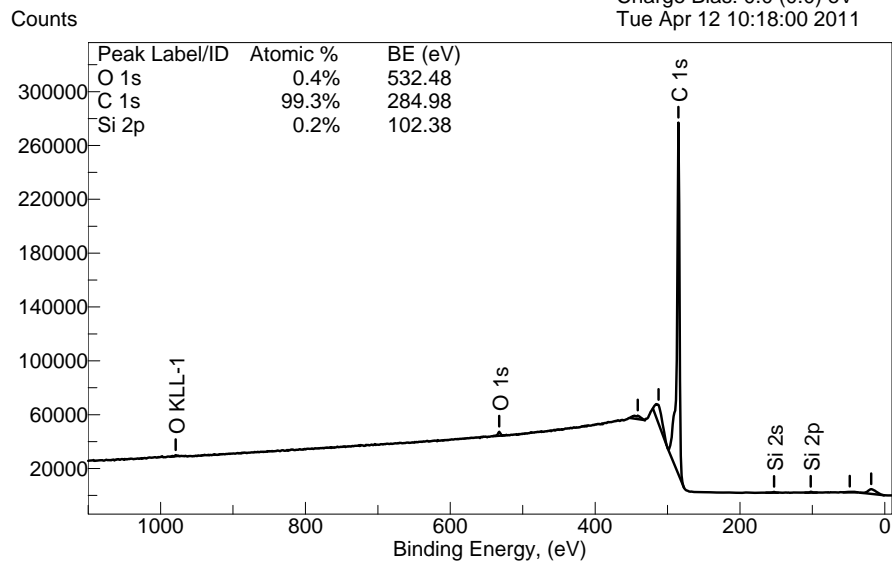
Nanocarbon grade 1

System Name: XY ASCII  
Pass Energy: 100.00 eV  
Charge Bias: 0.0 (0.0) eV  
Tue Apr 12 10:18:00 2011



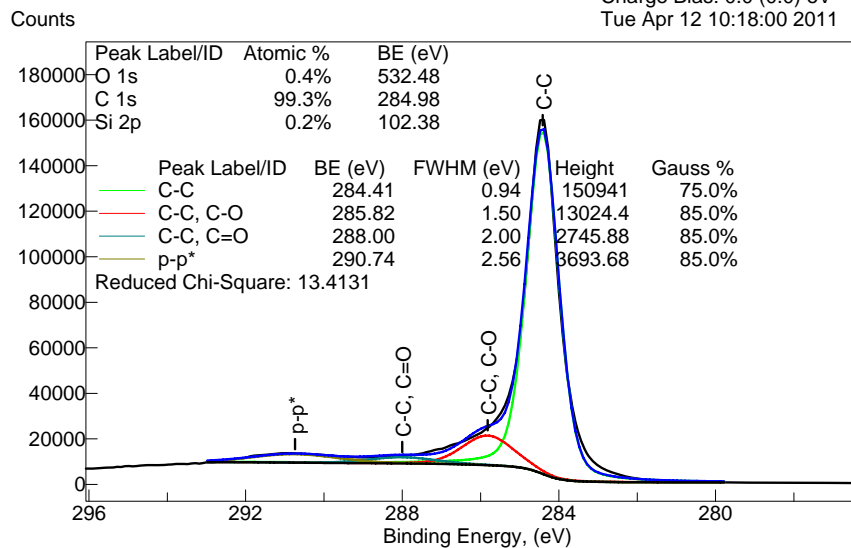
Nanocarbon grade 2

System Name: XY ASCII  
Pass Energy: 100.00 eV  
Charge Bias: 0.0 (0.0) eV  
Tue Apr 12 10:18:00 2011



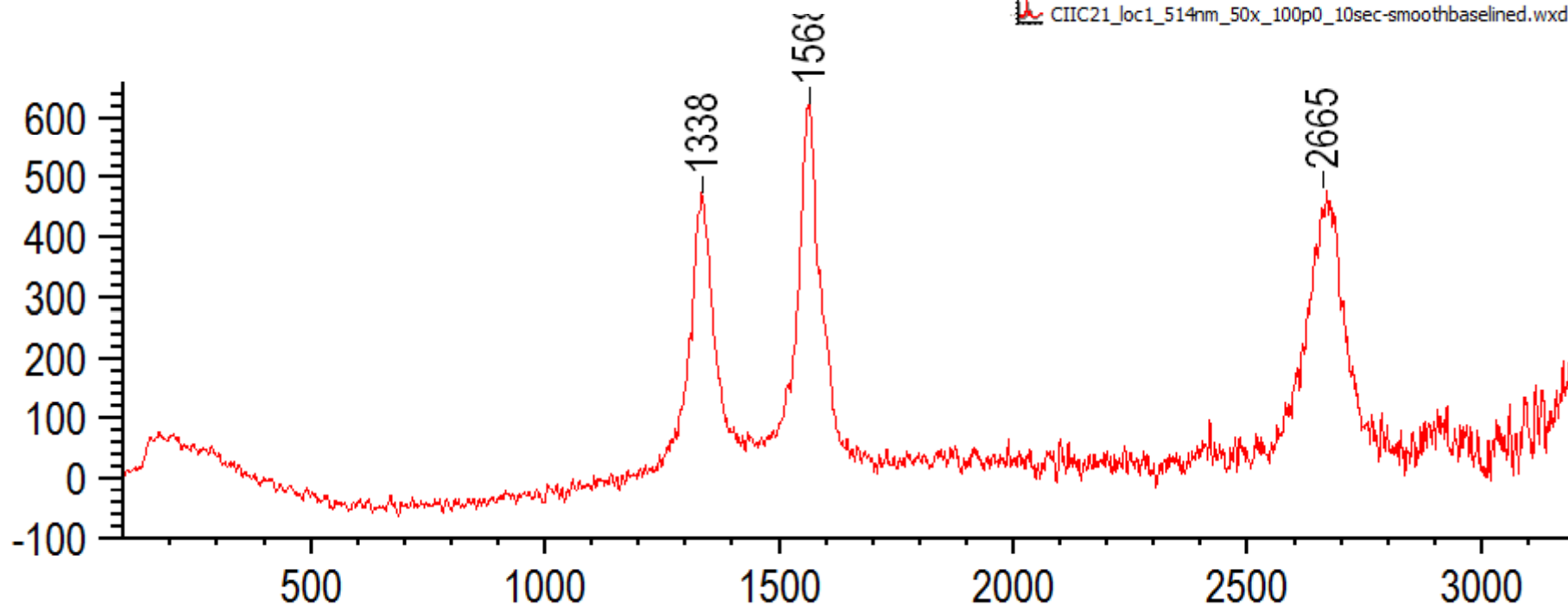
Nanocarbon grade 2

System Name: XY ASCII  
Pass Energy: 100.00 eV  
Charge Bias: 0.0 (0.0) eV  
Tue Apr 12 10:18:00 2011



# Sample 21 (Functionalized) Raman Peak Analysis

CIIC21\_loc1\_514nm\_50x\_100p0\_10sec-smoothbaselined.wxd



| Peak no. | Centre  | Height  | Width   | Area    | Absolute intensity | Low edge | High edge |
|----------|---------|---------|---------|---------|--------------------|----------|-----------|
| 1        | 1337.63 | 446.058 | 44.767  | 38186   | 475.371            | 1124.37  | 1447.68   |
| 2        | 1567.89 | 586.863 | 44.8777 | 51065.4 | 625.283            | 1450.71  | 1691.34   |
| 9        | 2665.27 | 443.355 | 81.0187 | 60764.1 | 482.645            | 2529.25  | 2798.45   |





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## Overview:

- Incumbent Training
- Hitachi S-4800 SEM
- Hitachi H-9500 TEM
- Thin Film Deposition
- Carbon Deposition



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## SEM: S-4800:

Sample preparation  
Instrument loading  
Image acquisition  
EDX/EDS analysis

## TEM: H-9500:

Sample preparation  
Instrument loading  
Image acquisition  
EDX/EDS analysis

## Thin Film Deposition:

- Vacuum operation
- Target selection / parameters
- Operating feedback
- Step height analysis
- EDX thin film analysis

## Nanocarbon Deposition:

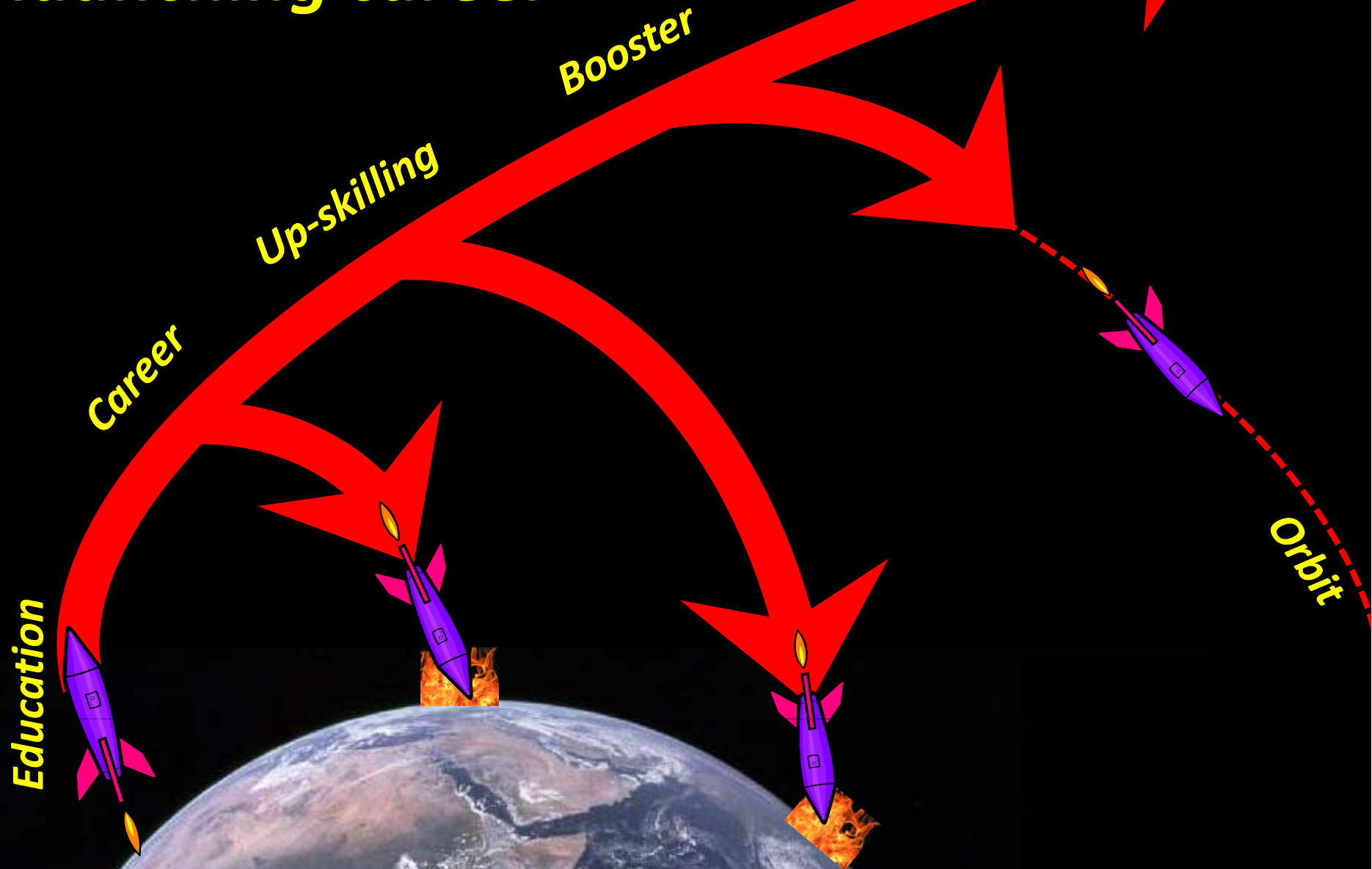
- Gas handling safety
- Gas monitoring
- Plasma operation
- Growth parameters
- Characterization



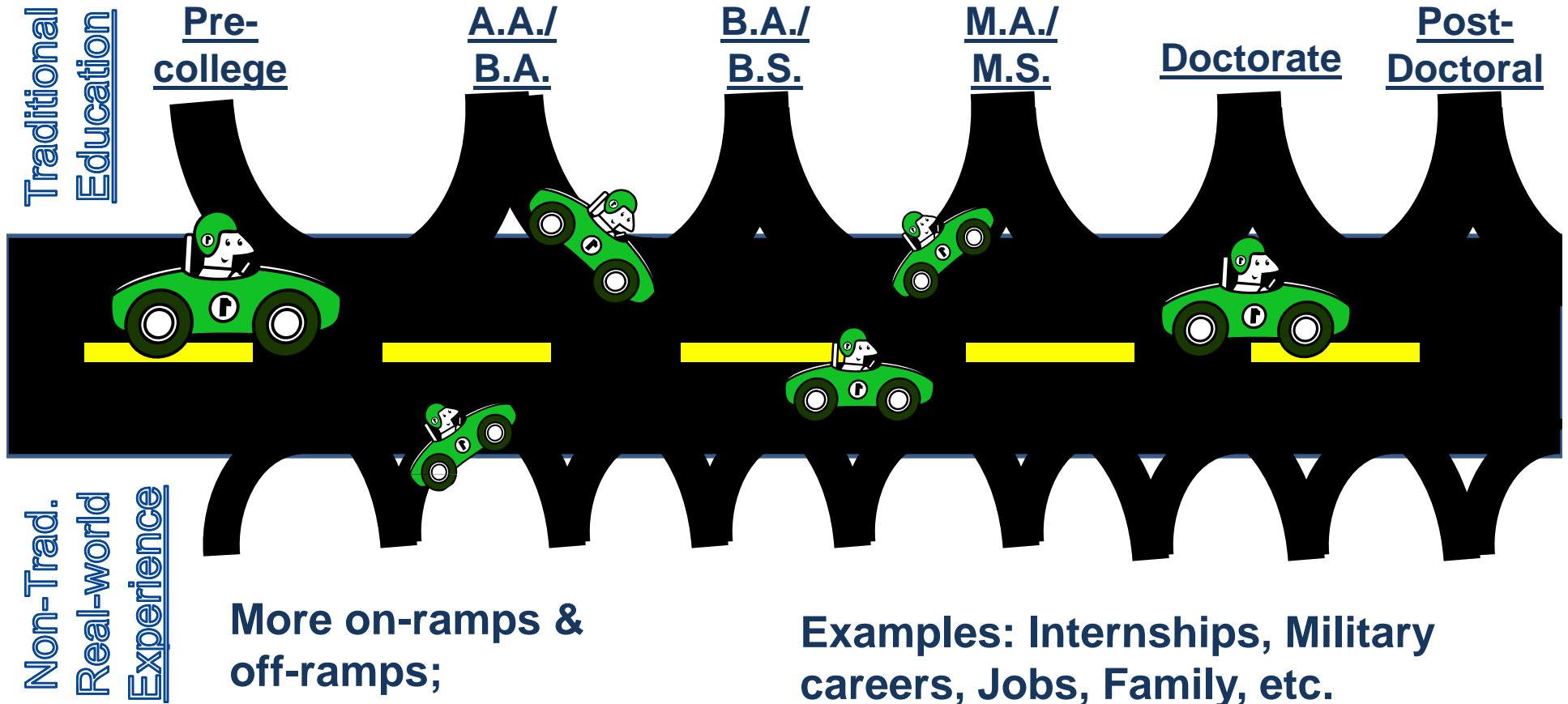
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# *Multiple stages of a launching career*



**Vision: Individually Customizable  
Student Training and Development Program**





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## Contact Info:

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<http://macs.advancedstudieslabs.org>

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- P. Murray, Foothill College Dean
- J. Gacusan, W. Page, D. Mo, E. Sandoz-Rosado, D. O'Brien, S. Takahashi, Nanocarbon growths
- Danny Cross, Tom Strickland, Steve Wallace, Clean Technology International Corp. (CTIC)



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