AMO Program in Covetic Nanomaterials

David R. Forrest, ScD, PE, FASM
Technology Manager
Dept. of Energy, Advanced Manufacturing Office

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Outline

- What are covetics?
- Why are they important?
- What are the key technical challenges?
- How is our program structured to address the key challenges?
- Why is this program a proper role for government?

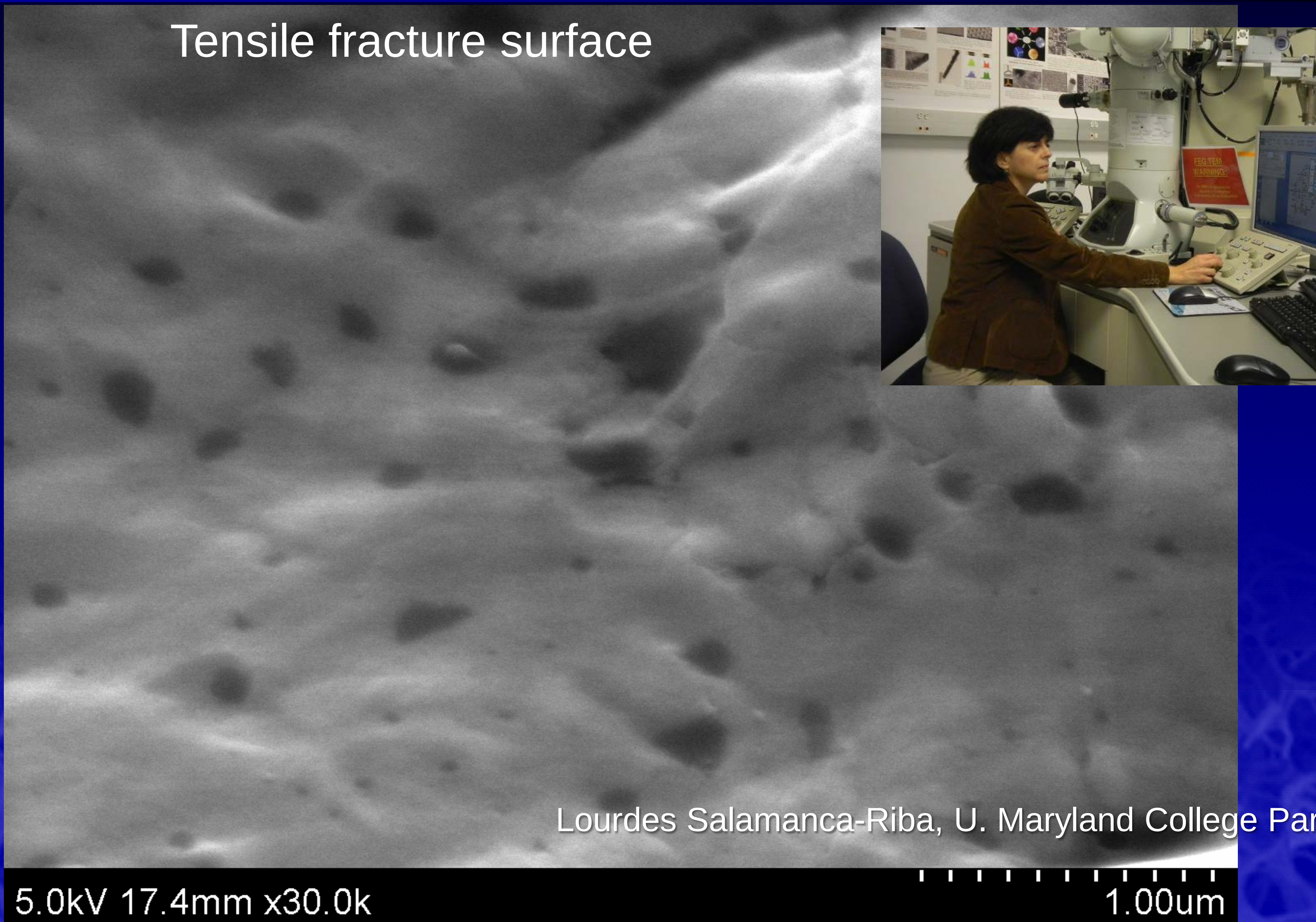
What are Covetics?

- Melt the metal, stir in carbon powder, submerse electrodes, apply voltage
- Works with a wide range of metals (Al, Cu, Au, Ag, Zn, Sn, Pb, and Fe and. . .);
- Conventional furnaces, electrodes, electromagnetic or gas stirring, infrastructure readily available
- Can remelt, dilute, alloy
- Particularly promising because of scalability

Background

- 1999 Roger Scherer
- 1999 Aluminastic
- 2005 Third Millennium Metals
- 2010 Naval Surface Warfare Center
- 2011 University of Maryland
- 2014 DOE Lab Funding initiated
- 2015 GDC Industries, LLC: research quantities, ~100 lbs Al, ~300 lbs Cu per heat
- 2016 General Cable began investing

Particles



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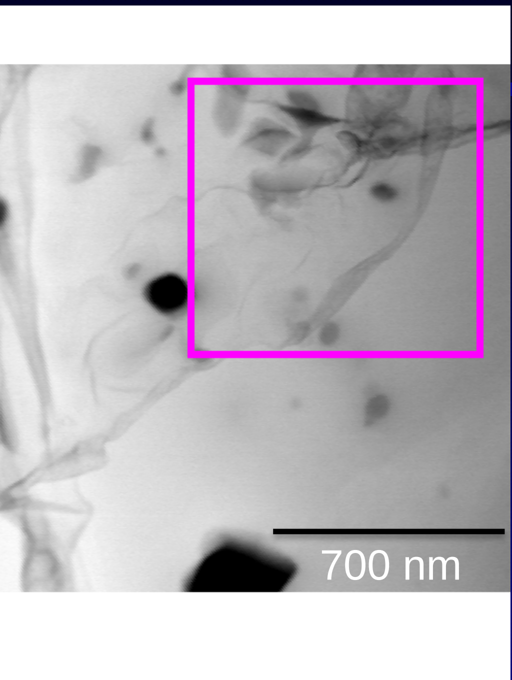
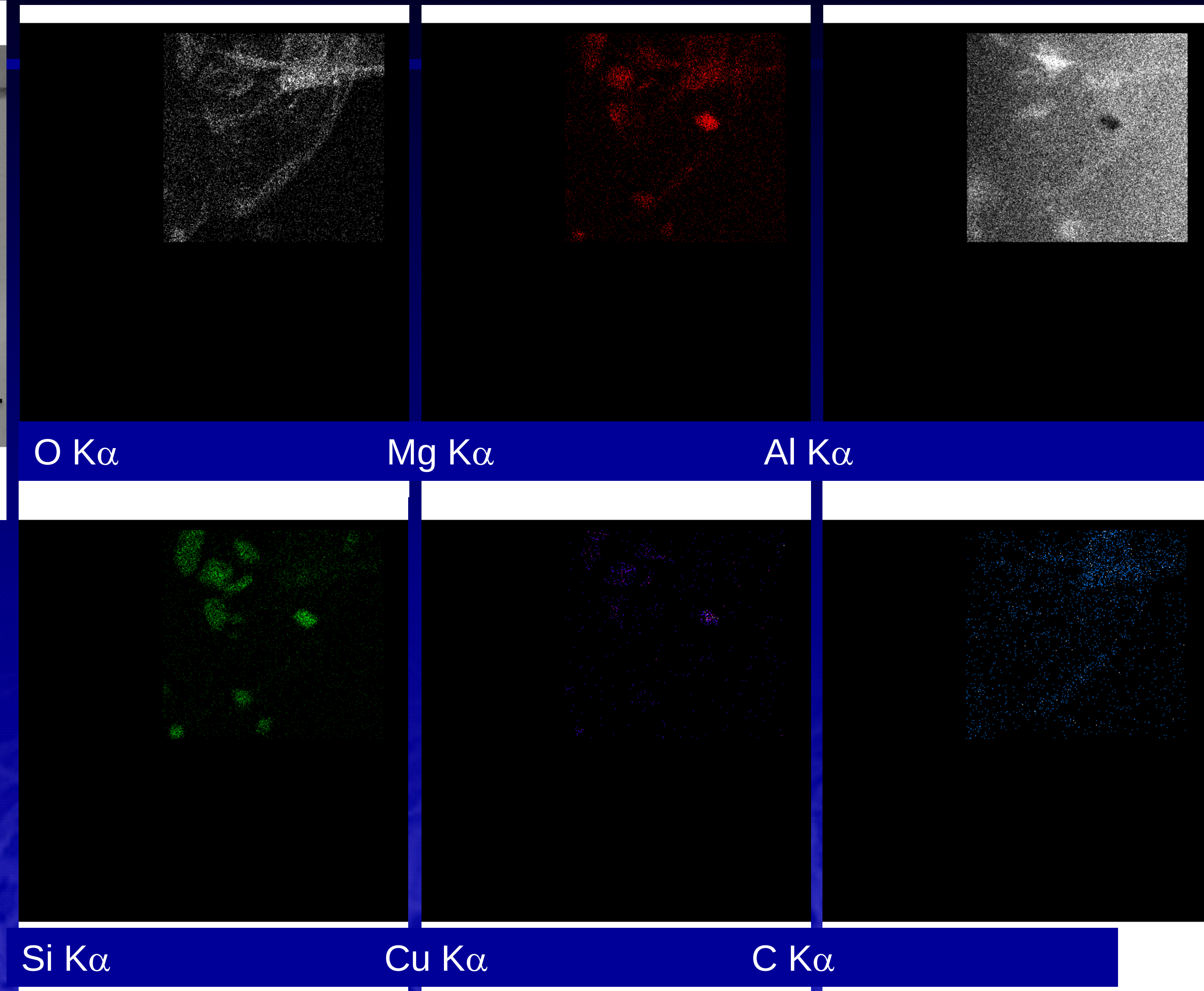
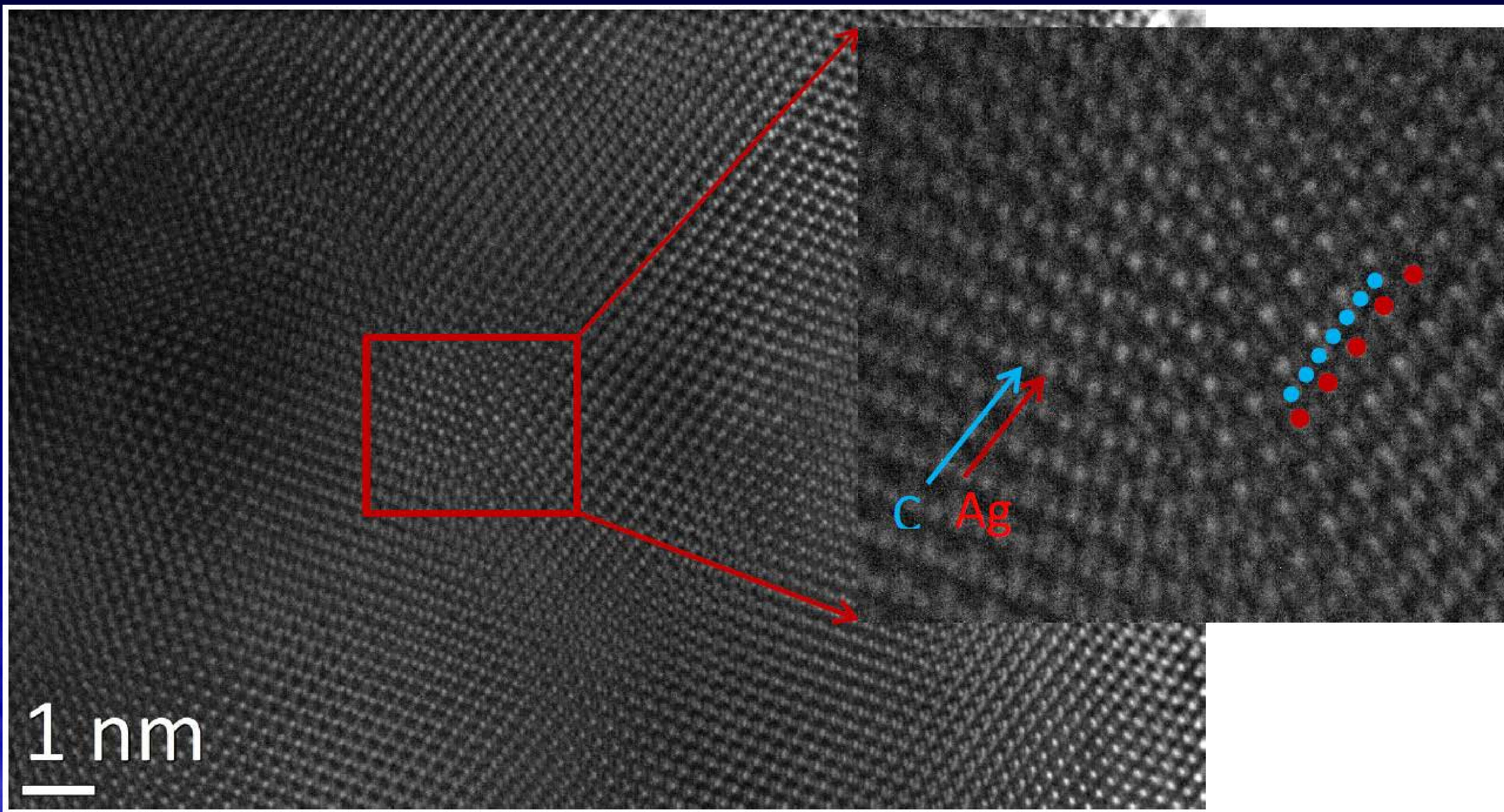
Ribbons





- Ribbon has high C and O content.
- Particles have Mg, Si and Cu.

Carbon Atoms in Between Metal Atoms



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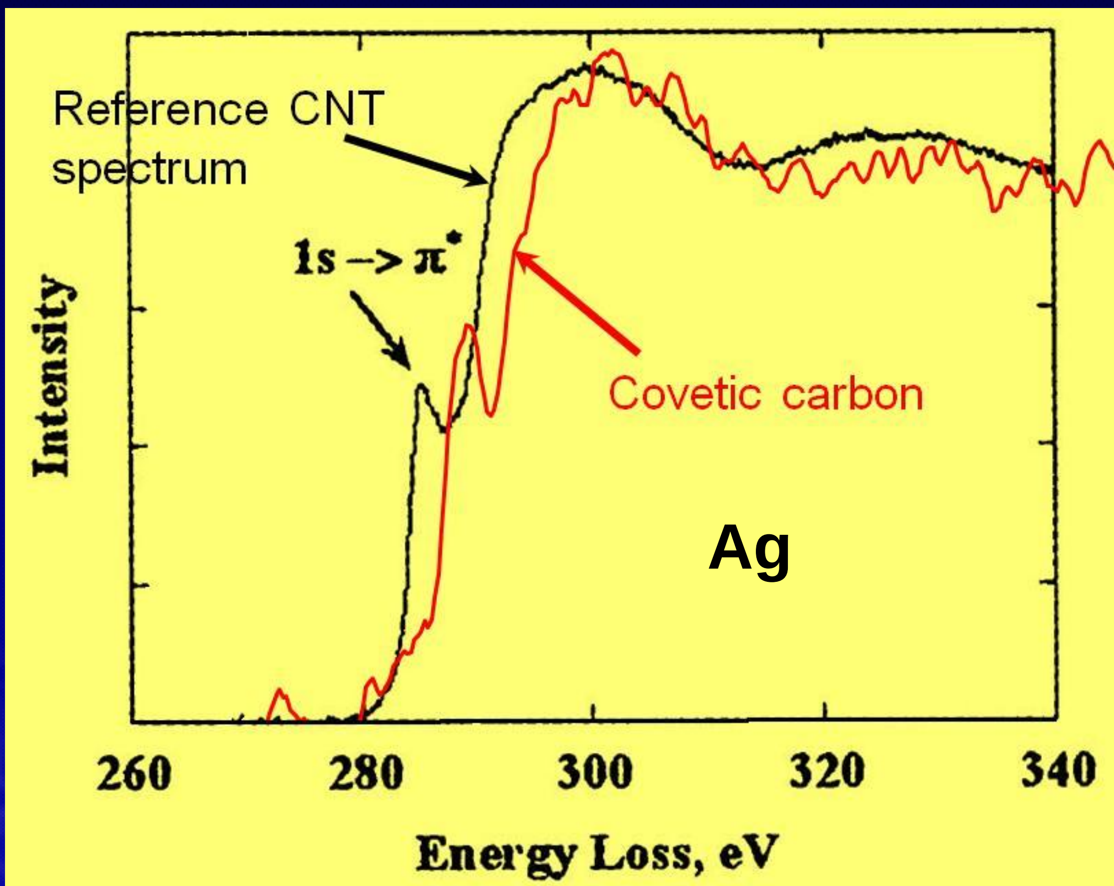
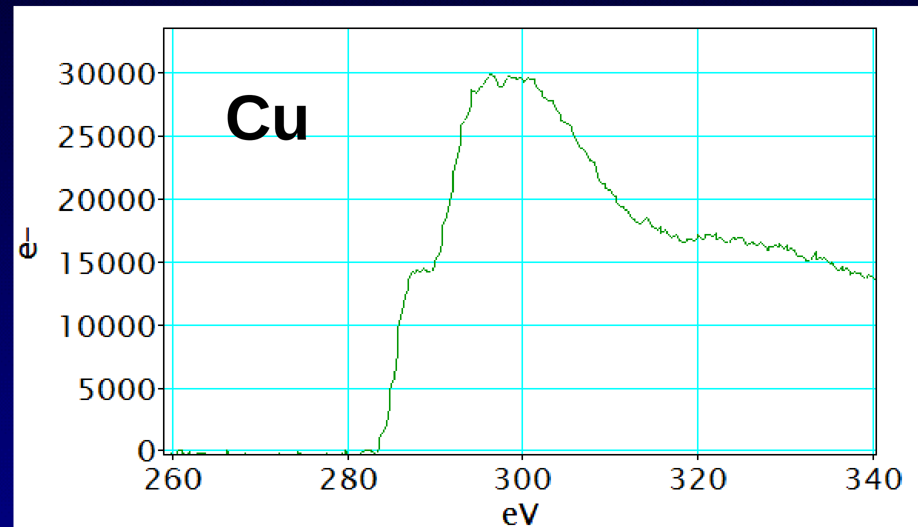
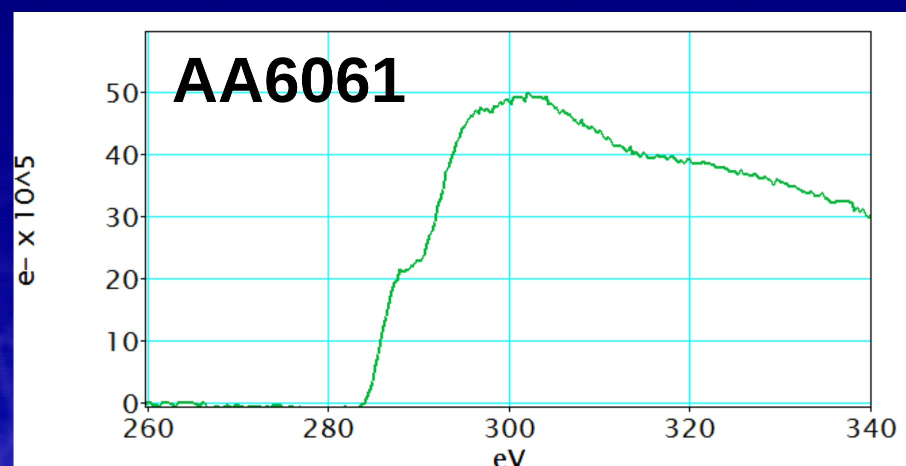
EELS and Raman: Looks variably like SWCNT, amorphous carbon, graphene







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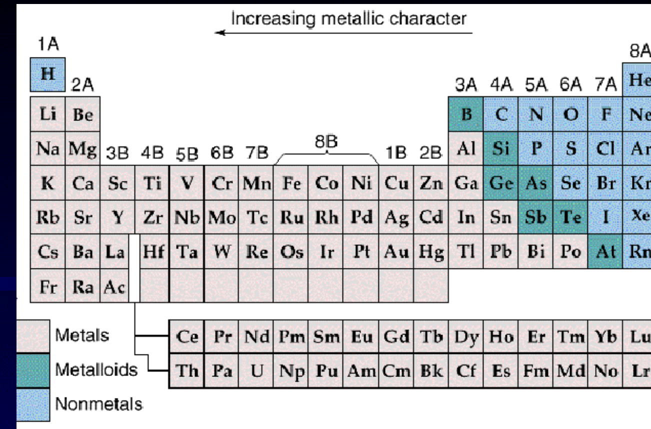
Schlittler, et al., “Single Crystals of Single-Walled Carbon Nanotubes Formed by Self-Assembly,” Science, New Series, Vol. 292, No. 5519 (May 11, 2001), pp. 1136-1139

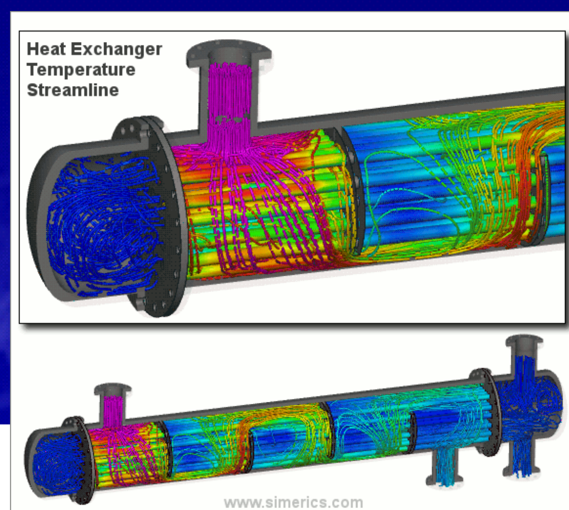
What are Covetics?

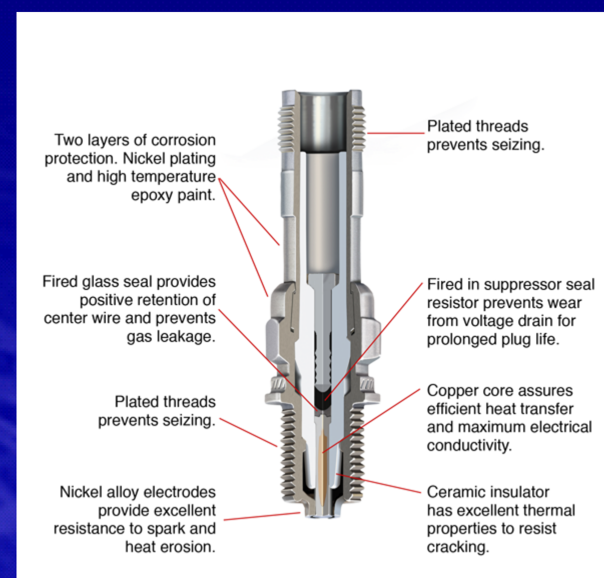
- Increased thermal conductivity: possibly up to 10X for some alloys
- Increased electrical conductivity: possibly 40% for aluminum alloys
- Increased melting point (20 - 30°C)
- New science: previously unknown nanophase
- Effect on strength is arguable; possibly improved at elevated temperatures
- Almost no effect on density (not a lightweighting technology)
- Properties have preferred direction; thermal conductivity is different: transient vs. steady state

Why are Covetics Important?



- Scalable process
- Raw material cost is low (1¢ / lb product)
- Far-reaching impact—possibly *all* the metals in the periodic table
- Thousands of energy applications





Key Technical Challenges

- No fast, reliable method for chemical analysis of C
- Need to reliably reproduce the conversion process in independent lab
- Physics of the conversion process are unknown
- Spatial distribution of disks and ribbons not quantified; anecdotally: highly non-uniform
- Physical properties are not consistent
- Don't understand nature of carbon bonding with metal matrix or role of oxygen if any
- Are there limits to amount of deformation processing?
- Need method to rapidly explore wide range of potential alloys/applications

How is our program structured to address the key challenges?

- Argonne (Balachandran):
  - Characterization of nanocarbon morphology, size, distribution, and interface
  - Thermal and electrical conductivity, isotropy, stress
  - Analytical methods
- ORNL (Feng): development of rapid synthesis methods, take advantage of small scale to study process of conversion of carbon to tenacious nanocarbon
- NETL Albany (Jablonski): Replicate process for kilogram scale heats, develop methods to improve uniformity of carbon distribution, develop improved conversion methods
- SBIR: 3 Phase I Projects funded
- Next Gen Electric Machines 2: Topic currently in play

Proper Role of Government; Aligned with AMO Mission

- Cross-cutting technology / Advanced Manufacturing Process
- Lack of a well-understood science base makes the technology look speculative and high risk
- Program de-risks covetic processing and covetic nanomaterials for private investment
- Establishes core competencies at national laboratories
- Develops infrastructure to explore new energy applications