Imaging Thin Films of Pentacene

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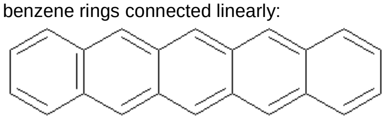
ABSTRACT

Recently, the electrical properties of pentacene, a molecule consisting of five benzene rings, have been studied extensively in light of their possible use as an organic semiconductor. It is of interest to the materials science community to have a reliable way of measuring both the topography and the crystal structure of thin films of pentacene. The advantages and disadvantages of three imaging methods have been analyzed in this context: Scanning Transmission Electron Microscopy (STEM), Atomic Force Microscopy (AFM), and Scanning Electron Microscopy (SEM).

BACKGROUND

Each molecule of pentacene consists of five benzene rings connected linearly:



Previous studies have shown that electronic mobility in pentacene can be comparable to that in amorphous silicon, the modern standard for semiconductors. However, this mobility has only been observed in very ordered samples of pentacene.

Like other crystals, pentacene grows in grains (finite bounded regions of identical crystal orientation). There is evidence that the limiting factor for electron mobility in disordered samples is in the grain structure.

Further Reading:

1. D.A. Muller, *Nature Mater.* **4**, 645 (2005).
2. L.F. Drummy, et al, *Adv. Mater.* **14**, 54 (2002).
3. L.F. Drummy, et al, *Ultramicroscopy* **99**, 247 (2004).
4. J.S. Wu and J.C.H. Spence, *J. Appl. Cryst.* **37**, 78 (2004).
5. J.G. Laquindanum, et al, *Chem. Mater.* **8**, 2542 (1996).

OBJECTIVES

1) To image thin film pentacene via three different imaging methods: TEM, AFM, and SEM.
2) To compare the advantages and disadvantages of each method.
3) To determine the best way to image pentacene grain structure (important for electronic analyses) along with the pentacene topography (important to verify correct sample preparation).

METHODS

1. Scanning Transmission Electron Microscopy:

(electrons passed through sample)

2. Atomic Force Microscopy:

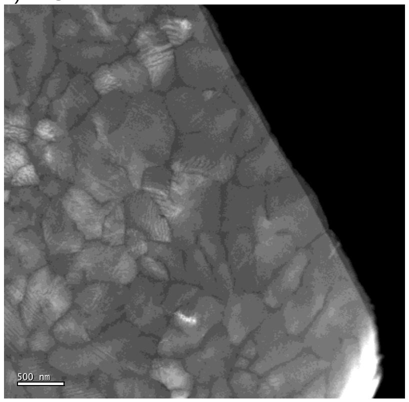
(sample probed with a cantilever tip of atomic dimensions)

3. Scanning Electron Microscopy:
(electrons dislodged from the sample surface)

RESULTS

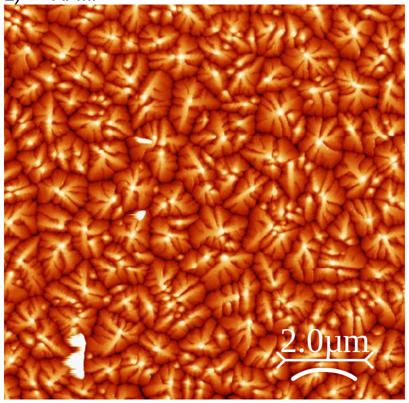
*Samples are 40nm thick pentacene deposited on Si_3N_4 Prepared by Alex Mayer, Department of Materials Science & Engineering

1) STEM:



- Difficult to distinguish grain boundaries
- Almost no topographic information
- Grain structure and twinning boundaries (stripes in image) very visible
- Sample damaged quickly under electron beam

2) AFM:

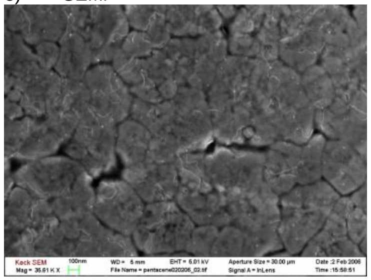


- Oustanding topographic resolution
- Grain boundaries very clear
- No crystallographic (grain structure) information
- No damage

RESULTS

*Sample is 40nm thick pentacene deposited on holey carbon film by Jared Mack, Department of Materials Science & Engineering

3) SEM:



- More topographic resolution than STEM
- No crystallographic information
- Still difficult to distinguish grain boundaries
- Sample damaged quickly

CONCLUSIONS

For topographic information and grain boundary definition, AFM is superior. For crystallographic information, such as twinning and crystal orientation, STEM is best. The SEM fails mainly in its inability to display crystal orientation (since electrons do not pass through the sample), but it is the lower electron beam energy in the SEM that allows us to see more of the topography of the sample. One possibility currently under investigation is to pass electrons through the sample at this lower beam energy. The idea is that the transmission of electrons through the sample will allow us to see the crystal orientation and twinning, while the lower electron energy will allow us to see how thick the sample is.