Fast but smooth - Cornell group wins MRS Poster Award for explaining new growth method for organic films

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The Materials Research Society (MRS) awarded a “best poster prize” to four collaborative groups at Cornell for their work “*In-situ* Real-Time Synchrotron Study of Small Molecule Organic Thin Film Growth from Hyperthermal Molecular Beams”, which reported the unexpected behavior of thin films of an organic semiconductor. The effort was headed by James Engstrom, faculty in the Cornell School of Chemical and Biomedical Engineering. This award was one of six bestowed on over 500 posters viewed by thousands of attendees at the San Francisco meeting held April 9-14, 2007.

The poster presented some of the first-ever results the team obtained using a new supersonic molecular beam growth chamber in the G3 X-ray station at the Cornell High Energy Synchrotron Source, CHESS. The growth system includes an ultra high-vacuum chamber and a supersonic molecular beam source, allowing fine control over the molecular beam energy and flux, with windows for full X-ray access, all built atop an X-ray diffractometer that provides *in-situ* characterization of film quality and ordering during growth. The supersonic molecular beam deposition chamber was built and tested by former graduate students Todd W. Schroeder and Aravind S. Killampalli. The set-up can be used to study how thin film growth dynamics depend on kinetic energy of arriving molecules, growth rate, substrate temperature, and chemical modification of the substrate surface. *In-situ* X-ray scattering is used to measure deposition rates and characterize the morphology and structure of thin films.

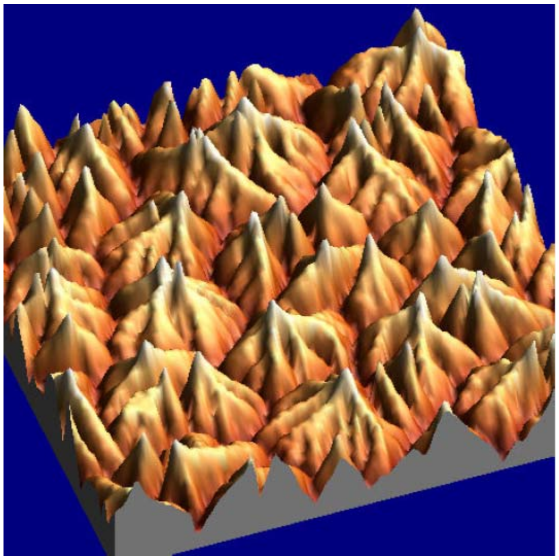
Aram Amassian, lead author on the poster, was in charge of the effort to couple the supersonic beam chamber to the G3 X-ray station; he was also first to observe the novel growth behavior. He is currently a NSERC (Canada) Postdoctoral Fellow in the Cornell Laboratory for Organic Electronics (CLOE). CLOE is led by George Malliaras, faculty in the Materials Science and Engineering department at Cornell. Coauthors included Joel D. Brock, Applied and Engineering Physics, director of the G-line division of CHESS, and Arthur Woll and Detlef Smilgies, who are staff scientists at G-line and CHESS, respectively.

Pentacene thin films are currently the organic semiconductors with the highest field effect mobility measured – even exceeding that of amorphous silicon. Growing high quality organic thin films, however, presents new challenges quite different from those found (and overcome) in the highly mature field of silicon device manufacture. Traditionally, thin films grown by deposition techniques show improved ordering and flatness at low deposition rates. Intuition predicts that during “slow growth” atoms and molecules have sufficient time and surface mobility to “self anneal,” forming more-or-less complete two-dimensional layers growing one atop the other.

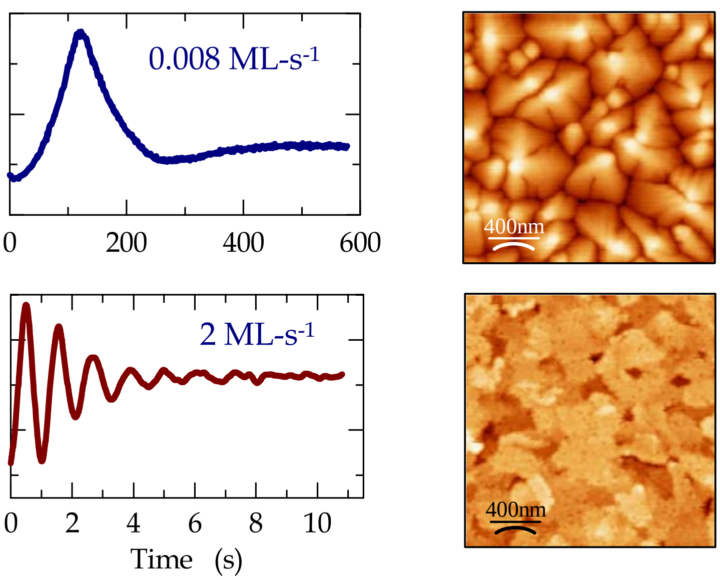
This poster shows early results that suggest that pentacene does just the opposite. That is, two-dimensional growth appears to be promoted under the highest deposition rates, resulting in films with smoother and flatter surfaces. X-ray data show the in- and out-of-plane structure of the rapidly-grown films are both different than found in films grown at low deposition rates. These findings raise the distinct possibility that some of the pentacene polymorphs may be synthesized with ultra-flat surface morphology, making them suitable for use in a number of electronics applications. In the past, the need for sharp, smooth interfaces has limited electronics device designers to using amorphous organic thin films.

The poster was organized into clearly legible sections guiding the reader from an introduction to the technique to first results from X-ray measurements. The “take home message,” “context” and “issues” sections started with the potential impact organic semiconductors and possible flexible electronic circuits might have on the global electronics world. Readers with active imaginations can envision flexible video displays, moving images in newspapers or magazines, and wearable electronic circuits of many kinds. The remainder of the poster explained how supersonic molecular beam deposition, in which whole pentacene molecules are evaporated from a source and accelerated to varying energies and flow rates, can be used to tailor film growth and to learn about optimal growth conditions and mechanisms.

Poster winners were announced at the beginning of the poster viewing session; even so, Amassian was surprised that hundreds of people “swarmed” the poster for photos and question during the week that the winning posters were on display in the main hall. “We certainly got very wide exposure,” he adds, but now the “main focus is on getting the analysis done and publishing in a high impact journal.”



Pentacene film “terrain” viewed by atomic-force microscope (AFM). Shown is a fairly rough film deposited under 3D growth conditions.



X-ray intensity oscillations at the anti-Bragg position (00½) indicating persistent smooth 2D film growth at high deposition rates (bottom) versus 3D growth at top. AFM analysis (right) confirms 2D growth morphology versus 3D islands.