Abstract:
We have developed a new method to induce preferential alignment in organic thin films of a highly anisotropic small molecule, pentacene. Growth on pre-patterned substrates results in grain nucleation along a lithographically defined pattern. This improvement in morphology control and grain registration in organic thin films allows further investigation of transport across grain boundaries and within single grains.

Summary of Research:
Organic electronics is an emerging technology with promises of low-cost and large-area processing and fabrication of organic thin film transistors and photovoltaics on flexible substrates [1]. With recent development of lithographic patterning methods for organic materials [2], our research focus has shifted to controlling the morphology and achieving grain-scale registration in organic thin films. Preferential alignment of organic films on a substrate is an important step in achieving high crystallinity and high performance of organic thin film transistors, where high crystallinity is not sufficient for high performance due to strong anisotropy in most organic materials. Therefore, registration between grain orientations and contact electrodes becomes an important criterion in device performance.

An early attempt to achieve preferential alignment of organic films was demonstrated with an atomically stepped silicon substrate [3]. In this case, pentacene grains nucleated and grew along the silicon step edges. This process produced large pentacene grains demonstrating a preferential crystallographic alignment to the silicon step edges. Unfortunately, the underlying silicon substrate is impractical for organic electronics applications.

In our work we developed an alternative and more robust method of creating step-edged substrate by patterning self assembled monolayers (SAMs) using photolithography. By utilizing SAMs, we are able to tune the step height and step edge energy through the length and chemical composition of the SAMs. The step edge density is controlled by photolithography. This process also allows us to use a wider range of substrates.

Currently, we are working with a single layer step edge model shown in Figure 1. This system inhibits the formation of large grains spanning multiple step edges due to...
to impingement of differently oriented grains produced by neighboring steps. Using this model we have grown pentacene films on substrate with 3 µm patterned lines of HMDS and 3 µm unpatterned lines of SiO₂. Produced thin films demonstrate preferential nucleation of pentacene grains along the step edges (Figure 2), as expected from the model. Therefore we are able to achieve preferential nucleation of pentacene grains along the patterned step edges leading to an improved registration between pentacene grains and electrodes upon further patterning. These films are now being used to investigate transport across grain boundaries and within single grains.

References:

Figure 2, right: a) AFM image of pentacene grown on a SiO₂ substrate patterned by 3 µm HMDS vertical lines separated by 3 µm. b) Average height profiles along the horizontal and vertical directions. Height profiles show grain spacing of 3 µm along the horizontal direction, corresponding to the spacing between the pre-patterned step edges.