4. Nuggets

4.1 Discoveries at and Across the Frontiers of Science and Engineering

4.1.1 The Controlled Evolution of a Polymer Single Crystal

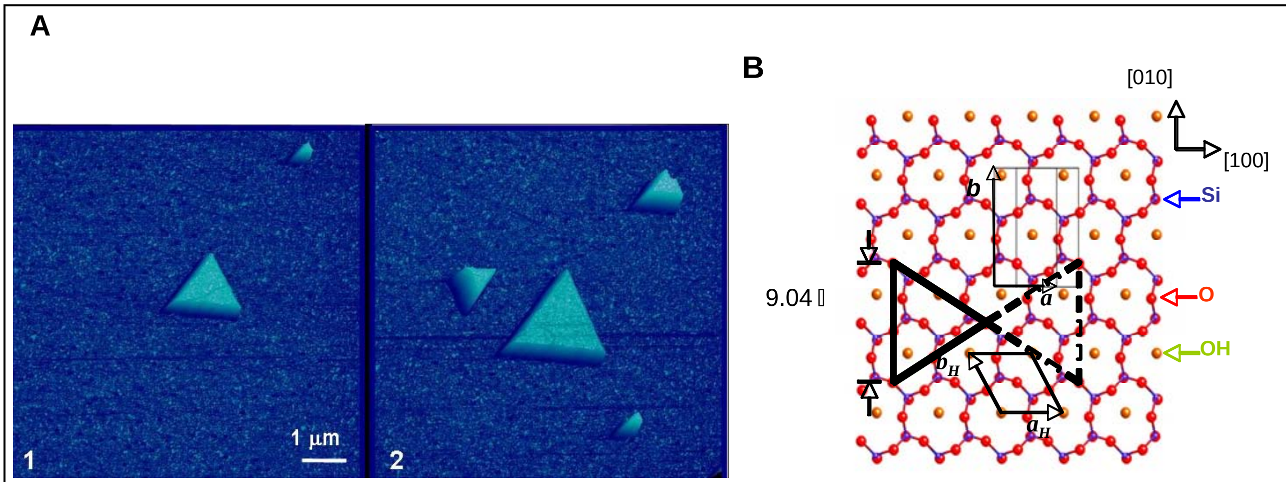
X. Liu, Y. Zhang, D. K. Goswami, J. S. Okasinski, K. Salaita, P. Sun, M. J. Bedzyk, C. A. Mirkin, "The Controlled Evolution of a Polymer Single Crystal," *Science*, **2005**, *307*, 1763–1766.

Crystallization is a crucial process in the production of a variety of products from electronics to pharmaceuticals, and is essential for the characterization of many materials. However, the understanding of the crystallization process (especially for organic, polymeric, and protein crystals) has been limited to the availability of tools to examine crystals in the early stages of formation. The understanding of crystallization processes using x-ray diffraction or spectroscopic techniques is limited until the crystal reaches a critical size of many microns.

NU-NSEC researchers demonstrated for the first time a novel method to initiate crystal growth of a polymer at a specific site, control that growth in a serial manner, and monitor the growth from nanoscopic seeds to macroscopic crystals.

They used Dip-Pen Nanolithography (DPN), a technology that employs an atomic force microscope tip coated with molecules to "write" on a surface in a controlled manner. While using DPN to "write" poly-DL-lysine hydrobromide (PLH) on a mica surface, they discovered that the process initiated crystal growth. They were able to study, record, and control the growth process, including the impact of environmental factors like humidity and temperature. Each pass of the atomic force microscope tip over the crystal causes it to grow by delivering more of the polymer to the crystal. The size of the smallest crystal the group studied in these experiments was 50 nm or five times smaller than what could be studied using traditional x-ray diffraction methods. Using the Northwestern University facilities at the Advanced Photon Source, the team was able to collect x-ray diffraction patterns from a large array to prove that the polymer islands were single crystals.

In the short-term this new method will allow researchers to gain important fundamental knowledge about crystallization. In the long-term the researchers envision being able to identify the ideal conditions for crystallizing biopolymers and proteins and developing a massively parallel DPN system capable of crystallizing hundreds of thousands of different compounds on many different substrates in a short time.



A) Two time-sequential 8 µm by 8 µm AFM images of mica obtained by continuously scanning an AFM tip coated with poly-DL-lysine (PLH) molecules in tapping-mode (Scan rate: 2 Hz). PLH triangles with edge lengths ranging from 100 nm to 10 µm and with heights from 5 nm to 50 nm have been generated. **B)** A ball-and-stick depiction of the atomic arrangement of the mica surface. X-ray diffraction showed that the triangular prisms that appear in A are single crystals and have the same orientations as the two crystallographic triangles outlined in B.