ORNL Workshop "Atom by atom fabrication with electron beams and scanning probes"

November 1-2, 2018, at Oak Ridge National Laboratory, Oak Ridge, TN

Organizing Committee:
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Background: The rise of nanotechnology was heralded by the experiments by Don Eigler (IBM), who used a scanning tunneling microscope (STM) tip to manipulate xenon atoms on metal surfaces. Concurrently, electron microscopy has emerged as a reliable and widespread tool, routinely offering atomically resolved images of materials. Unlike STM, electron microscopy has long been perceived as purely an imaging tool, with beam induced modifications in material structure considered as a hindrance, to be minimized by a proper choice of imaging conditions or beam energy. However, in the last 5 years, it was demonstrated that the electron beam can induce much more subtle and controllable changes in material structure, including chemical transformations of layered materials, chemical bonding between adsorbed molecules and substrates, crystallization of vacancy planes in oxides, controlled atomic dynamics of interstitial atoms, and single vacancy formation in layered materials. Combined with the development of beam control electronics, big data acquisition and analytic tools, and AI feedback systems, this puts electron microscopy at the brink of a transition from a purely imaging tool to one capable of creating structures with atomic precision and high throughput. If established, the field is poised for rapid growth enabled by thousands of STEM platforms worldwide. Rapid realization of the opportunities enabled by electron beam and scanning probe atomic fabrication and their synergies necessitates initiating an interdisciplinary research effort combining electron and probe microscopy, data analytics/image analysis, and electrical engineering communities, as well as stringent attention to materials science aspects of these phenomena.

Scope: This workshop will bring together experts in scanning probe atomic fabrication and atomically resolved electron beam studies to highlight the recent advances and opportunities to the attention of materials research communities and serve as a much-needed seed to establish its rapid growth. It will provide a forum to present recent achievements in electron beam manipulation, novel opportunities for instrumental development enabled by the availability of high speed data analytic tools and machine learning, integration of atomic-scale device engineering into semiconductor workflows, and opportunities for quantum information systems.

Outcomes: The workshop aims to identify areas where atom-by-atom fabrication can provide impact on quantum devices and quantum information system and establish the synergies in collaborations between the theory, instrumentation, and experimental communities.

Format: The workshop will comprise a 1.5 day lecture part given by researchers active in the field. This will consist of plenary lectures that introduce the key areas of interest, contributed talks and posters, and the demonstration of Center for Nanophase Materials Sciences (CNMS) facilities.

Confirmed plenary speakers: John Randall (Zyvex) and Toma Susi (U. Vienna)

Tentative Topics include:

- Electron beam induced dynamics of dopants, vacancies, and interstitials
- Beam induced reactions and phase transitions on atomic level
- Mechanisms and fundamental science of atomic manipulation by beams and probes
- Novel machine learning and crowdsourcing tools for guided beam- and probe fabrication
- Integration of atomic-scale device engineering into semiconductor workflows
- Fundamental science enabled by e-beam and probe fabrication