Advanced Focused Ion Beams Focus Topic
Room B110-112 - Session IB3-FrM

Beam Induced Defect and Material Engineering

Moderators: Tanvi Ajantiwalay, Pacific Northwest National Laboratory, **Gregor Hlawacek**, Helmholtz-Zentrum Dresden - Rossendorf

10:40am **IB3-FrM-8 Modeling and Experimental Demonstrations of Ion-Solid-Gas and Photon Beam Interactions During Nanoscale Synthesis**, ***Philip Rack,*** University of Tennessee, United States Minor Outlying Islands (the) **INVITED**

We study focused ion beam (FIB) processing using the Monte Carlo based simulation code EnvizION. This code simulates ion-substrate interactions and evolves the substrate to elucidate nanoscale milling and substrate damage. Additionally, we extended the simulation to include ion beam etching with a reactive precursor. The use of precursor gas for etching can greatly enhance material removal, allowing for enhanced etching at a significantly lower dose, and consequently, with much less associated damage to the bulk material. At the same time, the achievable resolution of the etched valley is impacted by a number of factors, such as the competition between chemical etching and physical sputtering, and the impact of the etching shape on gas coverage, and platform level patterning artifacts. EnvizION has been designed as a purpose built FIB simulation code, accounting for changes in the substrate configuration due to physical sputtering, as well as the dynamics of the precursor gas, while maintaining sufficient speed to practically simulate ion doses on the order of millions of ions. We study the etching of SiO2 using a XeF2 precursor gas. Etching simulations are validated against experimental data, and are used to identify how gas flux, beam current distribution, and platform level artifacts combine to determine achievable nanoscale resolution. Etching is studied for both Ne+and Ga+ion beam species, and the effective beam current distribution of each, corresponding to the experimental data, is identified. We additionally study the effect of the competition between etching gas flux and the beam dwell time, and in order to optimize resolution, we identify an intermediate gas flux for which etching resolution is the lowest.

In this presentation we will overview the EvnizION Monte Carlo simulation details including the ion-solid-precursor interactions and various sub-routines including secondary electron generation, surface energy minimization, vacancy-interstitial recombination, subsurface damage accumulation, and various precursor dynamics including adsorption, desorption, surface diffusion, secondary electron induced dissociation and ion-solid energy transfer induced dissociation. For each we will highlight the impact that the physical/chemical property effects the evolving nanoscale resolution of ion beam induced sputtering/chemical etching.

11:20am **IB3-FrM-10 Displacement Damage and Total Ionizing Dose Response of Ga_2O_3 MOSFETs**, ***Michael Titze,*** Sandia National Laboratories

Gallium Oxide (here β-Ga_2O_3) is a promising material for compact high-voltage electronics due to its high breakdown voltage compared to Si. Introduction of Ga_2O_{-3} devices in radiation environments however requires prior knowledge of their response to various types of radiation, most notably displacement damage (DD) from neutrons in reactor environments, and total ionizing dose (TID) as experienced in x-ray / gamma environments. Device testing in appropriate environments is typically expensive and requires very long exposures due to the small interaction cross section of neutrons / gammas. Instead, we use a dual-beam focused ion beam and scanning electron microscope system (FIB-SEM) to probe radiation effects through surrogate environments. The FIB is used to generate predominantly DD with a small amount of TID while the SEM generates exclusively TID.

We use SRIM and PENELOPE simulations to determine the amount of DD and TID for each beam and observe the drive current and threshold voltage shift in DD and TID environments. We find that DD degrades the drive current but does not alter the threshold voltage. TID does not alter the drive current but changes the device threshold voltage.

This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy (DOE) Office of Science. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. DOE's National Nuclear Security Administration under contract DE-NA-0003525. The views expressed in the article do not necessarily represent the views of the U.S. DOE or the United States Government.

11:40am **IB3-FrM-11 Helium Ion Microscopy for Morphological Analysis of Thrombi Extracted via Thrombectomy for Acute Stroke**, ***Michael Westphal***, *N. Frese,* University Bielefeld, Germany; *C. Sommer,* Institut für Neuropathologie, Universitätsklinik Mainz, Germany; *A. Kitsiou, W. Schäbitz,* Universitätsklinik für Neurologie, Evangelisches Klinikum Bethel gGmbH, Universitätsklinikum OWL, Germany; *A. Beyer, A. Gölzhäuser,* University Bielefeld, Germany

Strokes are one of the leading causes of death in the aging Western society. Especially in elderly patients, strokes are frequently recurring events. An essential component of stroke management after acute therapy is to diagnose the cause of the stroke forsecondary prevention. More than 50 thrombi extracted via thrombectomy were examined by chargecompensated helium ion microscopy to investigate possible correlations between their morphology and the origin.

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