# Ion Beam Milling and Secondary Electron Emissions: A Monte Carlo Simulation Study

Kyle Mahady[1], Philip Rack[1,2], Shida Tan[3], Yuval Greenzweig[4], Richard Livengood[3], Amir Raveh[4]

[1]*Department of Materials Science and Engineering, University of Tennessee, Knoxville, TN 37996, USA, kmahady@utk.edu*
[2]*Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA*
[3]*Intel Corporation, Santa Clara, CA 95054, USA*
[4]*Intel Israel (74) Ltd., Haifa 31015, Israel*

We present a simulation study of the emission of secondary electrons (SEs) due to ion beam milling. The emission of SEs due to the interaction of the ion beam with a target material forms the basis of ion microscopy, and contributes to chemical reactions associated with focused ion beam gas assisted etching. The basis of this study is our Monte Carlo based EnvizION code, which simulates the interaction of focused ion beams with targets of varying composition, including the cumulative removal of material during the milling process. The new version of EnvizION simulates ion induced SE generation, cascades, and emissions, simultaneously with ion milling (see figure for illustration). This enables us to track the dynamic evolution of the SE yield as an ion beam mills high aspect ratio features such as valleys.

In this presentation, we outline the features of the SE Monte Carlo method, as well as validating the simulated SE yields against experimental data for a variety of ion species and target compositions. Special care is taken to differentiate simulation methods for conducting versus insulating targets where the electron mean free path loss mechanisms vary. We focus on applications to ion microscopy, and the resultant target damage. We additionally describe applications to gas assisted etching, where SEs and binary collisions both contribute to the dissociation of surface adsorbed precursor molecules and subsequently the etch efficiency chemically-assisted ion beam sputtering.

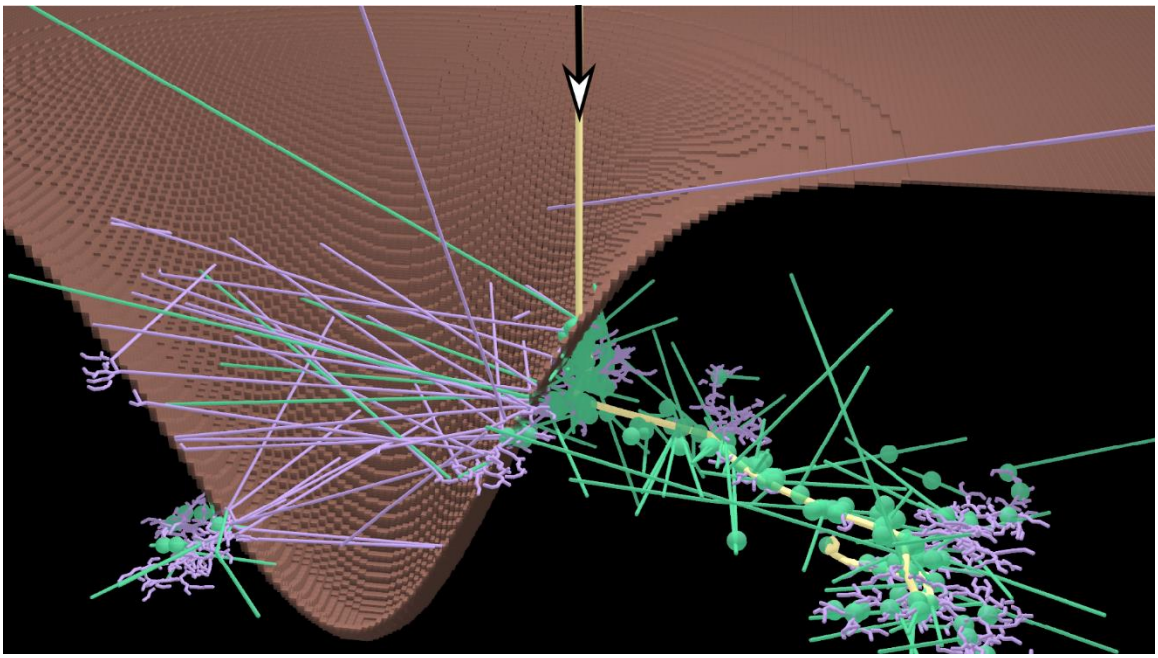

Figure: Illustration of a Monte Carlo simulation in a cutaway of a Gaussian shaped valley. An ion enters through the top of the domain (arrow), and follows the yellow path as it enters the target and transfers its energy to recoiling target atoms (purple paths). The primary ion and recoil atoms excite secondary electrons, whose paths are shown in green, with green spheres indicating SEs which are generated but do not travel more than a few angstroms.