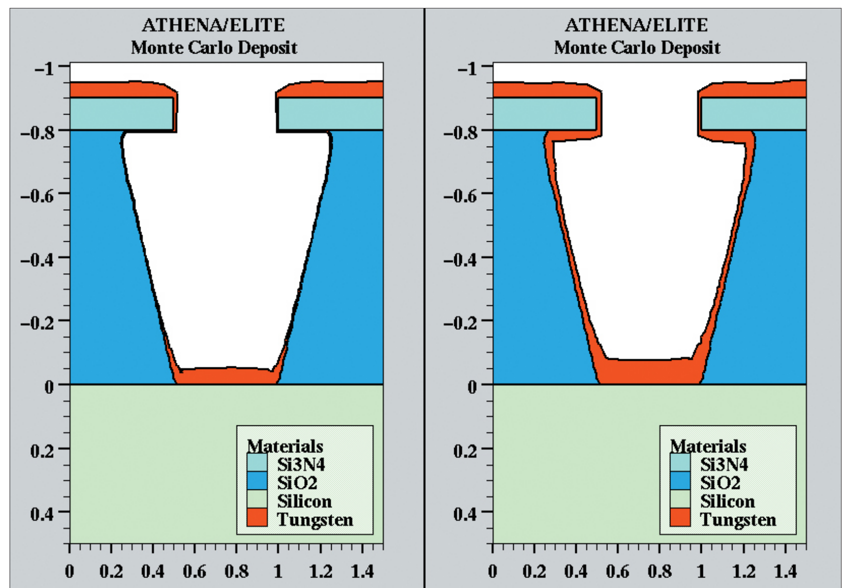
MC Deposit/Etch

2D MONTE CARLO DEPOSITION AND ETCH SIMULATOR

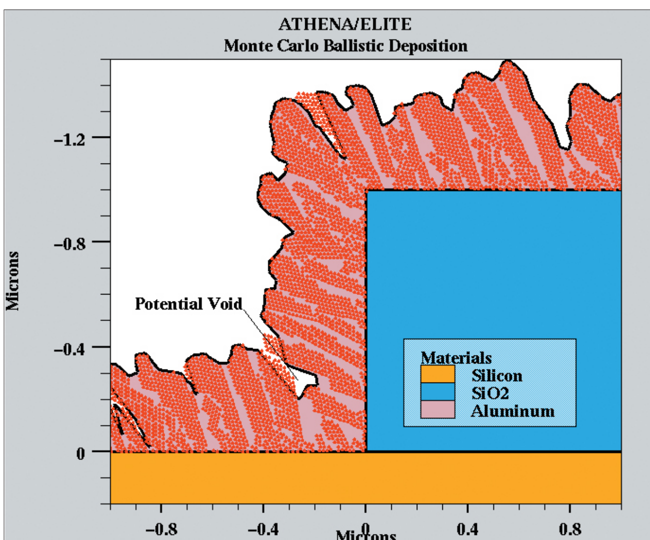
MC Deposit/Etch is an advanced topology simulation module seamlessly interfaced with Elite, through the ATHENA framework. The module includes several Monte Carlo based models for the simulation of etch and deposit processes which use fluxes of atomic particles.

Monte Carlo Deposition

The Monte Carlo Deposition model can be used to simulate low-pressure chemical vapor deposition (LPCVD). It simulates propagation of the deposited material particles along a specified direction. Since the particles are incident on the surface with non-zero velocities they may be re-emitted from the surface before they react and are incorporated into the deposited layer. The probability of atomic adherence is defined by the sticking coefficient. The re-emitted particles travel in random directions and may reach another surface which results in deposition in areas where the initial flux was shadowed. The analytical surface diffusion model provides smooth deposited layers.



In the figure above, the plot on the left is a Monte Carlo deposition with a low sticking coefficient whereas the plot the right is a Monte Carlo deposition with a high sticking coefficient.



The figure above shows Monte Carlo Ballistic Deposition over step. The deposition direction is 45 degrees from the wafer normal. The granular structure illustrates a potential void resulting from shadowing effect and variation of density inside the step corner.

Monte Carlo Ballistic Deposition

The Monte Carlo Ballistic Deposition model simulates metal film growth by random irreversible deposition of hard two-dimensional discs launched from random points at the top of the simulation area towards the structure surface. At the points of contact with the growing film, the incident discs are relaxed to the nearest cradle point where it contacts the largest number of neighbor discs. The level of this surface relaxation/smoothing is specified by a parameter related to the radius within which the disc can relax. This relaxation process simulates limited surface diffusion that usually occurs in the growing layers by reduction of the surface energy associated with areas of high curvature. This model therefore allows an estimation of the trends in local film density.

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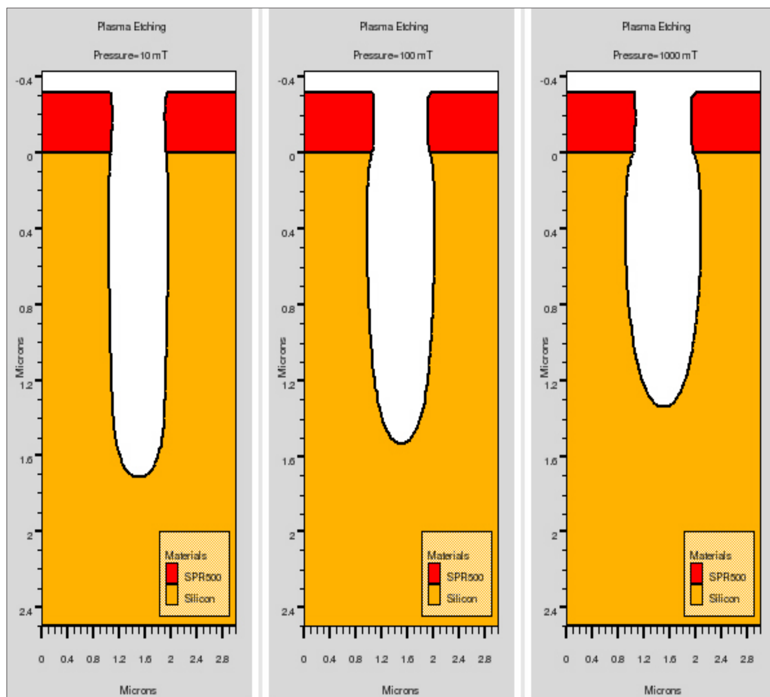
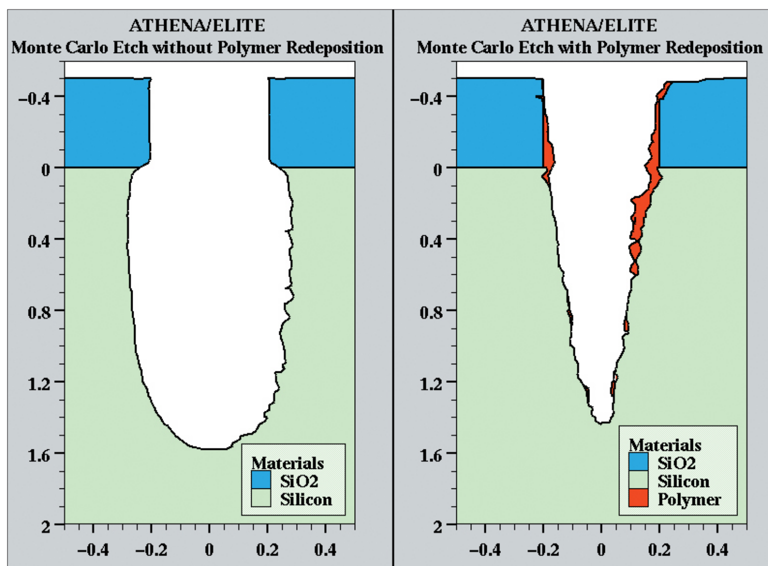
Plasma Etch Model

The Plasma Etch Model is based on a Monte Carlo simulation of the ion transport from the neutral plasma through the dark sheath surrounding the electrodes and walls and isolating the plasma. The ions are accelerated while traveling through the sheath due to the electrical potential drop between the plasma and electrodes. The Monte Carlo simulation follows a large number of ions and considers collisions with other gaseous species present in the etch chamber. The simulated Monte Carlo energy/angle distribution of ions are used to calculate an ion flux incident on the substrate surface. This flux is then used to calculate the etch rate. The "window of visibility" which depends on topology of the surface is taken into account when the local etch rate is calculated.



"The figure shows the effect of the pressure in the plasma reactor chamber on a trench etch in silicon." From left to right, the pressures used were 10, 100 and 1000 mTorrs.



The figure above demonstrates effect of polymer redeposition on etching of a deep trench in silicon. The redeposition process not only slows down etching but completely changes the shape of the trench. When simulating with the redeposition model the resulting trench has positive slopes instead of the "barrel" shape that occurs without redeposition.

Monte Carlo Etching Model

The Monte Carlo etch model is implemented into ATHENA/Elite. The main application of the model is simulation of plasma or ion assisted etching. The unique feature of the module is the capability to take into account the redeposition of the polymer material generated as a mixture of incoming ions with sputtered molecules of substrate material. In addition, the module has an interface to the C-Interpreter which allows not only user defined dependencies and parameters of the plasma etch but also user defined conditions corresponding to other processes, such as ion milling and sputtering deposition of various materials.

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