MC Depo/Etch

2D Monte Carlo Deposition and Etch Simulator

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Introduction

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

Key Benefits

- Accurately simulates low-pressure chemical vapor deposition (LPCVD)
- Accurately simulates deposition in aggressive topography like deep trench with small CDs
- Accurately simulates deep etches with small CDs
- Accurately simulates plasma or ion assisted etching
- Plasma etching model provides capabilities to analyze dopant enhanced etching
- Interfaces to C-interpreter for simulation other processes
- Seamless interfaces with Elite through ATHENA Framework

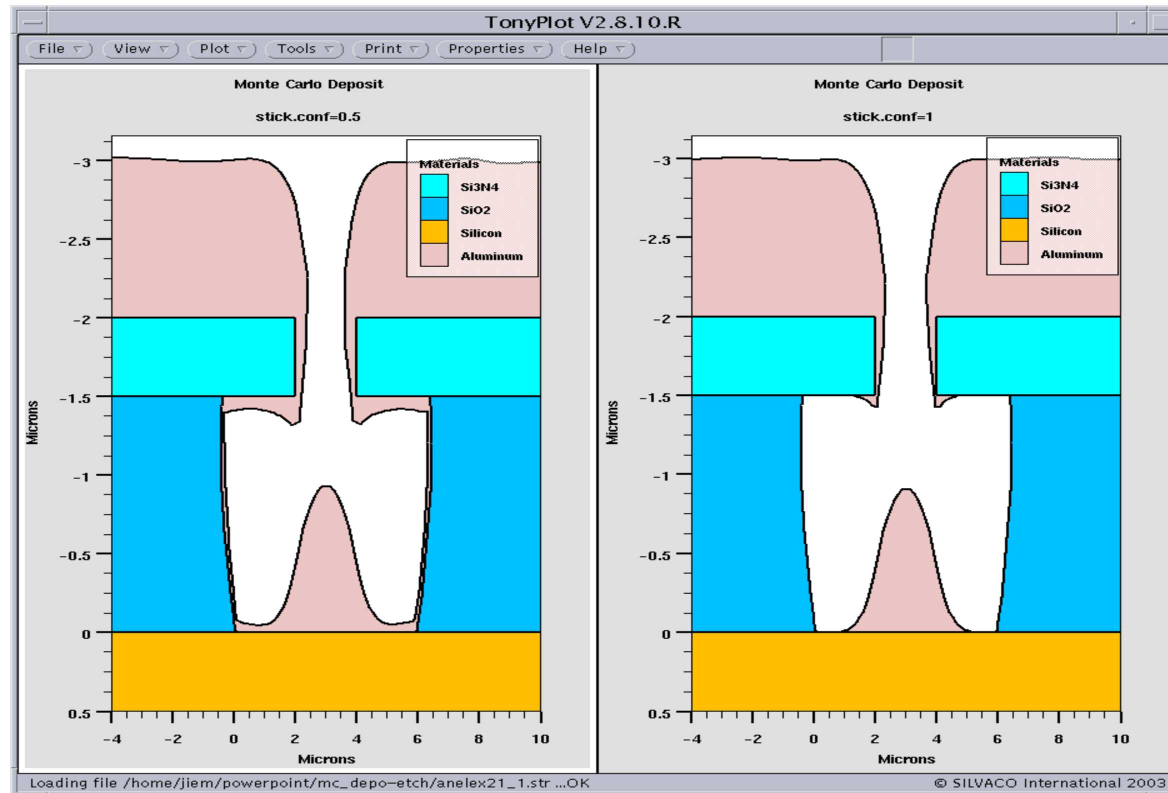
Monte Carlo Deposition

- 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 specified direction
- Since the particles are incident on the surface with non zero thermal velocities they may be re-emitted from the surface before they react and incorporated into deposited layer

Monte Carlo Deposition (con't)

- The probability of their sticking is defined by the sticking coefficient STICK.COEF
- The re-emitted particles travels in random directions and may reach another surface which results in deposition in the areas where the initial flux was shadowed
- The analytical surface diffusion model provides smooth deposited layers

Monte Carlo Deposition (con't)



Monte Carlo deposition with a low sticking coefficient

Monte Carlo deposition with a high sticking coefficient

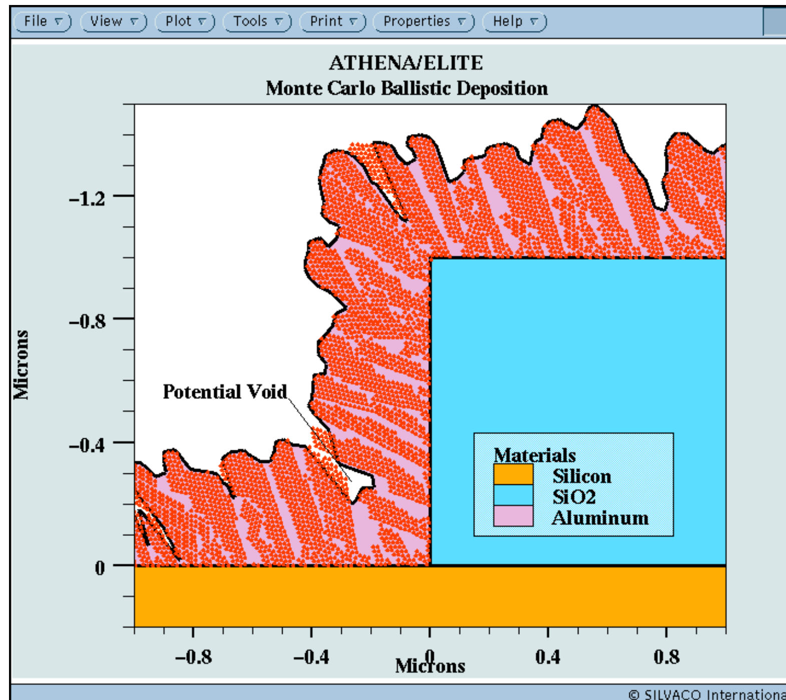
Monte Carlo Ballistic Deposition

- 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 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(SIGMA.DEP) related to the radius within which the disc can relax

Monte Carlo Ballistic Deposition (con't)

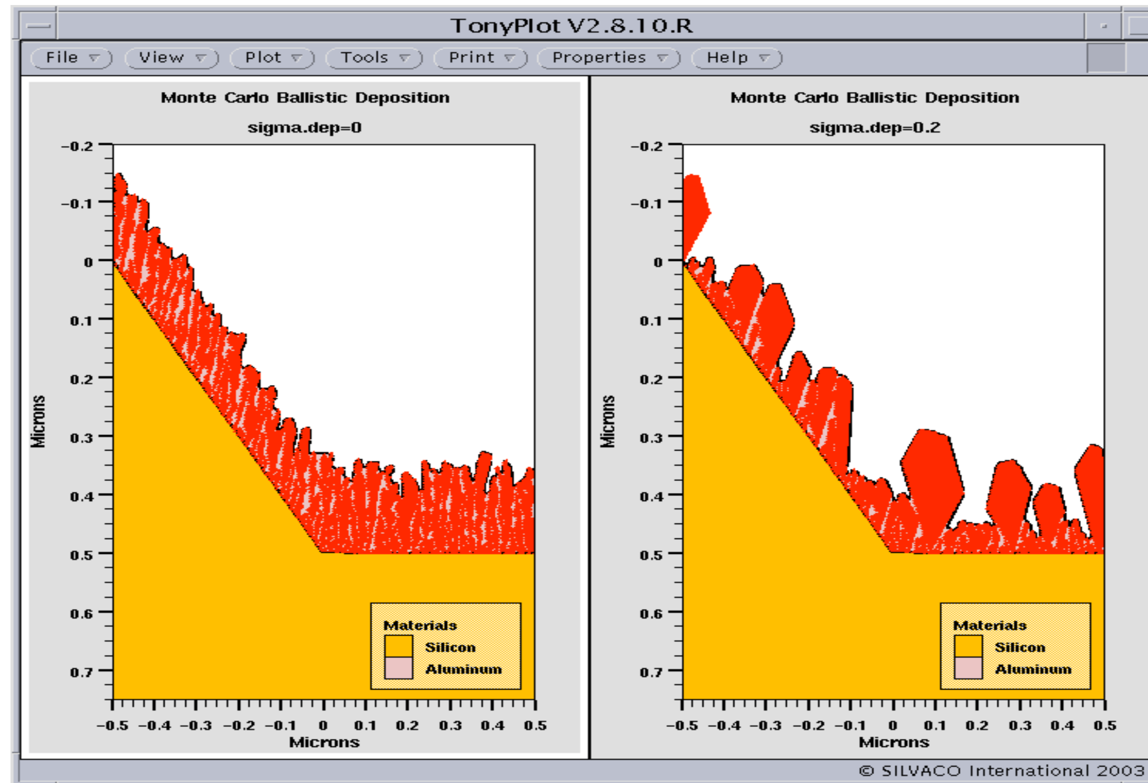
- This relaxation process simulates limited surface diffusion that usually occurs in the growing layers by reduction of the surface energy associated with areas of high curvature
- This model therefore allows estimation of the trends in local film density

Monte Carlo Ballistic Deposition (con’t)



- 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 (con't)



Monte Carlo ballistic deposition with sigma.dep=0

Monte Carlo ballistic deposition with sigma.dep=0.2

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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

Plasma Etch Model (con't)

- 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

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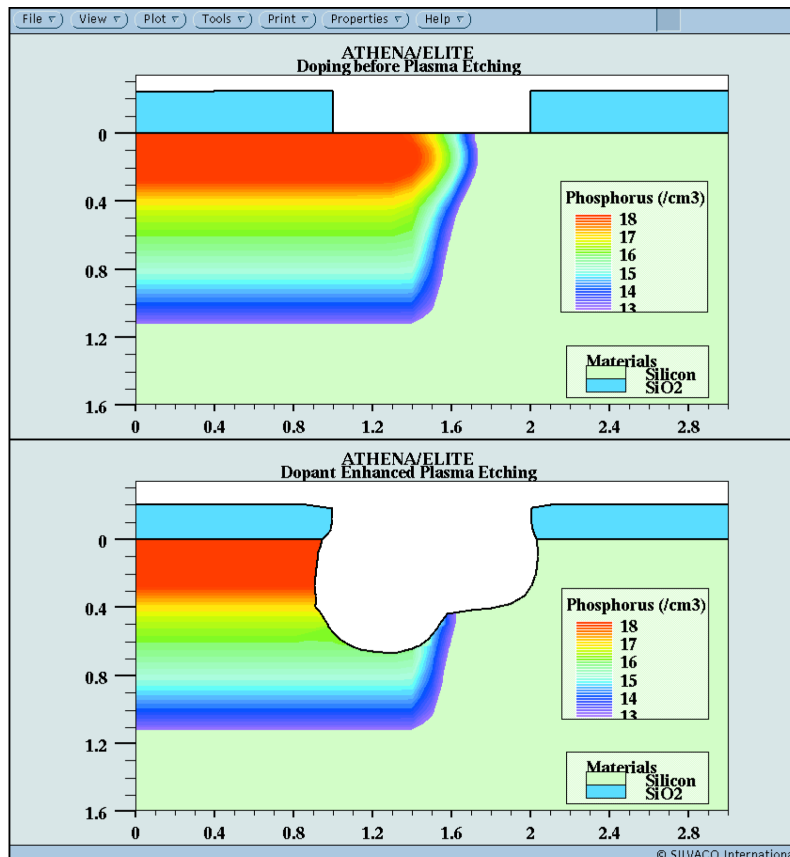
Plasma Etch Model (con't)

- Additional feature of the Plasma Etch Model is dopant enhanced etching model
- It is known that the etch rate may selectively depend on impurity concentration, damage or stresses present at the etched surface
- In order to simulate this effect the user can select a species present inside the structure as an enhancement "agent" as well as parameters of the enhancement formula
- As a result the local etch rate will be enhanced where the selected species is present

Plasma Etch Model (con't)

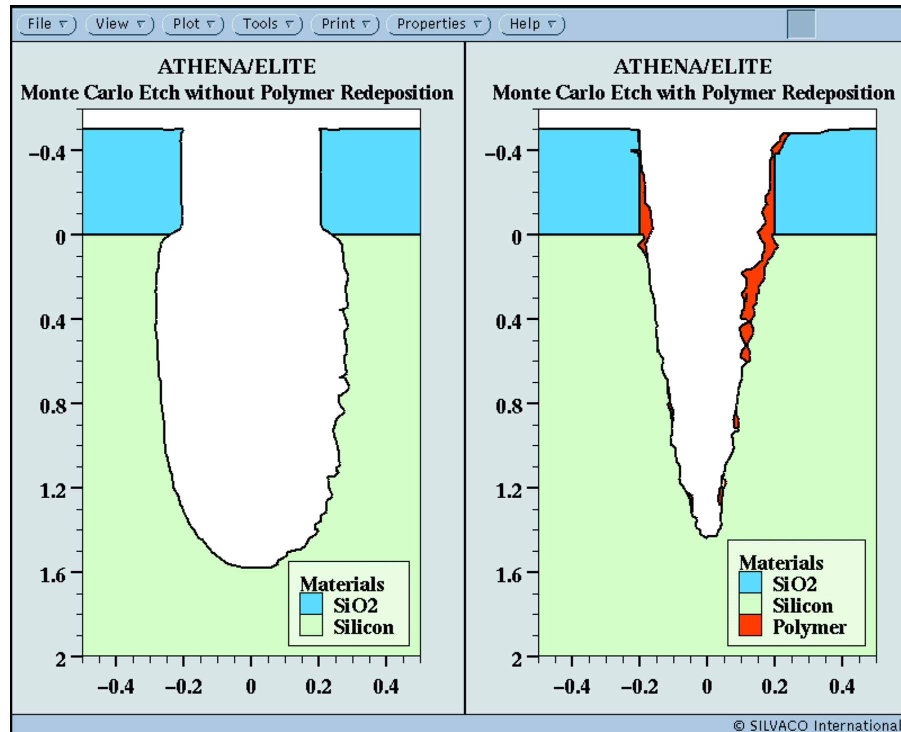


- The left part of the structure were doped with Phosphorus implant
- The Phosphorus doping enhancement was specified which resulted in asymmetrical etch profile
- Phosphorus was implanted into a part of the structure and a plasma etch was applied
- The doped part exhibits an increased etch rate

Monte Carlo Etching

- 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, e.g. ion milling

Monte Carlo Etching (con’t)



- 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:
  - the resulting trench has positive slopes instead of a "barrel" shape

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Conclusion

- The MC Depo/Etch module combines several models based on Monte Carlo simulation or particle interaction with materials
- It is interfaced with Elite and other process simulation modules with ATHENA