Mo-12:00/14 Predictive Simulation of Etching and Deposition Processes Using the Level Set Method

Clemens Heitzinger, Alireza Sheikholeslami, and Siegfried Selberherr
(heitzinger@iue.tuwien.ac.at, Institute for Microelectronics, Technical University of Vienna, Austria)
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Since the level set method provides several advantages over other techniques for describing surface evolution, a general simulator for deposition and etching processes as they occur in semiconductor manufacturing has been developed based on this method. Its main advantages are the straightforward and precise calculation of surface normals mandatory for radiosity simulations and the handling of corners both at the bottom and at the top of trenches.

The simulator developed consists of four independent modules, namely the level set module, a reaction module for the chemical reactions at the wafer surface, and a diffusion and radiosity module for tracking the transport of the particles above the wafer. It can be used for simulating all common deposition and etching processes.

In order to improve the level set method, a sophisticated algorithm for extending the speed function and narrow banding was implemented. It performs three level set computations in parallel: calculating the signed distance function via a fast marching algorithm, extending the speed function, and moving the narrow band according to the new zero level set. This gives rise to a fast and accurate level set algorithm.

For increasing the accuracy and speed of radiosity simulations, a coarsening algorithm ensures fine resolution of the surface in parts of the boundary with relatively high curvature, i.e., where it is needed most. These parts are typically the opening of the trench, its bottom, and places where microtrenching and side wall push back take place. At the same time the resolution is lowered where possible which reduces the demand on computational resources significantly.

Finally, a number of SEM images provided by Infineon Technologies were compared to simulations which agreed very well. Hence the process conditions were optimized with respect to the quality of the trenches and manufacturing throughput.

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1. Motivation

- **Developing a general topography simulator**
- **Providing a sophisticated level set algorithm**
- **Simulating processes relevant to industry**
  - Deposition of SiO_2 from TEOS
  - Deposition of poly-Silicon
  - Plasma etching

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2. Main Conclusions

- **General simulator**
  - Transport of particles by radiosity or diffusion
  - Tracking surface evolution: the level set algorithm devised combines narrow banding and extending the speed function, thus efficient and precise
  - Surface reaction module
- **Coarsening algorithm**
  - Adjacent surface elements are collapsed when they nearly lie in the same plane
  - Ensures high resolution where needed and decreases computational effort significantly

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3. Points for Discussion

- **Level set method vs. cellular format**
  - The cellular format can handle complicated structures consisting of different materials in a straightforward manner
  - The level set method provides higher accuracy

- **How to determine chemical reactions**
  - Which is the significant reaction path?
  - Which are the values of the reaction constants?