Investigation of the Effects of Charging and Secondary Electron Emission on High Aspect Ratio ONO Plasma Etching

Chenyao Huang[1], Steven C. Shannon[2] and Mark J. Kushner[3]

[1]*Department of Chemical Engineering, University of Michigan, Ann Arbor, MI USA*
[2]*Department of Nuclear Engineering, North Carolina State University, Raleigh, NC USA*
[3]*Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor, MI USA*

Abstract: Charging of features during plasma etching impacts the etch rate and critical dimensions. In this study, the effects of charging and secondary electron emission (SEE) on the etching of high aspect ratio oxide-nitride-oxide structures in a capacitively coupled plasma system were investigated using the Monte Carlo Feature Profile Model with newly introduced capabilities to address SEE combined with reactor scale modeling.

1. Introduction

During plasma etching for microelectronics fabrication, differential charging within the feature results from anisotropic ion energy angular distributions (IEAD) and isotropic electron energy angular distributions (EEAD). The charging generates intra-feature electric fields that can distort the trajectories of charged particles and lead to the formation of defects [1]. One phenomenon critical to the charging process is secondary electron emission (SEE), in which one or more electrons (secondary electrons SEs) are emitted from the surface due to the interaction with incoming particles (ions, electrons, photons). SEE results in additional charging at the incident site and redistribution of negative charges within the feature. In this study, we computationally investigated the effect of SEE on feature charging on the critical dimensions of trenches and vias during plasma etching. The SEE algorithms were applied to modeling high aspect ratio (HAR) plasma etching of oxide-nitride-oxide (ONO) structures as used in 3D-NAND memory.

2. Description of the Models

The Monte Carlo Feature Profile Model (MCFPM) is a 3D-voxel-based model that simulates the evolution and charging of the feature by tracking the trajectories of pseudoparticles that represent gas species and the interactions between the psudoparticles and surface voxel materials [2]. The model receives plasma produced angle and energy resolved fluxes from the Hybrid Plasma Equipment Model (HPEM) which simulates the reactor-scale low temperature plasma dynamics [2]. For this study, capabilities to statistically emit and track SEs resulting from ion, electron, photon, and hot neutral collisions were added to the MCFPM and the effect of SEEs on charging and HAR ONO etching were investigated [3].

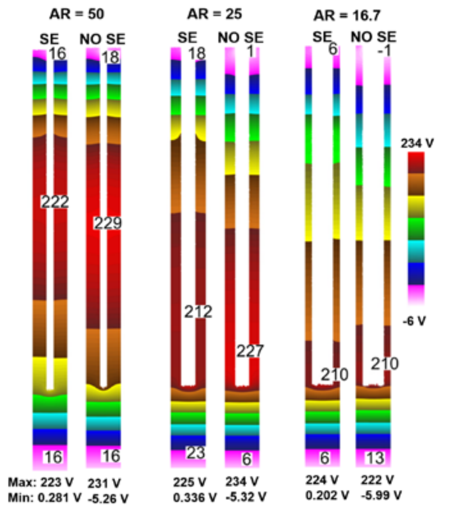

Fig. 1. Electric potential of SiO_2 feature at ARs of 50, 25 and 16.7 with and without SEE.

3. Charging of Features

Electric potentials are shown in Fig. 1 of a predefined trench in SiO_2 with aspect ratios (ARs) of 50, 25, 16.7 in a single frequency, 20 MHz, argon 10 mTorr, capacitively coupled plasma system with a constant voltage amplitude of 300V. At AR of 50, SEs emitted at the center of the feature reduce the overall electric potential by redistributing charges between the two sidewalls, making the charge distribution more uniform. As the AR decreases to 25 and 16.7, SEs emitted at the center are attracted to the bottom of the feature where the electric potential is most positive. With the larger feature width, higher electric potential in the center and lower electric potential at the bottom of the feature redistribute electrons throughout the feature.

4. Concluding Remarks

A comparative study between charging of pre-defined trench with and without SEE demonstrates the ability of SEE to redistribute charge and significantly affect the electric potential profile within the feature at ARs of 50, 25, and 16.7. Preliminary results of including SEE during active plasma etching have shown that microtrenching and sidewall slope of the feature are sensitive to SEE. Results will be discussed for fluorocarbon plasma etching of ONO HAR vias and trenches, the consequences of SEE will be assessed.

Acknowledgement

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References

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