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Pattern Dependent Profile Distortion in Plasma Etching of High Aspect Ratio Features

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In plasma processing for semiconductor fabrication, patterns are transferred from the overlying mask (typically photoresist, PR) to underlying features, ideally replicating the mask pattern. Feature distortion (e.g., twisting, tilting and edge roughness) during plasma etching can result from charging, polymer deposition and pattern dependencies. With feature sizes now less than tens of nm, there is randomness in the flux of particles into the feature. This randomness is enhanced at the etch front of high aspect ratio (HAR > 50) features due to conduction limits and side-wall scattering. Stochastic charging on the walls of features by ions can produce interference between neighboring features through the resulting electrostatic fields. The intrinsic randomness and electrostatic interference can result in profile distortion and feature-to-feature variation.
In this paper, we report on results from a computational investigation of feature distortion during pattern transfer from PR to silicon-dioxide using tri-frequency capacitively coupled plasmas sustained in fluorocarbon gases. The reactor scale modeling was performed using the Hybrid Plasma Equipment Model (HPEM). The feature scale modeling was performed using the 3-dimensional Monte Carlo Feature Profile Model (MCFPM) which was updated to address patterns having different arrangements of vias (e.g., rectilinear, honeycomb). Due to stochastic fluxes of different species into the features, non-circular profiles with contact edge roughness can occur. Charge deposition by ions on inner surfaces of features repels subsequent ions and deviates their trajectories, resulting in decreased etch rates and twisted profiles. With a periodic boundary condition when simulating a single via (circular HAR hole) little distortion is predicated. When simultaneously simulating multiple vias, pattern dependent distortion is predicted. The randomness of charging of surrounding vias produces stochastic electric fields which affects trajectories of ions in adjacent vias.

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