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Origin of electrical changes occurring at plasma etching endpoint

MARK SOBOLEWSKI, DAVID LAHR, NIST — When a plasma etch consumes one layer and exposes an underlying layer, changes are detected in measured electrical parameters, such as impedance magnitude, phase, and dc self-bias voltage. Consequently, these electrical signals are useful for endpoint detection. However, the mechanisms responsible for the observed electrical changes are not well understood. To investigate these mechanisms, we performed experiments and numerical modeling of CF4/Ar plasma etches of thermal silicon dioxide films on silicon substrates, in an rf-biased, inductively coupled plasma reactor. A wave cutoff probe was used to measure the plasma electron density as a function of time during etching. As the etch breaks through the oxide and exposes the underlying silicon, changes in the gas-phase densities of etch products and reactants cause the electron density to increase. This increase (and an accompanying increase in ion current) has a large effect on the measured electrical signals. Using a numerical model and measurements made at varying bias frequencies, the effect of changes in electron density can be distinguished from smaller effects caused by other parameters that vary at endpoint, including the electron temperature, average ion mass, and the ion-induced emission of electrons from the wafer surface. In addition to explaining the experimental results, the model provides predictions, over a wide range of conditions, for the sensitivity and reliability of the electrical endpoint signals.

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