Literature Digest
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Plasma Etching: Modeling

"Modeling of magnetically enhanced capacitively coupled plasma sources: Ar discharges"
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This paper describes the effects of magnetic fields in capacitively coupled reactors with industrially relevant geometries based on two-dimensional hybrid-fluid simulations. The significance of this work is given by the fact that the so called MERIE reactors are widely used in IC manufacturing and are well characterized on an empirical level, however fundamental studies of the underlying plasma physics have been published scarcely. The paper describes several non-linear effects in plasma density, ion energy and angular distribution, which can affect etch results ass the magnetic field is used. It is absolutely recommended literature to anyone involved in MERIE reactor design and process development in MERIE reactors.

The model used in the investigation is based on fluid hydrodynamics where the secondary electron effects are treated by Monte Carlo simulations. The pressures are in the range of 10 to 60 mTorr, the magnetic fields between 0 and 250 G, the RF power is kept at 100 W for most simulation, the gap between the powered electrode and the grounded top plate is 21 mm (wafer diameter 200 mm). The RF frequency is not mentioned in the paper, however it appears that the electron transient times are small compared to the RF time period (Industrial MERIE reactors use typically a frequency of 2 to 13 Mhz.).

The main effect of the B-field is a decrease in the electron mobility. This also reduces the range of the secondary electrons emitted by the surfaces and accelerated by the sheath. This leads to a shift of the ion density towards the powered electrode and towards the center of the reactor. The maximum density increases up to 100 G and decreases hereafter. The latter effect is attributed to the fact that as the magnetic field approaches and exceeds 100 G, the Larmor radius falls below the sheath thickness. For small magnetic fields < 50 G, the secondary beam ionization increases uniformly across the reactor because the mean free path of the secondary electrons becomes smaller than the reactor gap and hence fewer electron are being lost to the reactor walls (Commonly discussed among process engineers as the main effect of the magnetic field.). Further increases of the magnetic field however confine the secondary beam electrons closer to the powered electrode, resulting in a loss of emitted electrons which are returned to and collected by the electrode.

The decease of the ion density and flux for large magnetic fields can be attributed to two secondary order effects. (i) The excitation rate of electronic states (Ar(4s) metastables) is also confined closer to the electrode which results in an increased rate of loss due to diffusion since neutrals are unaffected by the magnetic field. (ii) The RF amplitude increases and the dc bias becomes more positive (Plasma becomes more resistive). The difference between the plasma potential and dc bias decreases which in turn leads to less energetic secondary electrons and hence to a net lowering of the ionization rate. For large B-fields, the discharge loses it's electropositive nature and the electric field in the powered sheath is reversed in the cathodic cycle. This reversal in the electric field confines and decelerates ions and accelerates electrons.

The ion energy and angular distributions show a decrease in average energy, widening of the energy range and broadening in the angular distribution with increasing magnetic field.