Low Damage Processing and Process Characterization

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Abstract

Two novel plasma sources (one neutral source and one pulsed inductively coupled plasma source) and their ashing process characterization were investigated. The primary goal of this dissertation was to characterize these source properties and develop corresponding applications. The study includes process damage assessment with these two sources and another continuous wave (13.56MHz) plasma source. A global average simulation of the pulsed discharges was also included.

The time-resolved plasma density and electron temperature from the double probe analysis were compared with single Langmuir probe results with sheath displacement corrections in pulsed discharges (200Hz~10kHz). The good agreement between the equivalent resistance method and nonlinear regression methods indicates probe data. The transient behaviors of the plasma density and electron temperature are in accord with the simple model of the discharge.

The hyper-thermal neutral source based on the surface reflection neutralization techniques was shown to provide enough fast neutrals for ashing applications. The surface roughness of the post-cleaned water was less than 10 *Å*. *Ex-situ* and *in-situ* measurements yield typical removal rates of about 10 *Å*/s without stream collimation. The removal rates at increasing pressures show a trade-off between creating higher density plasma, leading to a large initial neutral flux and attenuation of neutrals due to collisions. Both optical emission and Langmuir probe studies indicate a mode transition as the rf power is increased. Changing the reflector plate changes the neutral energy without changing the discharge composition. A novel technique, combining momentum and heat flux measurements, shows the neutral stream energy is 3~6 eV and the neutral flux is on the order of $3 \times 10^{15}\ cm^{-2}s^{-1}$. The derived etch rates from the measured neutral flux and energy values and the experimental rates are in good agreement. Quasi-static capacitance-voltage measurements demonstrate that the low energy neutral source induces much less damage than other plasma sources. Most of the neutral process damage is caused by uv photons escaping from the plasma source zone. The process-induced damage varies with the reflector bias and rf power.