TRANSMISSION LINE BASED MICROWAVE INTERFEROMETERS FOR PLASMA DENSITY MEASUREMENTS

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Here we report the development of microwave interferometers based on transmission-line (TL) structures for monitoring of plasma density for applications in process monitoring or real-time feedback control of plasma based semiconductor fabrication tools, such plasma etchers or PECVDs. The principle of this technique is the same as the conventional microwave interferometers except that the sensing microwave propagates along a transmission-line structure, where microwave propagates at a phase velocity determined by the structure and the electron density of the surrounding plasma. Thus the variation of plasma density can be estimated from the phase shift of the transmitted microwave from one to the other end of the transmission-line. Compared to the conventional microwave interferometers where lineaveraged plasma density is measured, the transmission-line type microwave sensor will be less susceptive to the interference caused by multi-passes reflection/refraction effect resulting from nonuniformity of the plasma density profiles. Therefore, it provides a measurement of higher sensitivity and wider dynamic range. Several types of TL have been investigated, namely, a coaxial dielectric surface waveguide, a ridged microstrip line and a air-bridge microstrip line. The dispersion characteristics of the transmission-lines immersed in a plasma of different electron densities were first analyzed by numerical simulation using a commercial tool, High Frequency Structure Simulation code (Ansoft HFSS), a full-wave electromagnetic simulator using the finite element method. The simulation results show that the phase shift increases gradually with the plasma electron density with a sensitivity 10-20 degrees / 10^{10} cm^{-3}, depending on the types of transmission-lines. The sensors as well as measurement have been constructed and experimental demonstration has been performed in an inductively coupled plasma etcher. The sensors were designed to mount on the inner wall of plasma chamber. Measurement results show that the dependence of electron density of plasma source RF power predicted by the sensor agrees with the Hairpin probe measurements.

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