Linear Microwave Plasma Source for Low Temperature Roll-to-Roll Processing

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A linear 2.45GHz microwave plasma system sustained by TE-TEM power coupling has been developed for low temperature roll-to-roll processing. The TE-TEM power coupling is achieved by coaxial circular TEM waveguide which is located at $3\lambda_g/4$ from end of rectangular waveguide with TE$_{10}$ mode. TEM waveguide is composed of quartz tube and copper rod electrode and the plasma is generated on the surface of quartz tube. The microwave power is absorbed by plasma along the quartz tube. Plasma pattern with wavelength of 10cm was observed at surface of quartz tube under low pressure and low microwave power. The electron temperature at surface of quartz tube is 3–5 eV, but drastically decreased to 1–2 eV at 5cm apart from quartz tube surface. This remote plasma property enables low ion bombardment, and low damage and low temperature processing of plastic substrates. The non-uniformity of temperature and electron density along the plasma source at the location 50 mm apart from quartz tube was less than 10%. In addition, the properties of microwave plasma with actual size was investigated through electromagnetic and 2D axisymmetric fluid simulation. Electric field pattern by simulation and experimentally identified standing wave pattern were almost identical. The properties of electron density and electron temperature show good agreement between simulation and experimental results. Finally, a-C:H films has been deposited using developed plasma source. Hydrophobic and wear-resistible a-C:H films was obtained with Ar/CH4 gas mixture and additional rf bias.