Monday, May 11

12:30 p.m. - 1:10 p.m. TS-1 Advances and Drawbacks of Microwave Plasmas

M. Moisan, Groupe de Physique des Plasmas, Université de Montréal, Montréal, Canada

Invited 40 min. Talk

As compared to conventional RF capacitive or inductive discharges, microwave-sustained plasmas exhibit a few specific characteristics that make them original in terms of physics and technology: i) the electric field sustaining the discharge is provided by wave propagation either along dielectric materials (including the plasma itself) or within the structure of field applicators that radiate outwardly to penetrate dielectric discharge vessels (transparent to microwaves): no electrodes need to be in contact with the discharge and, therefore, no self-biasing of the field applicators; ii) in the low pressure range there exists a highly efficient power absorption mode, the electron cyclotron resonance (ECR); iii) impedance matching is easier and more efficient than with RF systems. Despite the attractiveness of their features, microwave plasmas are suffering from severe difficulties when compared to other technologies (corona and dielectric barrier discharges at atmospheric pressure, RF discharges at reduced pressure) in the two main sectors of industrial applications, namely chemistry in gaseous phase and plasma processing of surfaces. Drawbacks are essentially: i) the (radial) contraction of microwave (tubular) discharges typically at pressures above 10-20 Torr and, additionally, their filamentation at frequencies above 1 GHz; ii) at reduced pressures (< 500 mTorr), the difficulty of scaling up microwave plasma sources for surface treatments. The scaling-up solutions adopted some twenty years ago with the distributed ECR (DECR) and duo plasma-line schemes calling on the distribution of the sustaining microwave-power field through an array of parallel linear sources still present strong limitations, basically due to the difficulty of achieving uniform standing wave patterns over the full length of long applicators. Recent advances in microwave plasma sources are addressing the above problems. At and above atmospheric pressure, we have shown that operation of tubular discharges at power density up to 1.4 kW/cm^3 at 6 bars is possible thanks to the design of efficient cooling systems. At reduced pressure, plasma scaling-up without limitation is now a reality thanks to new concepts based on wave propagation on external-to-the plasma non-dissipative structures or on the distribution of elementary plasma sources on two-dimensional (planar sources) or tri-dimensional networks (plasma volume) that include the so-called multi-dipolar and matrix plasmas. Impedance matching is definitely more efficient and reproducible with microwave components than RF match-boxes: as an example, we consider the case of surface-wave discharges sustained with the optimised surfaguide applicator that yields an impedance matching almost independent of operating conditions. All of these new features represent important breakthroughs. Design, performance and applications of these new generations of microwave plasma sources are reviewed.