

Ion energy distributions in bipolar pulsed DC discharges of methane measured at the biased cathode

THE STUDY

Ion processes at the growing surface of a depositing film are of huge importance in the achievement of special surface properties. The study of plasma processes at the sheath level complements the characterisation performed by other methods, and it provides a better assessment of the influence of deposition variables on material properties. Compact models of retarding field energy analysers (RFEA) are becoming popular instruments for measuring ion currents due to their rapid installation, high sensitivity to small currents and because no auxiliary pump is needed.

In this paper, the authors study the ion energy distributions (IED) of CH₄ plasmas measured with a compact RFEA Semion system from Impedans Ltd placed at the biased electrode, which acts as cathode and coincides with the substrate location for DLC deposition.

METHOD

The analyser consisted of a set of plane-parallel metallic grids, each one biased to a determined voltage set by the control unit in order to probe the ion current at different retarding potentials. The first grid faced the plasma and was electrically connected to the RFEA housing. A sweeping potential was applied on the discriminating grid, which selected the ions with determined energies. Finally, a negatively biased grid was located between the discriminator and collector in order to screen secondary electrons generated on the collector surface.

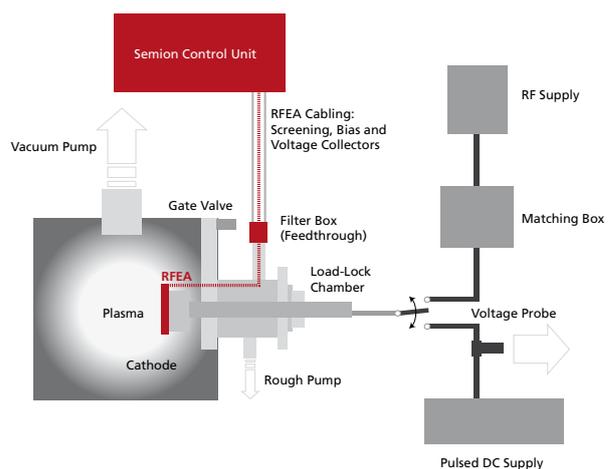


Figure 1: Experimental setup prepared for IED measurements with a compact RFEA placed on the biased cathode

High-energy peaks in the IED were detected at low pressures, whereas low-energy populations became progressively dominant at higher pressures. This effect is attributed to the transition from collisionless to

collisional regimes of the cathode sheath as the pressure increases. But, pulsed-dc plasmas showed broader IED than RF discharges. This is connected to the different working frequencies and the intense peak voltages (up to 450 V) driven by the pulsed power supply.

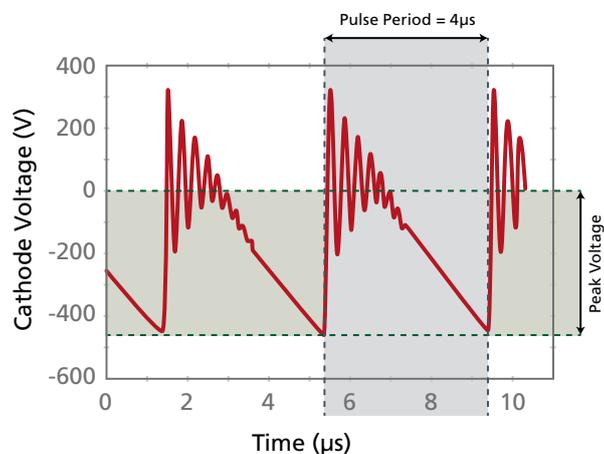


Figure 2: Bi-polar pulsed-DC signal: voltage waveform. The voltage waveform of the asymmetric bipolar pulsed-dc signal is measured with an oscilloscope

CONCLUSIONS:

The IED curves corresponding to bipolar pulsed-dc discharges in CH₄ were successfully measured in the range 1–10 Pa by the Semion. Pulsed-dc power provided energetic ion bombardment onto the cathode, which is beneficial for diamond-like carbon production. IED

peaks of pulsed-dc CH₄ plasmas were generally shifted to higher energies in comparison with RF discharges. Moreover, the evolution of these peaks was used to explain the dependence of ion flux with the working pressure, *p*. The IED curves provided, whose variation with *p* evidenced the transition from collisionless to collisional sheath regimes. IED of pulsed-dc discharges showed broader and more complex structures than those measured in RF plasmas, mainly due to the time-averaged ion flux measured by the RFEA. In general, pulsed-dc discharges showed higher efficiency in power transmission than RF discharges. However, cathode sheaths developed in pulsed-dc discharges showed collisional regimes in the whole range of *p*.

The natural continuation of this work is based on IED measurements performed in time-resolved mode, aside from developing recently opened research lines: investigations using various pulse waveforms; the utilisation of different gas precursors, and the simulation of IED curves.

This study improves our understanding in plasma processes at the cathode level, which important for the growth and processing of materials requiring controlled ion bombardment. Examples of industrial applications are plasma-cleaning, ion-etching processes during fabrication of microelectronic devices, and plasma-enhanced chemical vapour deposition of hard coatings (diamond-like carbon, carbides and nitrides).

References

- * *Ion energy distributions in bipolar pulsed-dc discharges of methane measured at the biased cathode*
 IOP PUBLISHING PLASMA SOURCES SCIENCE AND TECHNOLOGY.
Plasma Sources Sci. Technol. 20 015006 doi:10.1088/0963-0252/20/1/015006
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 Published 7 January 2011