ON THE DETRMINATION OF ENERGY FLUXES BETWEEN PLASMA AND SUBSTRATES

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Plasma-surface interaction is of great importance in a large variety of applications in plasma processing such as etching, deposition, and modification of thin films. In these mechanisms the energetic conditions at the substrate surface play a dominant role [1,2].

For the experimental determination of the energy fluxes calorimetric probes can be used [2,3]. By such probes the energetic contributions of various plasma species (electrons, ions, neutrals) as well as radiation and energies released by chemical reaction, recombination and condensation can be determined.

The basic principle for measuring the incoming power by calorimetric probes is based on the rate of change in the temperature of a test substrate, dT_S / dt, which implies measuring the temperature characteristic of the heating process when the probe is exposed to an energy flux and the following cooling without this energy flux, see fig.1

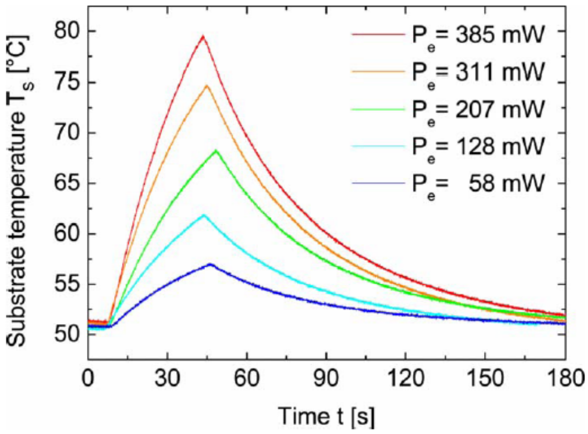

Fig. 1: Temperature characteristics $T_S(t)$ of the calorimetric probe displaying heating and cooling curves. The power was supplied by an electron beam at different voltages.

For reliable and quantitative measurements the exact knowledge of the effective heat capacity of the calorimetric probe is essential in order to calculate the incoming power. For this purpose we applied for the first time a very simple setup for the calibration, which uses a hot filament as electron source [4].

In the following the use of the calorimetric probe is illustrated by measurements in an ion broad beam experiment [5]. The energy flux is dominated by energetic argon ions and neutral argon atoms. The energetic atoms stem from charge-exchange collisions that discharged a part of the beam ions. There are no other relevant energy sources heating the probe substrate, which keeps the experimental situation simple and makes it well suited for a demonstration of the thermal probe. The energy of the ions is set by means of the anode voltages (U_A = 200, 300, 400 V) in the ion source.

Fig. 2 shows the measured energy fluxes and currents at the distance z = 30 cm for different radial positions in the beam.

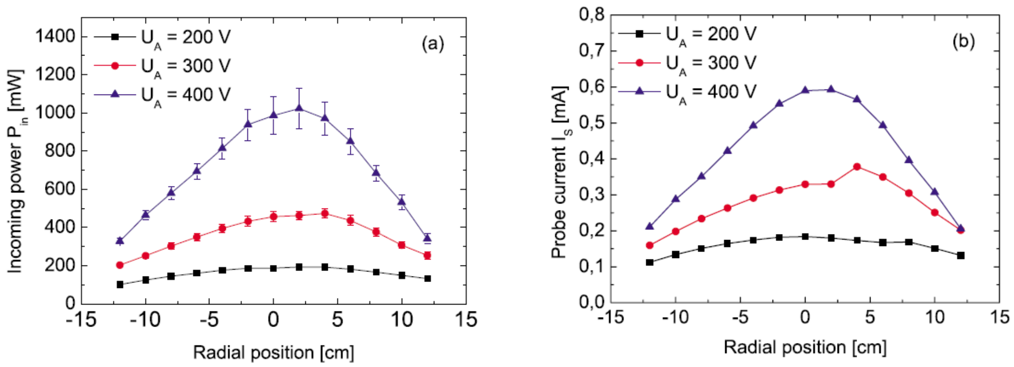

Fig. 2: Radially resolved measurements of incoming power P_{in} (left) and current I_S (right) in a distance of *30 cm* to the grid system of the ion beam source for three different anode voltages.

One can estimate the contribution of the ions P_i to the total energy flux P_{in} from the measured ion current and the kinetic ion energy gained in the potential drop $U_{pl} - U_S$ from the source plasma down to the probe surface. The calculated ion powers for the center of the beam are derived from the corresponding currents $I_S = 0.18, 0.33, 0.59\ mA$ are $P_i = 50, 125, 283\ mW$ for the three anode voltages. We compare this to the measured beam powers $P_{in} = 190, 450, 1000 mW$. The ratio $P_i / P_{in} \sim 0.3$ is in good agreement with the expectation based on the composition of the beam (*30%* ions and *70%* neutral atoms).

The potential of calorimetric probes for rather simple diagnostics in technological applications of plasma processing has also been successfully demonstrated for rf-plasmas [6] as well as for high power impulse magnetron sputtering (HiPIMS) [7].

References

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