ON THE CONTAMINATION OF LANGMUIR PROBES

Sonja Tscholl, **Carsten Winkler** and Roman W.Schrittwieser

Institute for Ion Physics, Univ. of Innsbruck,
Technikerstr. 25, A-6020 Innsbruck, Austria

1. Introduction

In plasma physics, Langmuir probes are an often used diagnostic tool. These probes are placed into the plasma directly, and current-voltage (I-V) characteristics are taken by applying various voltages to the probe, and by recording the corresponding currents. Important plasma parameters, i.e., the electron temperature, the plasma density and the plasma potential, can be derived from the I-V characteristics. The shape of the characteristics is, besides the geometry of the probe, mainly modified by the contamination of the probe with plasma ions and residual gas particles, see Fig. 1, and a high or a time dependent contamination leads to large errors in the determination of the plasma parameters. In the present paper, the contamination of Langmuir probes has been studied experimentally by taking and analysing I-V characteristics as function of the probe temperature T.

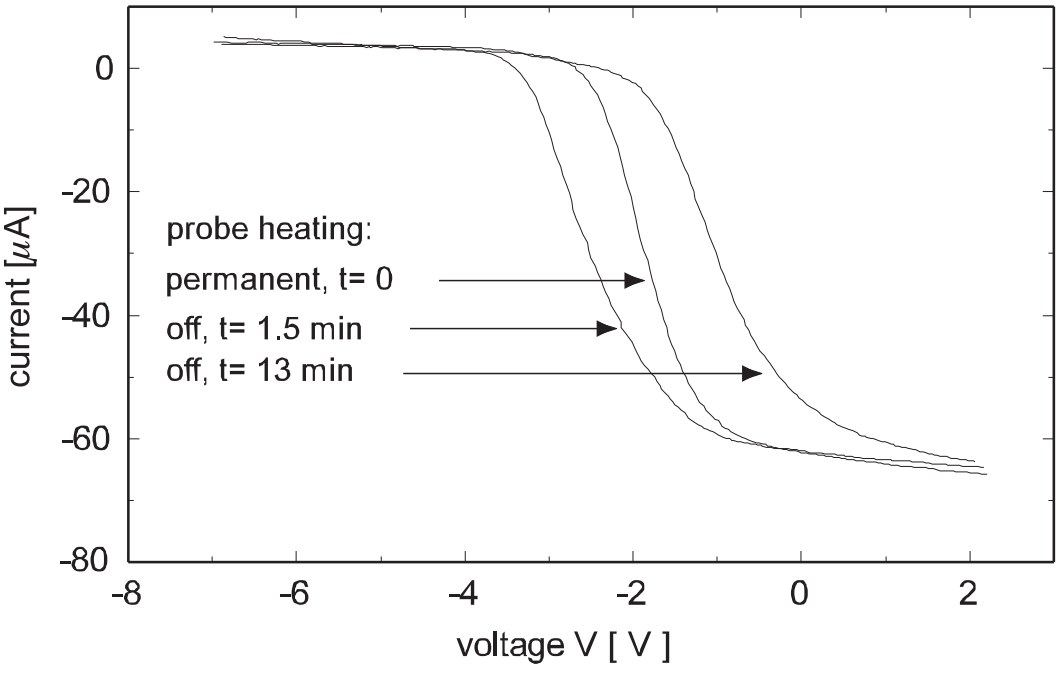

Fig. 1. I-V characteristics taken at different degrees of probe contamination Θ, $\Theta \propto t$.

2. Experimental set up and data analysis

The experiments have been performed in the Innsbrucker Q-machine [1] by using an indirectly heated tungsten probe [2] in a potassium plasma, Fig. 2.

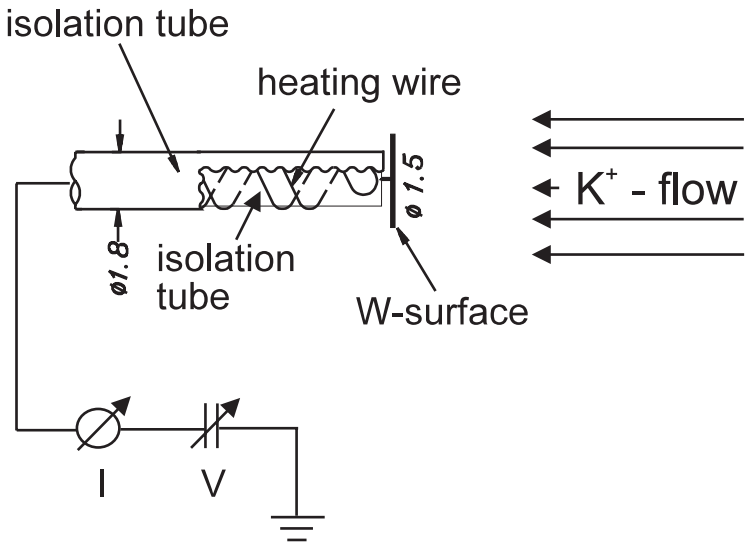

Fig. 2. The experimental set-up.

By taking into account the typical operating conditions of the present apparatus with a pressure in the range of $p_R \approx 10^{-6}\ mbar$, corresponding to a collision rate of $Z_R \approx 3 \times 10^{14}\ cm^{-2}s^{-1}$ to the surface, and particle fluxes of about $Z_K \approx 6 \times 10^{14}\ cm^{-2}s^{-1}$, one finds that it takes just a few seconds to form a monolayer on the probe surface. On a clean W-surface, K as well as residual gas compounds -the latter mostly in a dissociative way- tend to form strongly bound chemisorbed complexes that are hard to remove and lead to a change of the work function of the surface [3], and with that to a shift of the I-V characteristics along the V-axis. In the case of increasing contamination, the bindings of the adatoms become looser and inhomogeneous structures are formed, which results in a change of the curvature of the characteristics in addition to the shift, and a proper determination of the plasma parameters is no longer possible, see Fig. 3. By heating the probe, the mobility of the loosely bound particles on the surface increases and chemical reactions with desorption are promoted. The most probable reactions in the present case are (ΔH_f = enthalpy of formation):

$$K + 2O \rightarrow KO_2\ , \quad \Delta H_f = -2.93eV$$

and

$$K + OH \rightarrow KOH\ , \quad \Delta H_f = -4.41eV.$$

The data obtained for the electron temperature and the plasma density with continuous heating of the probe up to about $800K$ are in good agreement with the expected values for a Q-machine [4]. In this case, just a few monolayers of mainly K can be assumed to be on the probe surface.

3. Conclusion

The results of the previous chapter show that a permanent heating of Langmuir probes up to $800K$ forces chemical reactions between K and residual gas components on the surface, which leads to an acceptable cleaning of the probe surface and enables a reliable determination of relative changes of the plasma parameters.

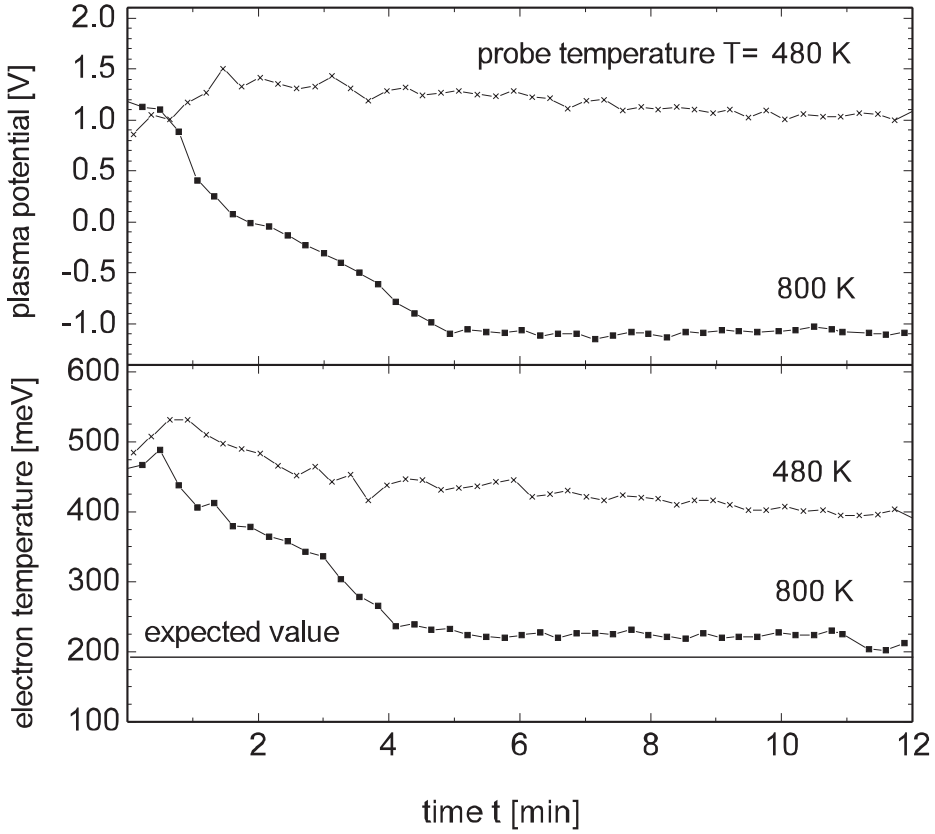

Fig. 3. Temporal (temperature dependent) evolution of the calculated plasma parameters. $T = f_{(t)}$ with $T_{(t \leq 0.5\,min)} = 300K$ and $T_{(t \geq 5\,min)} = 480\,K$ (crosses) and $800K$ (squares), respectively. In addition, the expected value of the electron temperature in a Q-machine is shown.

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