HOT NEGATIVE IONS BY SHEATH MANIPULATION

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ABSTRACT

In the plasma of a positive column in an Ar-SF_6-mixture the transport of negative ions to the wall or to an orifice probe is investigated. Only the F^--ion reaches the wall, the other ions are assumed to be trapped. By an anodic orifice probe the different negative ion species can be extracted having temperatures of some volts.

1. INTRODUCTION

Negative ions influence the elementary processes and the transport properties (Lergon and Müller (1)) of a plasma column. Depending on their density relative to electron density, n_-/n_e, different modes can be distinguished, characterized by the transport mechanism for positive ions, (+), negative ions, (-), and electrons, (e) :

mode	ambipolar diffusion of	radial potential distribution, schematically
A	(+) and (e)	
B	(+) and (-) at the axis (+) and (e) at the wall	
C	(+) and (-)	

The density of negative ions has to be determined experimentally; approaches to calculate it suffer from lack of detailed information about the involved elementary processes (see e.g. Nicolopoulou, Bacal and Doucet (2)). To measure the negative ion density Langmuir probes (Doucet (3)) and mass spectrometers may be applied. According to the potential distributions sketched above the negative ions are expected to be trapped in mode A and B. To extract them through an orifice probe to a mass spectrometer anodic probe potentials have to be applied. However these extraction potentials may change the plasma or even form an independent secondary plasma in front of the probe.

In this paper this problem of wall transport of negative ions is investigated in a nonthermal plasma using a combined mass spectrometer - probe diagnostic (see Lergon and Müller (4)) including energy analysis. From the energy distribution of the charge carriers conclusions can be drawn on transport in the sheath and the adjacent plasma.

2. EXPERIMENTAL

As a model-plasma for the investigation of negative ions the nonthermal plasma of a positive column (diameter 2.8 cm, pressure about 0.1 mbar, current 30 mA) in Ar with a small fraction of SF_6 (1 %) has been analysed. By a variable fraction of SF_6 the density of the negative ions may be regulated. Negative ions have been extracted by an orifice probe of diameter 6.2 mm, of orifice diameter 0.05 mm and of orifice depth 0.05 mm, located at the wall of the tube. Following characteristics have been measured :

probe characteristic	: probe current I_p versus probe voltage U_p,
negative ion characteristic	: current I_- of a negative ion species to mass spectrometer versus U_p,
retarding field characteristic	: I_- versus retarding voltage U_{ret} .

3. RESULTS AND DISCUSSION

Fig. 1 shows a typical set of characteristics. In the lower part the probe characteristic is given, the evaluated electron current of which has been plotted logarithmically (see upper part), increasing linearly for two decades and giving an electron temperature of 1.5 V. Since for probe potentials U_p close to floating potential U_{fl} only the energetic electrons reach the probe, the measured electron temperature has to be attributed to the distribution of these energetic electrons. The asymmetry of the probe characteristic indicates a small contribution of the negative ions to the current of the wall probe, typical for the modes A and B.

From the negative ion characteristics two types of negative ions may be distinguished. The first one is represented by the F^--ion, which is already detectable at floating potential and thus is able to reach the wall of the tube. The logarithmical increase corresponds to a temperature of 5.3 V. This unexpected high temperature is confirmed by the retarding field characteristic of Fig. 2. Temperature measurements by ion characteristics have been demonstrated in (4).

The other ions : S^-, F_2^-, SF^-, S_2^- and SF_3^-, SF_4^-, SF_5^-, found in the experiment belong to the second type. In Fig. 1 we have shown only the most intense ones. Their characteristics have a steep onset at an anodic potential of U_p = -97 V. This is correlated to a steplike increase of F^--current and of negative probe current, indicating a change in mechanism of current transport to the probe. Parallel to this the sheath in front of the probe disappears and is replaced by a plasma, as has been observed visually. This change in transport may be interpreted by the formation of a secondary plasma or by a breakthrough of the main plasma.

Additional information about the negative ions is given by the retarding field characteristics of Fig. 2. The corresponding working point is indicated in Fig. 1 by an arrow. The temperatures evaluated from the different characteristics are summarized in Table 1. The F^--ions which reach the wall have a temperature of about 5 V; the ions of the second type, which are not detectable near floating potential, show lower temperatures of about 3 V.

In the momentary experimental situation the type of plasma in front of an anodic probe, and thus the origin of the ions of the second type, remain uncertain. This problem has to be taken into account in the diagnostic of the main plasma by mass spectrometry of negative ions extracted through an anodic orifice probe. The property of the sheath, to select negative ion species, is important in surface treatments.

ACKNOWLEDGEMENT

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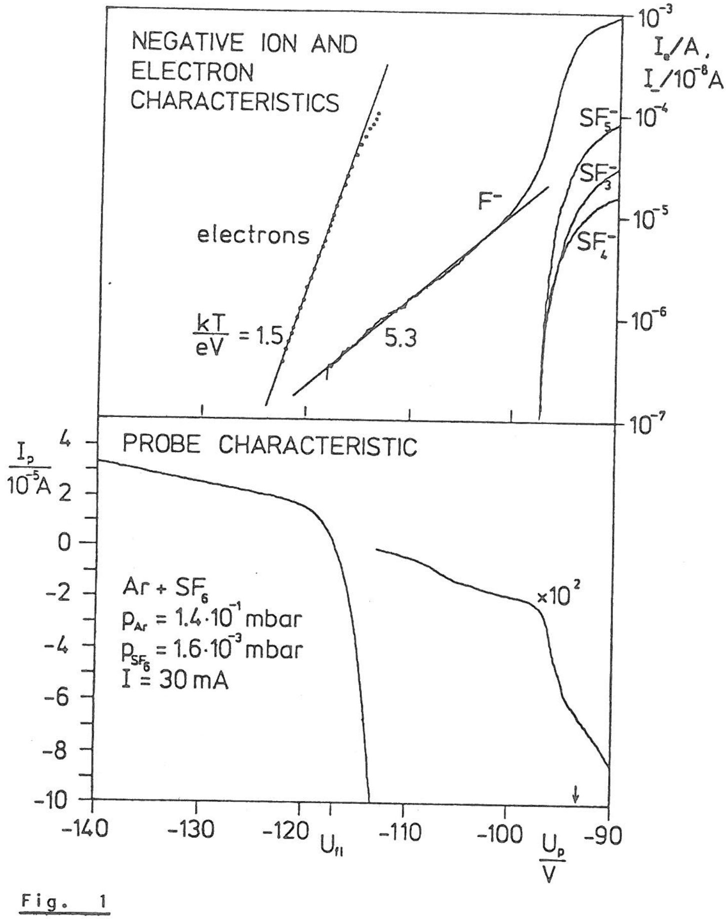

Fig. 1

Upper part : Negative ion characteristic I_- versus U_p for different ion species and electron characteristic I_e versus U_p evaluated from the probe characteristic.

Lower part : Probe characteristic I_p versus U_p. Arrow indicates working point of the characteristics of Fig. 2. Temperatures, evaluated from the slope, are given in volts.

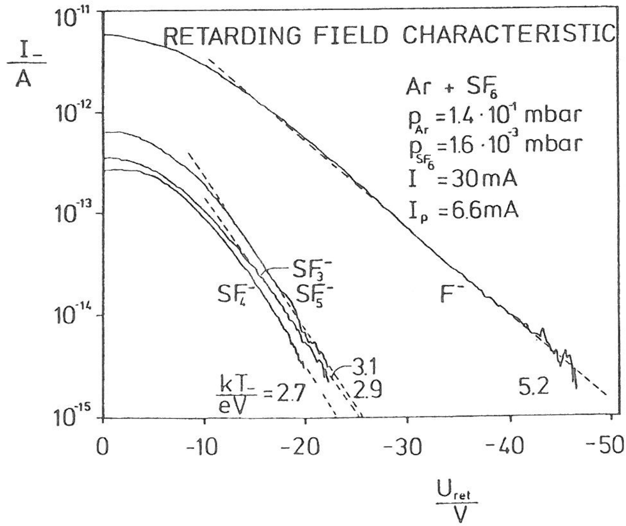

Fig. 2

Retarding field characteristic I_- versus U_p of different negative ion species for the working point : I_p = -6.6 mA, U_p = -93 V. Temperatures, evaluated from the slope, are given in volts.

method	temperature in volts
probe characteristic	1.5
F^- - characteristic	5.3
retarding field characteristic at $I_p = -6.6$ mA for following ions:	
F^-	5.2
SF_3^-	3.1
SF_4^-	2.7
SF_5^-	2.9

Table 1

Temperature of negative ions and electrons, evaluated from the characteristics of Figs. 1 and 2.