11. Inter. Conf on Phenomena in Ionized Gases Praha 1973



## 5.5.3.1

### A SOURCE OF HYDROGEN ION BEAM FOR PLASMA CORPUSCULAR DIAGNOSTICS APPARATUS CALIBRATION

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We describe in this paper a method of ion beam production the absolute energy value of which is defined with the accuracy ± 1 eV. The minimum energy value reached is about 120 eV without additional deceleration.

The source of $H_1^+$, $H_2^+$, $H_3^+$, and $H^-$ ions is a Penning discharge with unsymmetric Al cold cathodes supply [1] ($V_K > V_R$) and axial ion extraction through the reflector cathode channel (fig. 1). Dimension of the discharge chamber are such as to satisfy a discharge plasma condition $\Delta z \ll 1$, where $\Delta z$ is axial length of the cathode fall potential regions $\Delta V_K$ and $\Delta V_R$ and 1 is the length of the plasma column. Intensity of the magnetic field is about 800 Oe.

The typical energy spectrum of the ion beam is shown in fig. 2. The positive hydrogen ion beam $I_1^+$ (the rate of its atomic and molecular components depends on the discharge chambre gas pressure) whose energy $E_1$ is given by the reflector cathode fall

$$\Delta V_R = V_R - \Delta V_{AR} \qquad (1)$$

where the potential fall $\Delta V_{AR}$ between the anode and the axis of the plasma column varies which makes the ion beam unsuitable for the accurate energy analyser calibration.

The negative ion beam $I^-$ contains the ions $H^-$. These ions originate in the bombardement of the cathode surface by the plasma positive ions. The secondary ions $H^-$ emitted at the cathode are released with small energy $E_0^- < 2$ eV. They are accelerated by the cathode fall electric field and after passing through the discharge plasma and decelerating field of the reflector cathode fall, they form the negative ion beam the energy of which agrees with the potential difference $V_K - V_R$ (without including the energy $E_0^-$). Intensity of the negative ion beam $I_K^-$ cannot be treated in a simple way. However, as a rough approximation, equation (2) can be used assuming the cosine - law distribution

$$I_K^- = K \; I_A \sin^2 \Theta \qquad (2)$$

where we take the coefficient of the negative ion secondary emission $K = 10^{-4}$, the intensity of the positive ions, bombarding the cathode surface with the energy about 500 eV, $I_A$ = 3 mA and the semi-angle of the cone into which the accelerated ions are directed to form the ion beam $\Theta = 30°$.

On passing the discharge chamber the negative ions undergo the collision processes. The dominating process is electron detachment with the cross section $\sigma_{\bar{1}0} \doteq 10^{-15} \text{cm}^2$. The intensity is then defined by the attenuation equation

$$I^- = I_K^- \exp(-n \sigma_{\bar{1}0} \; x) \qquad (3)$$

where the neutral gas density is $n = 2.10^{14}$ cm$^{-3}$ and $x = 5$ cm.

The beam of $H_1^+$ ions $I_2^+$ (fig. 2) is produced in the stripping collision between fast hydrogen atoms and hydrogen gas molecules in an outside region of the discharge. The energy of the ion beam is

$$E_2 = E^- + E_1 + \Delta E_P - E_i \qquad (4)$$

where $\Delta E_P$ expresses the variation of the plasma potencial $V_P$ along the axis of the plasma column and $E_i$ is the ionization energy of $H_1$. The potencial $V_P$ can be positive or negative [2].

The ion beam with the energy $E_3$

$$E_3 = E^- + 2E_1 + 2 \Delta E_P - E_i \qquad (5)$$

is formed by $H_1^+$ ions produced partly in the stripping collision process between fast hydrogen atoms and hydrogen gas molecules in the region of the plasma column l which, under the condition of two collisions, expresses equation (6) [3], partly in the two-electron detachment collision between fast negative ions and hydrogen gas molecules - equation (7):

$$I^+ = I_K^- \left\{ 1 - \exp(-n \sigma_{\bar{1}0} \, l) - \frac{\sigma_{\bar{1}0}}{\sigma_{\bar{1}0} - \sigma_{01}} \left[ \exp(-n \sigma_{01} \, l) - \exp(-n \sigma_{\bar{1}0} \, l) \right] \right\} \qquad (6)$$

$$I^+ = I_K^- \left[ 1 - \exp(-n \sigma_{\bar{1}1} \, l) \right] \qquad (7)$$

In our experiment the intensities $I^-$ and $I_3^+$ were in a good agreement with the calculated values which verifies our hypothesis about the origin of the negative ion beam with the energy $E^-$.

Applying the values of the energies $E_1$, $E_2$, $E_3$ and $E^-$ to the equation (1) and (4) or (5) we can find the potencial differencies $\Delta V_{AR}$ and $\Delta V_P$ and we obtain the potential distribution along the axis of the discharge chamber (fig. 1).

As an example we present data of typical values of the ion energies in eV and the corresponding discharge potentials in V for the discharge in hydrogen atmosphere. These results show that the potential differencies between the anode and the discharge axis are negative and small.

| $V_K - V_R$ | $E^-$ | $V_R$ | $E_1$ | $\Delta V_{AR}$ | $V_K$ | $E_2$ | $\Delta V_P$ | $E_3$ | $\Delta V_P$ |
|---|---|---|---|---|---|---|---|---|---|
| 274 | 274 | 184 | 182 | -2 | 458 | 441 | -1 | 622 | -1 |
| 372 | 372 | 124 | 123 | -1 | 495 | 480 | -1 | 603 | -1 |
| 429 | 429 | 145 | 145 | 0 | 574 | 560 | 0 | 705 | 0 |

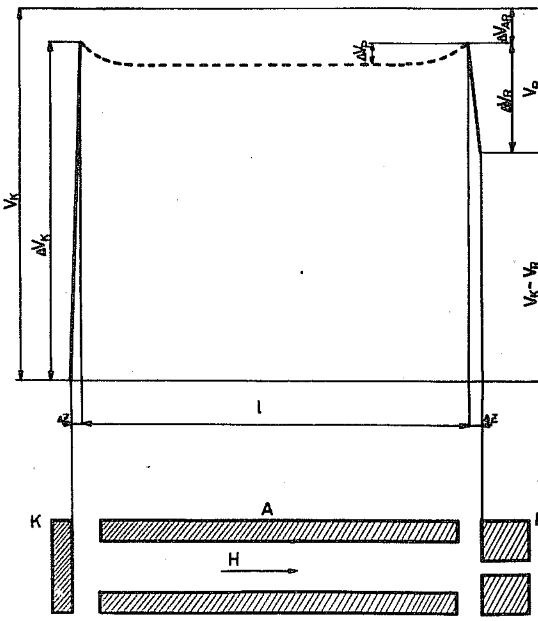


FIG. 1.

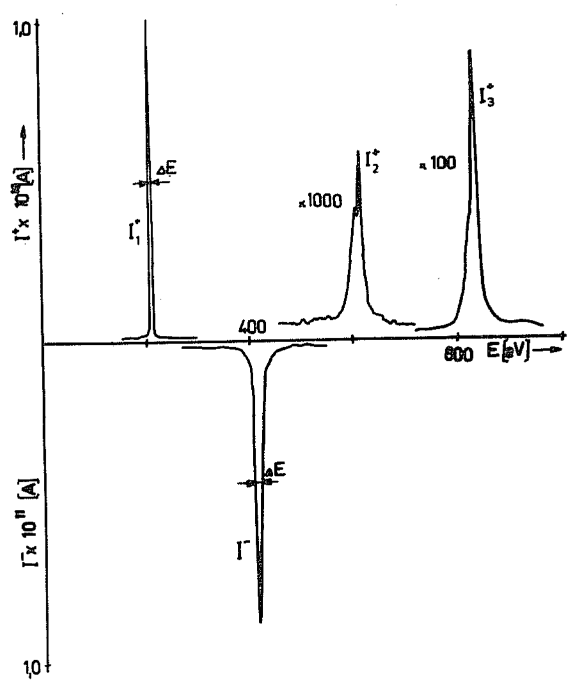


FIG. 2.

References:

[1] J. Flinta: Nucl. Instr. 2 (1958) 219.
[2] E. Heinicke, K. Bethge, H. Baumann: Nucl. Instr. and Meth. 58 (1968) 125.
[3] B. Michalik (to be published)