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Amplification of current and radiation intensities in the negative glow plasma of a hollow cathode discharge in magnetic field

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Fisica del plasma. — *Amplification of current and radiation intensities in the negative glow plasma of a hollow cathode discharge in magnetic field.* Nota di EUGEN BADAREU, CONSTANTIN POPOVICI e MARIA SOMEŞAN, presentata (*) dal Socio G. BERNARDINI.

RIASSUNTO. — Nel presente lavoro sono esposti i risultati delle determinazioni di corrente e d'intensità della radiazione nella scarica a catodo concavo in campo magnetico parallelo.

Le forti amplificazioni ottenute per valori critici della pressione e della differenza di potenziale sono spiegate considerando un'interazione fascicolo–plasma nella cavità catodica.

1. – INTRODUCTION.

Much experimental and theoretical knowledge exists concerning the peculiarities of the " hollow cathode " discharge [1–10] which has been studied extensively as a source of high current and radiation amplifications at constant cathode fall. It has been shown [11–13] that these amplifications of discharge current (i) and radiation (I) from the negative glow, may be strongly enhanced for given critical values of the pressure (p), intercathode spacing (D), cathode fall (V_c) and magnetic field (H). Measurements of the pressure dependence of the current intensity at constant cathode fall, carried out in magnetic fields applied on the discharge, have shown that in the optimum pressure domain of the hollow cathode effect, a parallel magnetic field produces an amplification of the discharge current density of about 10^2 times the current intensity without magnetic field and $\sim 10^4$ times the intensity in a usual simple cathode discharge at the same pressure and cathode fall. At the same time it has been pointed out [4, 14–15] that in hollow cathode " effect " conditions, the radiation of the metal atoms sputtered by the cathode in the cavity, grows much more than that of the gas atoms.

The present work reports a part of the results obtained in the study of the influence of a parallel magnetic field on current and spectral intensity amplifications in the negative glow of a hollow cathode discharge.

2. – EXPERIMENTAL RESULTS.

The measurements have been carried out in Neon gas, in a plane-parallel geometry (fig. 1), the " hollow cathode " being a pair of Molibden discs, and the anode a surrounding cylinder. A parallel magnetic field is

(*) Nella seduta del 10 febbraio 1968.

applied in order to amplify the discharge current: The H dependence of this current amplification at constant current falls of 210 V and 200 V and pressures of 1,8 and 1,7 mmHg is also given in fig. 1. The spectral intensities of the lines 5852 Å of Ne and 3864 Å of Mo, measured simultaneously with the above electrical parameters are shown in fig. 2.

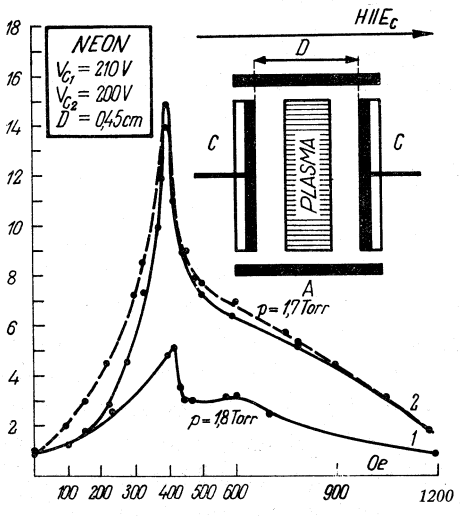

Fig. 1.

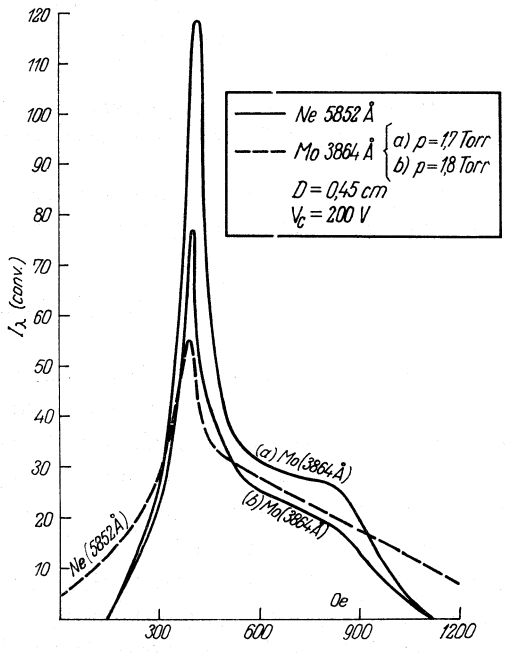

Fig. 2.

It is obvious that the presence of a longitudinal magnetic field manifests itself by a strong increase of the discharge current, that passes through a well-marked maximum for a given H value (400 Oe in our conditions) and then falls strongly (sometimes even to zero) for high values of the magnetic field. The amplifications of the spectral intensities emitted by gas atoms (defined by the ratio $I_{effect}/I_{no\ effect}$) (fig. 2) have roughly the same values as those of the current intensity (fig. 1). But they are much stronger for metal atoms as can be seen in fig. 2. It is to be observed that the amplifications of the radiation of metal atoms in hollow effect conditions are difficult to represent in terms of the ratio $I_{effect}/I_{no\ effect}$ as the intensity of the metal lines vanishes in no-effect conditions. The amplification of the spectral intensities of metal atoms manifest themselves even at constant current intensity; I (H) curves for the mentioned Ne and Mo lines at i = constant and the behaviour of the potential in the same conditions are given in fig. 3.

At constant pressure, cathode fall and magnetic field, the " effect " conditions of the hollow cathode discharge are assured in a very thin domain of D values. Measurements at V_c = const. were difficult to perform due to the

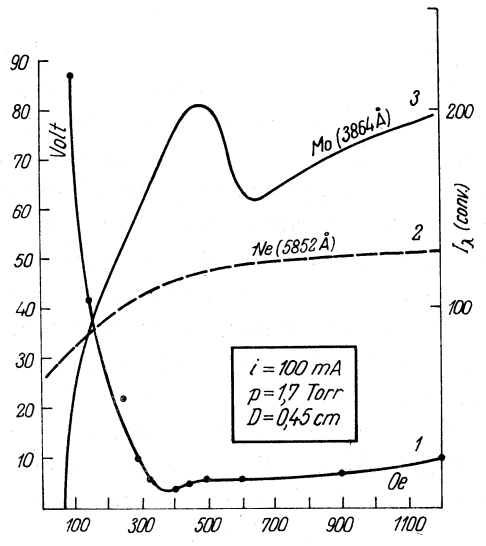

Fig. 3.

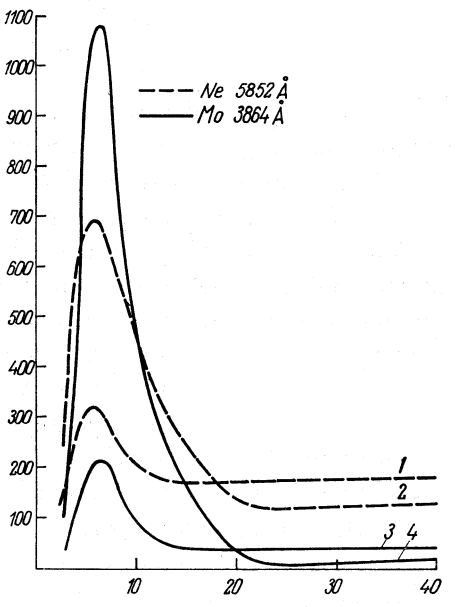

Fig. 4.

excessive high current amplifications. But even at i = const., the I (D) curves show a strong maximum as may be observed in fig. 4 in which the spectral intensities of the lines Ne—5852 Å and Mo—3864 Å at H = 0 and H = 500 Oe,

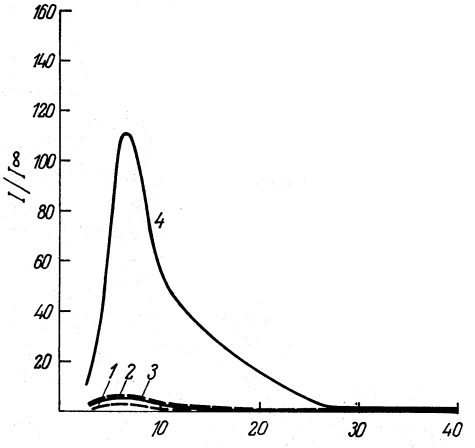

Fig. 5.

for p = 2,5 mmHg, are represented as a function of intercathode spacing. The amplifications of the radiation (measured by the ratio $I_{maximum}/I_{no\ effect}$) have values of the order 10^2 at i = const, as it is shown by fig. 5.

3. – Conclusions.

The above results demonstrate that in " effect " conditions of a hollow cathode discharge in magnetic field, the strong parallelism between excitation and ionization phenomena, that characterises the ordinary glow discharge, breaks off. It is not possible to explain the enhancement of the intensity of radiation in " effect " conditions, through a rise of the density of metal atoms in the plasma. Of course at $i = \text{const}$, the potential passes through a minimum in the effect domain and so there are no reasons to assume an enhanced sputtering rate of the cathode. Not even the rise of density of metal atoms in the negative glow as a consequence of the compression of the plasma in " effect " regime, may be regarded as responsible for radiant intensity amplifications exceeding 10^2.

The results we have obtained concerning current and radiation amplifications in the negative glow of a hollow cathode discharge in magnetic field seems to be explained only by assuming a change of the distribution function of electron velocities during the effect. Such an alteration of the velocity distribution curve is physically justified if we regard the hollow cathode effects as a manifestation of the growth of plasma—beam instabilities in the cathode cavity in certain conditions (16–17).

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