# CHARACTERISTICS OF THE HOLLOW ANODE ION-ELECTRON SOURCE

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## Abstract

A new type of ion-electron source based on a hollow anode discharge is presented. In such a type of discharge the maximum plasma density is localized at the exit aperture. Constant hydrogen ion current in excess of 1 mA has been obtained with the 1 mm diam. exit aperture and the extraction voltage of 3 kV.

## Introduction

One of the ways to increase ion source efficiency is to form an inhomogeneous plasma with the maximum ion density near the exit aperture. In the hollow anode type ion source /1/, based on the hollow anode discharge /2/, the maximum ion density and the electron temperature is achieved in the exit aperture.

## Hollow Anode Discharge

A hollow anode discharge is realized in the diode shown in Fig.1. It consists of the concave cathode (CC)

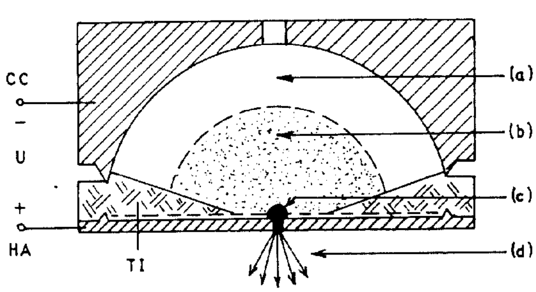


Fig.1. Schematic diagram of the hollow anode discharge: CC - concave cathode, HA - hollow anode, TI - teflon insulator; (a) - cathode dark space, (b) - negative glow, (c) - hollow anode glow, and (d) - outflow of the plasma.

and a hollow anode (HA). The hollow anode is represented by a disk (made of aluminum alloy) with the aperture in the center 1 mm in diameter. The upper side of the disk, facing the cathode, is insulated by a thin ceramic layer deposited by a plasma arc (dashed line on Fig.1) thus making only the inner surface of the anode aperture conductive. Teflon insulator (TI) enables the hollow anode to be in the center of the concave cathode curve and knife-edge seal. The operating gas, controlled by a needle valve, enters from the cathode side of the diode and is pumped away through the hollow anode aperture by a standard vacuum system.

When in such a diode the discharge is established then in the hollow anode a very bright plasma is formed - hollow anode discharge (HAD). It has distinctive arrangement of dark and luminous regions between the cathode and anode /3/. They differ strongly according to both colour and intensity of the emitted light: dark space near the cathode, followed by bright region, and very bright part of discharge in the hollow aperture of the anode. By analogy with the conventional glow discharge, they may be nomenclatured as (Fig.1): cathode dark space region (a), negative glow region (b) and hollow anode glow region (c). An intensive outflow of the plasma through the hollow anode (d) has been observed. The length and the colour of the various regions depend on the kind and the pressure of the gas and on the discharge current. The discharge is very stable and transition into an arc, or spark of the ceramic-metal junction has not been observed.

The cathode end of the negative glow is sharply defined and concentric with the concave cathode curvature due to beamlike properties of the electron stream from the cathode. The intensity of the anode glow depends on the hollow anode diameter, discharge current and pressure. The anode glow forms a small hemisphere outside the anode aperture which is concentric with both the negative glow and the concave cathode curvature. The optical spectrum of the argon HAD consists of argon ion lines only (neutral argon lines, anode or cathode material lines are not recorded). This indicates that the electron temperature is high. Very intensive argon ion lines and the absence of neutral argon lines in the spectrum points to a high degree of argon ionization and excitation in the anode glow of the HAD. Due to beamlike properties of the electron stream and focusing of the concave cathode, high efficiency of ionization and excitation in the hollow anode aperture is obtained.

## Hollow Anode Ion-Electron Source

Hollow anode ion-electron source is presented in Fig.2. It consists of a concave cathode (CC) with a curvature radius R=30 mm and a hollow anode (HA) 1 mm in diameter. Both CC and HA were made of aluminum alloy. The upper side of the anode, facing the cathode, is insulated thus making only the inner surface of the anode aperture conductive. The hollow anode was tested both with a thin ceramic layer and a mica insulator. In the latter case proper manufacture and alignment of the mica insulator is necessary. Teflon insulator (TI) with the knife-edge seal is placed between the concave cathode and hollow anode. The heat sink (HS) on the concave cathode enables alignment of the concave

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cathode - teflon insulator - hollow anode assembly. Viton "O" rings (OR) have been used. The operating gas enters the source from the cathode side and is pumped away through the hollow anode aperture by the standard vacuum system.

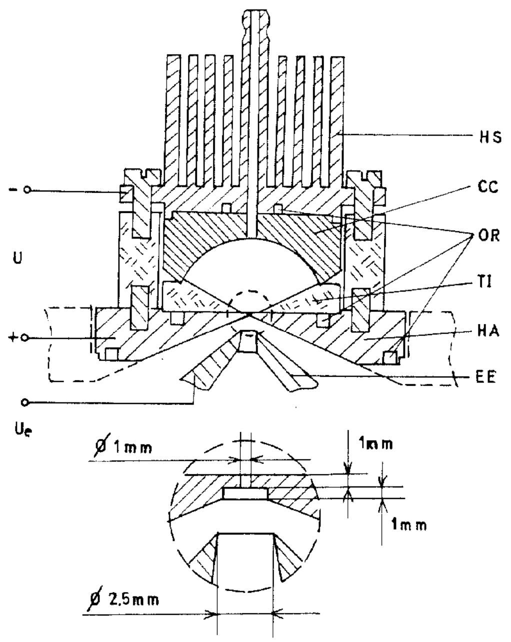


Fig.2. Cross-sectional view of the hollow anode ion-electron source: HS - heat sink, CC - concave cathode, OR - "O" rings, TI - teflon insulator, HA - hollow anode, EE - extraction electrode, U - discharge voltage, and Ue - extraction voltage.

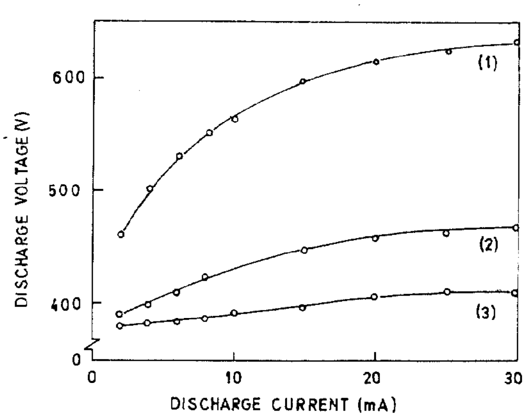


Fig.3. Current-voltage characteristics of the ion cource discharge for hydrogen pressure: $p=1\cdot10^{-2}$ Torr - curve (1), $p=3\cdot10^{-2}$ Torr - curve (2), and $p=5\cdot10^{-2}$ Torr - curve (3).

The lower side of the hollow anode is the exit aperture of the source (dashed circle on Fig.2) and together with the extraction electrode (EE) represents a modified Pierce's system /4,5/. In order to study extraction system only, a collector electrode is connected to the extraction electrode. Suppression of the secondary electrons from the collector electrode is provided by means of permanent magnets in the extraction electrode.

When the HAD is established and the extraction voltage (Ue) equals zero, an intensive outflow of the plasma through the hollow anode-source aperture is observed. Then, the ion current is obtained even at low acceleration voltages. The plasma boundary and ion beam are localized in the high vacuum region. Constant hydrogen ion currents in excess of 1 mA have been obtained. It depends on the discharge current, source aperture and extraction potential, and can reach several mA. Typical current-voltage characteristics of the ion source discharge for hydrogen pressures: $p=1\cdot10^{-2}$ Torr - curve (1), $p=3\cdot10^{-2}$ Torr - curve (2) and $p=5\cdot10^{-2}$ Torr - curve (3) are shown in Fig.3.

The ion source is tested with the concave cathode R=17,5 mm. In this case higher operating pressure is necessary.

## Conclusion

The hollow anode source has certain advantages as: small dimensions of the source, no heated cathode, a high degree of gas ionization with low-flow gas rate and good power efficiency, no unwanted ions of the cathode or anode material, and an instantaneous ion beam after switching the source on. Small surface of the electrodes enables easy outgasing of the source what is of importance when it is dealt with pure gases. The simple construction of the source enables easy replacement of the concave cathode and hollow anode due to the change of the material and/or their geometry. Consequently the source can be adapted for different applications. By choosing the appropriate material for electrodes, the source can be successfully used with the chemically active gases.

These advantages point to the possible application of the hollow anode discharge as an effective long lived ion-electron source.

## References

/1/ V.I.Miljević, Hollow anode ion-electron source, Rev.Sci.Instrum., Vol.55, pp.931-933, June 1984.

/2/ V.I.Miljević, Spectroscopy of hollow anode discharge, Appl.Opt. Vol.23, pp. 1598-1600, May 1984.

/3/ V.I.Miljević, unpublished.

/4/ G.G.Kelly, N.H.Lazar, and O.B.Morgan, A source for the production of large DC ion current, Nucl. Instrum.Methods Vol.10, pp.263-271, April 1961.

/5/ J.R.Pierce, Theory and Design of Electron Beam, New York: van Nostrand, 1954.