SELF-SUSTAINED UNSTABLE MODES FOR OPERATION OF GLOW DISCHARGE. AN APPLICATION

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Abstract. Two self-sustained unstable modes for operation dependent on the operating $i$-$V$ point are observed in a hollow cathode discharge (HCD). They manifest themselves as either galvanic oscillation or pulsation. The instabilities take place under $i$-$V$ sections of both positive and negative differential resistance. The frequency $f$ of the instabilities is found depending on the current discharge value $i$. The function $f(i)$ is a precondition some deviations of both gas pressure and purity fixed to be noticed.

1. INTRODUCTION

Glow discharge (GD) is known as a medium of certain important and only possible applications (Marcus et al. 1993). As a rule, the stability of the selected mode for operation is a necessity vs. above field. A GD modification, e.g. hollow cathode discharge (HCD) is known as a stable light - and sputtered atoms source enlarging some of these applications (Caroli et al. 1993). However, from another point of view the plasma in a GD is known as a typical nonlinear dynamical \textit{open system} with a large number of degrees of freedom. Within these frames a HCD should possess one more additional degree of freedom due to the intensive atomization of the cathode surface. Some new HCD application fields revealed instabilities vs. both induced and spontaneous $\Delta i$-$\Delta V$ deviations (Lee et al. 1987 and Zhechev et al. 1998). The instabilities are observed under $i$-$V$ branch of $(\partial U/\partial i) < 0$. The latter arises due to Penning ionization (Dimova et al. 2004 and Dimova et al. 2003).

In this study two self-sustained unstable modes for operation of a HCD are analyzed vs. the operating $i$-$V$ point. The self-sustained instabilities are analyzed as an indicator of $\Delta p$ - and $\Delta P$ deviations of both pressure $p$ and purity $P$ of the gas medium.
2. EXPERIMENTAL

The stability of a HCD dc operation is studied at absence of any external perturbation. Figure 1 contains a schematic drawing of the standard experimental set-up. Time-dependent change in the impedance of the discharge was determined by measuring the voltage $\Delta U(t)$ across the 50 $\Omega$ resistor $R_m$. A trademarked HCD modifications, i.e. trademarked lamp Ne/Ca/Ba (“Cathodeon Inc”) was used.

Both regions of negative dynamic resistance $\partial U/\partial i < 0$ and great slope variety of some HCD $i$-$V$ curves (Zhechev et al. 1998) drew our attention to $i$-$V$ operating points of different $\partial U/\partial i$ values.

3. RESULTS AND DISCUSSION

3.1. Generally, self-sustained oscillating components were observed under some operating $i$-$V$ points on overlapping $i$-$V$ parts of both $\partial U/\partial i < 0$ and $\partial U/\partial i > 0$ (Figure 2) and under operating $i$-$V$ point close enough to the critical low one. At the beginning a self-sustained oscillating voltage component (18 Hz, $\sim 7$ V) was detected under operating points of $\partial U/\partial i < 0$ (Figure 3). Both frequency $f$ and shape of oscillation change within the discharge current values of (1.5 - 1.9) mA. Earlier, self-sustained oscillations were observed in (Lee et al. 1987). The oscillation negative peaks were observed to extinguish the discharge and HCD passes into a twinkling mode for operation of the same frequency. Self-sustained instability of pulsing type and frequency (50kHz) was observed for the first time. It takes place at $i \in [3.0 \div 6.8]$mA where $\partial U/\partial i > 0$.  

![Figure 1: Experimental scheme: $R_b$ - ballast resistor (11 k$\Omega$), C (0.47 $\mu$F) - decoupling condenser, $R_m$ - measuring resistor.](image-url)
Both oscillation-and pulsation frequencies depend strongly on their $i$-value.

The genesis of the observed instabilities may be analyzed formally within the frames of an equivalent HCD circuit.

Both self-sustained oscillations and light-induced conductivity are precondition for OG optogalvanic transfer of instability within the sections of a segmented GD including that used as a laser medium (Mihailova et al. 2003). This opportunity was checked.

3.2. Generally, the methods for monitoring of either gas pressure $p$ or purity $P$ are based on some simple measurable effect dependent on the value of $p$ and $P$. Earlier the shape of the optogalvanic signal was discussed as a sensitive indicator of changing $p$ and $P$ (Zhechev et al. 2003). The sensitivity of both oscillation - and pulsation frequency $f$ vs. current discharge value, $i$, is a precondition any deviation $\Delta p$ or $\Delta P$ to be noticed by using the function $f(i)$. Indeed, either of $\Delta p$ or $\Delta P$ stimulates change in the gas medium effective potential of ionization, i. e. $\Delta i(\Delta p)$. The latter influences the self-sustained oscillation frequency $f$.

Obviously, the sensitivity $\Delta f(\Delta p)$is a function of the operating $i$-$V$ point. The steeper the $i$-$V$ sections the higher sensitivity $\Delta f(\Delta p)$.

4. CONCLUSIONS

Two self-sustained unstable modes for operation of a HCD are observed. The low frequency oscillations (of tens Hz) take place under $i$-$V$ operating points of negative dynamic resistance. The discharge passes into a twinkling mode for operation of the same frequency. Pulsations of tens kHz frequency arise under $i$-$V$ operating points of
positive dynamic resistance. The frequency of the self-sustained unstable modes for operation depends on the discharge current value. This function is a precondition for gas pressure and purity monitoring.

References


