SPECTROSCOPIC STUDIES OF INTENSE PULSE DISCHARGE IN HYDROGEN

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Spectroscopic methods were used to study the properties of intense pulse discharge in a gas. It is shown that in the initial stage of the process, while the discharge is contracting onto the axis of the chamber, the velocity of the luminous front is as high as $6 \times 10^8$ cm/sec. A calculation of the number of ionized atoms is carried out. Experiments in which the luminosity of the pulse discharge plasma was investigated are described. The results of intensity measurements on the spectral lines of a hydrogen plasma are presented.

Introduction

In the present article we describe experiments devoted to spectroscopic investigations in the little known field of low pressure gas discharges at currents of several hundred thousand amperes.

Spectroscopic studies carried out for dynamic conditions make it possible for us to get some idea as to the change in the properties of the gas in which the discharge is taking place as the discharge runs its course, primarily with respect to the concentration of charged particles and the time variation of their distribution. For given conditions, it is also possible to learn something of the particle velocities in the gas discharge plasma. Let us note that when compared with other methods, the optical method of investigation has one definite advantage; this is related to the fact that the measurement process in this case takes place without any interference with the course of the effect being studied.

The large values of the current through the gas which were achieved in the experiments could have been obtained only in pulse discharge. The discharge circuit consisted of a condenser bank with a total capacitance $C = 30 \mu F$, charged up to a voltage $U_0 = 30-40$ kv. By operating a special device, a periodically attenuated discharge was initiated in the discharge chamber. The discharge chamber was a glass cylinder with an inner diameter of 185 mm and an interelectrode distance of 450 mm. The experiments were performed at various hydrogen pressures within the interval from 0.04 to 5 mm Hg. At maximum, the current was 270-300 ka.

Measuring apparatus

An OK-17 double beam pulse oscillograph was used to record the current and voltage in the discharge process. The current was measured with the aid of a Rogovsky bridge. A low-resistance voltage divider was used to measure the potential across the electrodes. The spectroscopic investigations were performed by two methods: photographic and photoelectric. An ISP-51 spectrograph with three glass prisms was used for photographing the visible region of the spectrum. The time variation of the various lines of the spectrum were recorded with the aid of a UM-2 monochromator connected to an FEU-19M photomultiplier by a special attachment. The signal generated in the photomultiplier circuit by a separate line or part of the spectrum defined by the monochromator slit was fed through a cathode follower to a wide-band amplifier, whose output fed the oscillograph plates. Thus the optical effects could be recorded in synchronization with the current or voltage of the discharge gap.
The apparatus at our disposal made it possible not only to study the behavior in time of the separate lines, but could also be used to obtain a quantitative evaluation of the energy radiated by the pulse discharge in the visible region of the spectrum. For the latter, however, it was necessary to know the absolute sensitivity of the measuring apparatus. The following simple method was used to calibrate it. An incandescent lamp with a tungsten filament was chosen as the light source. \( W = 96 \) watts, \( V = 127 \) volts. The color temperature of such a lamp is 2850 K. The spectral distribution of the radiation intensity from tungsten is known in relative units for a given color temperature: in the visible region it is identical with black body radiation at the same temperature. A table of absolute values of the spectral intensity for the case of interest can be taken, for example, in the work of Forsythe [1], on the assumption that the radiation is isotropic in space. The distance from the lamp to the first slit of the monochromator was chosen large compared to the dimensions of the lamp filament. In this case the light source could be considered a point source with little error. The operating conditions of the incandescent lamp were held constant and were continuously regulated. Thus the absolute sensitivity of the measuring apparatus could be determined for any region of the visible spectrum.

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C(\lambda) = \frac{i(\lambda)}{W(\lambda)}.
\]

Here \( C(\lambda) \) is the sensitivity we are looking for in amps/watt, \( i(\lambda) \) is the output current of the photomultiplier in amps, \( W(\lambda) \) is the power radiated by the source in the interval of wavelength from \( \lambda \) to \( \lambda + \Delta \lambda \) into a solid angle of \( 4\pi \) calculated from the tabulated data, and \( a \) is a geometric factor which determines the fraction of the source radiation that enters the spectroscopic apparatus. If, now, the incandescent lamp is replaced by any other source, its radiation for an arbitrary region of the spectrum can be easily found in absolute units, independent of the method for recording the electric signal at the photomultiplier output.

Figure 1 shows the experimentally determined curves for \( C(\lambda) \) and for \( a(\lambda) \), the spectral sensitivity of the photomultiplier. The quantity \( a(\lambda) = C(\lambda) / k(\lambda) \), where \( k(\lambda) \) is the transmission coefficient of the monochromator; the values of \( k(\lambda) \) were determined in independent experiments.

Results of the Measurements

Figure 2 shows the most characteristic spectrograms of the discharge. The spectra were photographed on panchromatic plates with a sensitivity of 45 units (All-Union State Standard 2817-50) during the course of one discharge for a spectrograph slit width of 0.002-0.003 mm.

It follows from analysis of the spectrograms that in the visible part of the spectrum, in addition to the lines of atomic hydrogen, the lines of other atoms are observed. Both the relative and the absolute intensity of the impurity lines decreases as the initial hydrogen pressure is increased, and the lines of atomic hydrogen become brighter; the intensity of the over-all background also increases with pressure. As the initial pressure is increased, the total brightness of the discharge increases rapidly. The impurity lines, whose presence indicates the strong thermal effect of the discharge on the chamber wall, occur starting with some minimum value of energy liberated by the discharge.

Figure 3 shows the intensities of the lines \( H_\alpha, H_\beta, H_\gamma, Si II (\lambda = 4128 \) Å), synchronized with the current for an initial pressure of 0.1 mm Hg. From the oscillograms it is seen that starting at a time corresponding to

![Graph showing C(\lambda) and a(\lambda)]