II. MICROWAVE GASEOUS DISCHARGES

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A. ELECTRON COLLISION LOSSES AT LOW ENERGIES

An investigation is being started to determine the presence of collisions between slow electrons and diatomic molecules which excite rotational and vibrational states. The collision process will be studied in the afterglow of a low-pressure, 10-cm microwave gas discharge by following the procedure shown in Fig. II-1.

Electrons are produced in the cavity by a breakdown pulse, and are allowed to come to thermal equilibrium with the gas molecules. Then a microwave heating field is applied long enough to establish steady state at a higher electron energy (1 ev to 2 ev). When the heating pulse is turned off, the electrons lose their energy in the order of microseconds by collision with the gas. Since the conductivity of the plasma depends in general upon the electron energy, a measurement of this quantity (1) by a low-level search signal during the energy decay yields the rate of energy loss as a function of energy. This may also be given by the expression

$$\left\langle \frac{\text{d}u}{\text{d}t} \right\rangle = -\frac{2m}{M} \left\langle \nu_m u \right\rangle - \left\langle \text{Inelastic Energy Decay} \right\rangle$$

where $m =$ electronic mass, $M =$ molecular mass, $u =$ electron energy, $\nu_m =$ collision frequency for momentum transfer, and the brackets denote averaging over electron and gas distribution functions.

The first term on the right represents energy decay due to elastic recoil. The presence of the second term, when the electron energy is kept below the electronic excitation energy, indicates that rotational or vibrational states are excited.

B. ELECTRON-ION RECOMBINATION IN HYDROGEN

The experimental setup has been completed, tested, and found to work well in principle. However, the coupling discs protruding into the cavity were found to introduce noticeable asymmetries in the gas discharge, and new couplings were constructed where the end faces of the coupling discs were in the same plane as the walls of the cavity. The asymmetries in the discharge, for all practical purposes, then disappeared. This possible disturbance from the coupling mechanism motivated building a new cavity where the arrangement for the heating signal was excluded in order to check earlier measurements on thermal plasmas and in order to find out if the coupling arrangements for the heating field had any influence on the results.

Some time has been spent on improving the coupling arrangements and the external
Fig. II-1
The variation of experimental parameters as a function of time in the afterglow.

Fig. II-2
Cavity with probe (probe structure enlarged).
circuit for the breakdown signal, in order to get better control over the initial spatial electron distribution in the bottle. This has been possible, and the coupling construction now allows us to reach electron densities above plasma resonance. Some improvements in the measuring technique have been made possible by using a swept probing signal, by decreasing the coupling to the probing mode, and by decreasing the attenuation in the external probing circuit. The frequency-shift measurement has been improved by using a signal transmitted through the echo box, instead of the reflected signal from the echo box. The possible measuring range in time has thus been increased by a factor of two to three.

The measurements so far show agreement with earlier measurements, when considerations of difference in time ranges are taken into account.

C. OSCILLATIONS IN DC DISCHARGES

The low-pressure mercury arc discharge tube described previously (2) has been processed. The investigation of this discharge tube indicated no high-frequency oscillations were excited by the injected electron beam. Tests of the electron-gun system showed the electron density of the beam was much lower than that of the electron beams used in earlier experiments. The electron density of the beam may be lowered by three factors: general inefficiency of the gun structure, beam spread due to long path lengths, and electron collisions with gas atoms. The electron loss due to these last two factors may be reduced by shortening the path length. A new tube is being prepared which will reduce the path by a factor of 5 and increase the beam electron density by a factor of 50. The electron beam density and the plasma electron density of the new tube should be comparable to the densities reported in previous experiments on plasma oscillations.

D. PROBE STUDIES

A program has been started to solve the problem of determining the accuracy and the limitations of density and temperature determinations by probes. The temperature and the density obtained from probe curves are to be compared with the values obtained by microwave methods. Preliminary experiments have been performed in the steady-state discharge maintained in a cylindrical cavity by 10-cm power. The cavity was excited in the $TM_{020}$ mode. A floating bipolar probe was inserted at the node of the E-field in order to prevent leakage of microwave power by way of the probes. Probes of various shapes were tried, and the type of probe shown in Fig. II-2 seemed to give satisfactory probe curves over the largest range in pressures.

The mean energy of the electrons is obtained, from probe curves, by taking the slope of the curve of $ln \left[ \left( \frac{\sum i_p}{i_{e_2}} \right) - 1 \right]$ vs $V_d$. It should be noted that


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\[
\ln \left[ \frac{\sum i_p}{i_{e2}} \right] = -\frac{eV_d}{kT} + \ln \sigma
\]

where

\[
\sum i_p = i_{p1} + i_{p2}
\]

is the sum of the positive ion saturation currents to the probes as determined from the saturation values; \(i_{p1}\) and \(i_{p2}\) are the positive-ion saturation currents to probes No. 1 and No. 2, respectively; \(i_{e2}\) is the electron current to probe No. 2; \(V_d\) is the externally applied potential to the floating bipolar probe; \(\sigma\) is a constant; \(e\), \(k\), and \(T\) are the electronic charge, Boltzmann's constant and electron temperature, respectively.

The electron density is computed from the positive-ion saturation value of the probe curves assuming that \(n_p = n_e\). The mean energy by the microwave method is determined from the known value of \(E_e/p\), using the data by Varnerin and Brown (3). The electron density at the point where the probes are inserted is computed from the shift in resonant frequency, assuming a density distribution in the cavity as suggested by Herlin and Brown (4).

References

2. Ibid. p. 8