

II. MICROWAVE GASEOUS DISCHARGES

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A. HIGH-DENSITY MICROWAVE GASEOUS DISCHARGE

The program of studying the high-density plasma by means of microwaves is being continued. The gap in the thin coaxial line used as a probing element was reduced to only 1.5 cm to minimize the effect of the walls of the bottle containing the plasma on the wave transmitted through the line. The power transmitted through the line was measured as a function of the electron density in the plasma (determined by a double probe) for various pressures and different frequencies of the probing signal. A typical curve of power transmitted vs. density exhibits a maximum that is assumed to occur at plasma resonance. A log log plot of the plasma density at maximum transmission vs. frequency of the probing signal at a constant pressure results in a straight line whose slope seems to depend on pressure. The relation between the two is not yet clear. For the range of pressures used (0.5-1.3 mm Hg), the slope varied from about 3 to 6, increasing with increasing pressure. This is to be compared with the theoretically predicted value of about 1.3.

Another way of analyzing the experimental data is to plot plasma density at the maximum transmission vs. pressure for a given frequency of the probing signal. This procedure requires correcting the current reading of the double probe for the changing pressure. The assumption made in the last report that the current collected by the double probe is related to the electron density at the probing line by a multiplicative constant which is independent of pressure is not a good one. Other workers (1) have obtained a crude theoretical expression for the pressure dependence of this constant, but there is some doubt in the mind of this writer as to the experimental verification of this expression.

The theoretical solution to the problem of transmitting an electromagnetic wave through a coaxial line in which a part of the outer conductor is a medium of complex conductivity is progressing satisfactorily. The transmission coefficient is being expressed in terms of a variational principle. The integrals involved are complicated and may require machine computation.

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References

1. G. J. Schulz, Ph. D. Thesis, Department of Physics, M.I.T.(1954), p. 101.

B. PLASMA OSCILLATIONS

Until now, the mechanism of plasma oscillations produced by the interaction of a beam of electrons with a plasma in the tube built by Looney (1) and an improved one (2)

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presently in use has been described in the following way. The beam of electrons, entering a uniform region of the plasma of an arc discharge in mercury vapor through an accelerating positive ion sheath, is modulated in velocity because the plasma oscillations cause the plasma potential at the sheath to vary. After an appropriate drift length, the velocity modulation causes a bunching of the beam electrons which drives the plasma electron oscillations.

The mechanism by which the energy of the oscillations was fed back to the electrons in the sheath region was never understood. It was thought that the plasma could propagate a space charge wave and that it was the returning wave which supplied the energy for the oscillation, and, interacting with the forward wave, set up the observed standing-wave patterns along the beam. The boundaries off which the waves were reflected could be either the sheath or the bounding electrode over which the sheaths were formed.

This picture is weak in the following details: It cannot predict the phase velocities of the waves; in fact, experimentally, the phase velocities depend on the boundary conditions and the bunching points in no well-defined way. The required bunching distances are much less than simple bunching theory predicts.

It is now clear that actually there are two beams to consider. A second beam of comparable electron density moves within the first beam in the opposite direction. It is produced by secondary electrons, coming off the nickel reflector, which are accelerated by the fields within the sheath. The velocity spread is small and the beam usually terminates in the other sheath.

The second beam can provide the feedback mechanism if it is assumed that the beams propagate space charge waves which interact with one another to produce the standing-wave pattern. The sheaths provide the modulation for the two beams, and the space charge waves are coupled to the plasma along the entire length of the beam.

This assumption is checked experimentally by varying the sheath voltages in such a way as to maintain a particular mode of oscillation. This varies the position of the sheath edges and the velocity of the beams. Calculation of the transit time of a wave front from one sheath to the other along one beam and back again on the return beam shows that the transit time is the same for the various combinations of sheath voltages and is compatible with the period of the oscillation. An exact check is not yet possible because the phase velocities are not known.

The problem of determining the phase velocity for such a propagation is not too difficult to solve approximately; this is being done.

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References

1. D. H. Looney, Ph. D. Thesis, Department of Physics, M.I.T. (1953).
2. Quarterly Progress Report, Research Laboratory of Electronics, M.I.T., April 15, 1955, pp. 11-12.

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C. MICROWAVE DETERMINATION OF THE PROBABILITY OF COLLISION OF SLOW ELECTRONS IN NEON

The microwave complex conductivity of a neon plasma $\sigma = \sigma_r + j\sigma_i$ has been measured as a function of electron temperature in the range from room temperature to about 30,000°K. The method is the same as that used by Gould and Brown (1) for helium. A plot of the measured parameter $\rho = (1/p_0)(\sigma_r/\sigma_i)$ (p_0 is the pressure normalized to 0°C) as a function of the electron temperature at the center of the cavity T_{e0} is shown in Fig. II-1. No appreciable change was observed between the ρ values measured in pure neon and in neon contaminated with argon (approximately 0.1 per cent), in the range from room temperature to 5000°K. In the last case, the decay is controlled by ambipolar diffusion (2) and in experimental conditions the electron density distribution in the quartz bottle is expected to be cosinusoidal. Therefore, the probability of collision as a function of energy will be determined from the measured ρ curve by using this hypothesis. Integrals to be used in these calculations are programed to be computed by Whirlwind.

Without applying any correction for the disuniformity of electron temperature inside the cavity, a preliminary value of the probability of collision in neon at room temperature is $1.6 \text{ cm}^2/\text{cm}^3$ per mm Hg.

Small changes in the average electron energy resulting from conduction and convection of energy from regions of high energy to regions of low energy have been observed

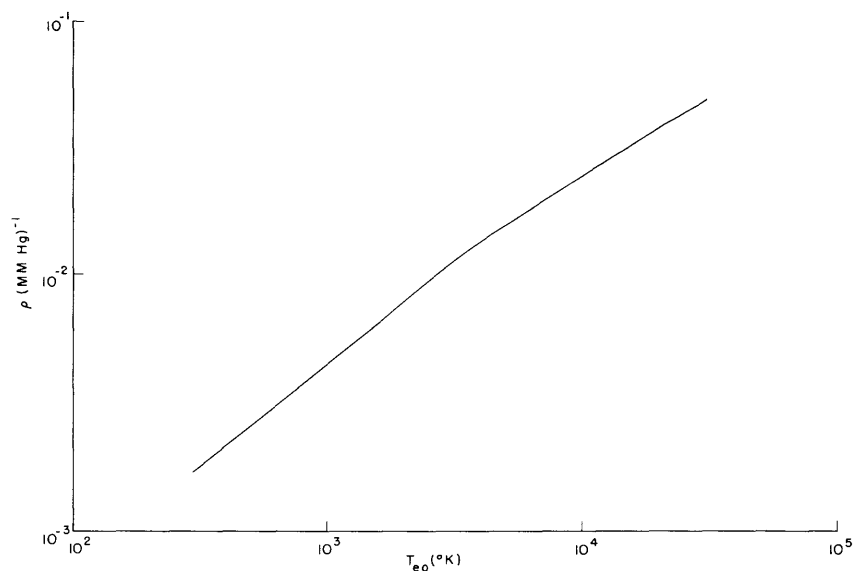


Fig. II-1

Conductivity ratio ρ as a function of the electron temperature T_{e0} at the center of the quartz bottle.

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as a function of pressure. The curve shown in Fig. II-1 has been measured at high enough pressure, compatible with the condition $\gamma_c^2 \ll \omega^2$, so that energy gradient effects are unimportant.

It has been impossible until now to perform measurements in neon contaminated with argon at temperatures over 5000°K because of instabilities in the afterglow decay. We hope to overcome this difficulty and use the same apparatus to study the diffusion coefficient as a function of electron temperature.

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References

1. L. Gould and S. C. Brown, Phys. Rev. 95, 897 (1954).
2. M. A. Biondi, Phys. Rev. 83, 1078 (1951).