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Measurement of Electron Mobilities in Argon Gas in a Pure Vapor Cloud Chamber*

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Measurements have been made of the mobilities of electrons in argon gas using pure vapor cloud-chamber techniques. Electron mobilities were measured in the E/P_0 range (P_0 is the pressure corrected to 296°K) from 7.9 to 11.4 V/cm mm Hg. The electron mobilities were found to be approximately constant over this E/P_0 range with a value of k_0 of about 3.0×10^6 cm²/vsec mm Hg.

INTRODUCTION

THE purpose of the present work is to measure the mobilities of electrons in argon gas using pure vapor cloud-chamber techniques. Raether[1] and Riemann[2] have studied prespark avalanche phenomena by means of conventional cloud-chamber techniques, but until the advent of a cloud chamber operating with a pure vapor little quantitative data could be obtained using cloud-chamber techniques. This is because in the conventional cloud chamber the gas in which the predischarge phenomena is to be studied, the permanent gas, is fouled with water vapor, alcohol vapor, and other impurities. Raether and Riemann also were handicapped since at time of their work none of the modern methods of pulse techniques were available for the production and observation of their high-voltage accelerating pulses.

Attempts[3,4] have been made to operate conventional cloud chambers in which the permanent gas pressure was quite low, but the sensitive times were on the order of milliseconds. This is because with a low permanent gas-pressure diffusion from the free liquid surface of the vapor source is not inhibited and the rapid evaporation of warm vapor quickly terminates sensitivity. However, if the free liquid surface is isolated from the cloud chamber during an expansion, it is then possible to operate a cloud chamber with a pure vapor.[5]

APPARATUS

The apparatus consists of the pure vapor cloud chamber, the argon vapor source and filling system, and the electronic pulse circuitry. The pulse circuit performs two functions: It produces ultraviolet photons which eject photoelectrons used to initiate the electron avalanches and it produces high-voltage pulses in whose electric field the electron avalanches develop.

The cloud chamber is shown schematically in Fig. 1; it is of the volume defined type. The adiabatic expansion is performed by allowing a sylphon bellows in the cloud chamber to move to a geometrically defined final position. The cloud chamber consists of a pyrex cylinder $3\frac{1}{2}$ in. in diameter by $\frac{1}{2}$-in. high clamped between two aluminum plates which form a plane parallel electrode system. The vacuum seals between the cylinder and the plates are made with indium gaskets. The bottom plate is used as the hole plate with the expansion bellows below the plate. The cloud chamber is surrounded by two concentric cylindrical jackets. The inner jacket contains liquid nitrogen which cools the chamber to 77° while the outer jacket is a vacuum insulating space. Pyrex windows sealed with indium gaskets are provided in the nitrogen jacket for illumination and observation of the cloud chamber sensitive volume. Quartz windows are provided for illumination of the bottom chamber plate with ultraviolet light. The expansion bellows is

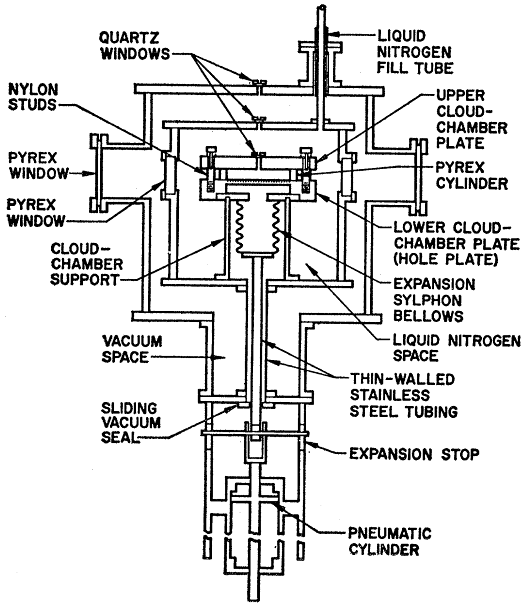

FIG. 1. Schematic diagram of pure vapor cloud chamber.

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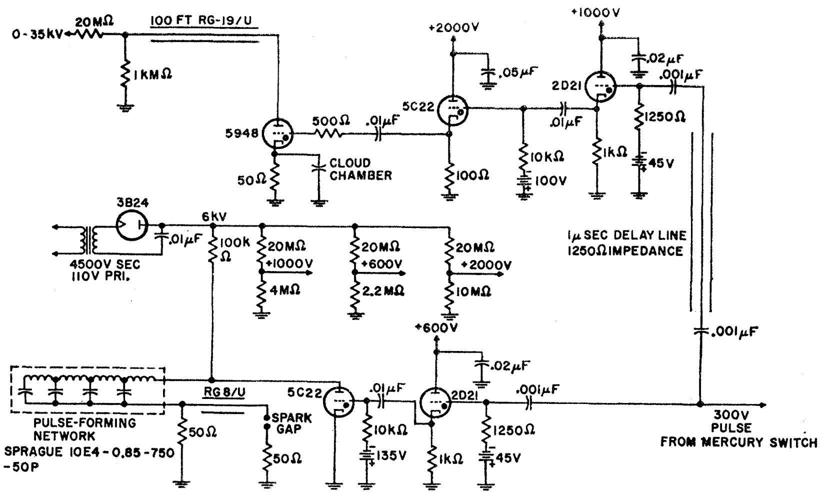

FIG. 2. Electronic pulse circuitry.

actuated by a pneumatic cylinder outside the refrigeration and vacuum spaces.

The vapor source consists of glass vessels for fractionally distilling the argon which is condensed by cooling with liquid oxygen. The final vapor-source vessel is connected to the cloud chamber by a metal capillary tube. The chamber filling time through this capilliary is about 100 sec so that the filling pressure can be readily reproduced to less than one half of one percent. The saturation pressure of argon corresponding to the cloud-chamber wall temperature (77°K) is 170 mm of Hg. Since the vapor in the cloud chamber should be slightly undersaturated with respect to the wall temperature in order to insure there is no liquid phase, a cloud-chamber filling pressure of 160 mm of Hg was chosen. For the avalanche studies the cloud chamber is operated with an expansion ratio of 1.40 which produces a calculated final argon temperature of 59.7°K and a supersaturation of 8.9.

Experience with diffusion cloud chambers shows that evaporation from a clean liquid surface produces a vapor source which is free from condensation nuclei. Thus, the cloud chamber is operated by filling with argon vapor, expanding the vapor for observaions, pumping the vapor from the chamber, filling the chamber again, etc. In this mode of operation the re-evaporation nuclei are simply removed from the chamber and vapor free from condensation nuclei is introduced. This method of operation allows a very short time between observational expansions.

The electronic circuitry is shown in Fig. 2. The pneumatic cylinder which operates the cloud-chamber expansion bellows trips a mercury switch at the end of its travel, i.e., immediately after cloud-chamber expansion, which triggers the circuitry. The pulse from the mercury switch immediately triggers thyratrons which discharge a Sprague 0.85-μsec pulse forming network into a spark gap. The spark gap is mounted so that the ultraviolet photons created in the spark discharge pass through the quartz windows on the cloud chamber and eject photoelectrons from the cloud-chamber bottom plate.

One microsecond after the triggering of the spark gap, just after cessation of the 0.85-μsec pulse and, therefore, photoelectron production, the initiating pulse appears across the terminating resistance of the 1-μsec delay line. This delayed pulse triggers thyratrons which discharge a 100-ft length of RG-19/U into a 50Ω terminating resistance in parallel with the cloud chamber plates. The pulse which appears across the chamber is variable from 0 to 17.5 kV and has a length of 0.33 μsec. The pulse is reasonably square, having a rise and fall time of 0.02 μsec and a maximum voltage variation of 5% across its top. This pulse is used to produce electron avalanches from the initiating photoelectrons. The avalanches are photographed using usual photoflash techniques.

RESULTS AND CONCLUSIONS

The velocity of propagation of the avalanche, i.e., the electron drift velocity, can be measured readily since the pulse length is known and the distance traveled

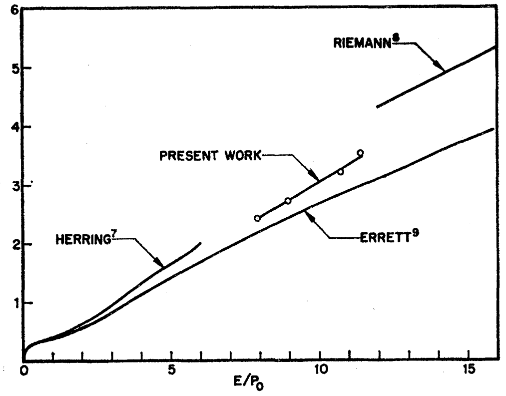

FIG. 3. Electron mobilities in argon.

by the electrons during this time can be measured from the avalanche photographs. Using the observed drift velocities the corresponding values of E/P_0 are calculated (P_0 is the final cloud-chamber pressure corrected to 296°K and, hence, corresponds to the argon gas density used by other observers). These results along with results of other observers are shown in Fig. 3. The present data indicate that in the range of E/P_0 values used (7.9 to 10.4 V/cm mm Hg) k_0 is independent of E/B_0 and has a value of 3.04×10^5 cm^2/V sec mm Hg. Herring[6] measured drift velocities with E/P_0 values up to 6 V/cm mm of Hg. Herring's data is in excellent agreement with Nielsen's[7] data over Nielsen's range of E/P_0, i.e., E/P_0 values of less than four. Nielsen's data is usually considered to give the best drift velocity information for electrons in pure argon. The present mobility measurements appear to agree quite well with this data if its range is extended, although they are from 10 to 15% higher than the mobilities measured by Errett.[8] The higher mobilities measured by Riemann[9] can be understood in the light of Errett's measurements of the effect of water vapor on electron mobilities in argon; Errett showed a sizable increase in electron mobilities in argon containing a very small admixture of water vapor. The fact that the present measurements made using tank argon fractionally distilled in the vapor source agree well with results in purified argon is not surprising. Bortner, Hurst, and Stone,[10] using tank argon fractionally distilled, using liquid nitrogen as the coolant, measured electron mobilities that agreed quite well with Nielsen's measurements. In the present measurements the nitrogen and oxygen impurities are estimated to be less than 0.1% which according to the measurements of Errett would produce an increase in the mobility measurements over that in the pure gas of 5% or less in the E/P_0 range used.

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Lattice Thermal Conductivity of Disordered Semiconductor Alloys at High Temperatures*

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The high-temperature thermal conductivity of a disordered semiconductor alloy is derived using the Klemens-Callaway theory. It is assumed that the reciprocal relaxation times depend on frequency ω as ω^4 for strain and mass point defects and as ω^2 for normal and umklapp three-phonon anharmonic processes. The thermal conductivity is expressed in terms of the lattice parameters and mean atomic weights of the alloy and its constituents. Agreement is obtained between theory and published experimental data on Ge-Si alloys at temperatures 300–1200°K, and on (Ga,In)As alloys at 300°K, using the value 2.5 for the ratio of umklapp to normal relaxation times. It is found that the large thermal resistivity of Ge-Si alloys is predominantly due to mass defect scattering, whereas that of (Ga,In)As alloys is mainly due to strain scattering.

I. INTRODUCTION

SOLID solution alloys are well suited for studying the effects of imperfections on the transport of heat by lattice waves. The present investigation is concerned with semiconductor alloys, in particular Ge-Si alloys and III-V compound alloys, because extensive experimental and theoretical data, relating to the thermal conductivities of these systems, are already available. The choice of the temperature range is motivated by the general interest in these materials for high-temperature thermoelectric devices.

The simple phenomenological model of thermal conductivity, developed by Klemens[1–4] and Callaway[5,6], is used in the present work. An alternative treatment of thermal conductivity is by the variational method of Ziman,[7] or modification thereof by Tavernier.[8]

The high-temperature limit of the theory was applied

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