On the Electron Drift Velocity in Solid Neon

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The electron drift velocity in solid neon is reported for the field strength range 1 to 50 kV cm⁻¹.

The electronic transport properties of solidified rare gases have received continuing interest since these materials represent the most simple solids. Detailed measurements of the electron drift velocity as a function of field strength were reported for sAr, sKr, and sXe by Miller, Howe, and Spear [1]. The low field mobilities were 1000, 3700, and 4500 cm² V⁻¹ s⁻¹, respectively. In solid helium, on the other hand, Keshishev [2] reported mobilities of 10⁻⁵ cm² V⁻¹ s⁻¹ or lower for the negative charge carrier. Although some unpublished data on solid neon of Spear's group have appeared in a later review [3], no data on the field dependence of the electron drift velocity in sNe have been published so far. Recently, interest in the application of solid neon as detection medium in ionization chambers for high energy physics has developed [4]. During our investigation of the transport properties of excess electrons in liquid neon we also measured the electron drift velocity in solid neon. These results are presented here.

The experimental set-up has been described in detail already [5]. Excess electrons were injected into the solid neon by illumination of a metal cathode of a diode cell with a strong light pulse from an excimer laser. The pulse duration, approximately 8 ns, was short compared to the drift time of the electrons.

An example of the photocurrent as a function of time is shown in Figure 1. The yield of injected

electrons, as determined by integrating these curves, rose almost linearly to approximately 2% of the vacuum yield at 50 kV/cm.

Fig. 1. Oscilloscopic trace of the photocurrent signal in solid neon at 8.75 kV/cm.

The electron drift velocity as a function of the applied electric field is given in Figure 2. Below 1 kV cm⁻¹ no data could be obtained since the signal to noise ratio became too small. In the range of field strength from 1 kV cm⁻¹ to 50 kV cm⁻¹ a sublinear dependence of v_d on E is observed, which is indicative of hot electron effects. Above 30 kV cm⁻¹ the drift velocity saturates and the value of $v_{ds} = 1.9 \times 10^6$ cm s⁻¹ is in line with the values of sAr (1.07×10^6), sKr (0.76×10^6), and sXe (0.56×10^6). For values of the electric field strength smaller than 1 kV cm⁻¹ the dependence was extrapolated according to the behavior of solid argon and taking into account a low field mobility value of $\mu_0 = 600$ cm² V⁻¹ s⁻¹ as quoted by Spear et al. [3].

Fig. 2. The field dependence of the electron drift velocity in solid neon (24.5 K).

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Fluorescence Spectra of Lightly and Heavily Doped $\text{NH}_4\text{Cl}:\text{Tl}$

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The excitation and emission spectra of pure and thallium activated ammonium chloride have been examined at room temperature. It is found that excitation bands at 242 and 256 nm and emission bands at 380 and 460 as well as 500 nm are characteristics of lightly and heavily doped $\text{NH}_4\text{Cl}:\text{Tl}$, respectively. It is suggested that internal electronic transitions in TlCl molecules and $(\text{TlCl}_n)^-$ complex ions are responsible for the two emission band groups.

The thallium doped alkali halides $\text{NaCl}:\text{Tl}$ and $\text{KCl}:\text{Tl}$ have been investigated in great detail [1–7]. Less is known about the excitation and emission spectra of the ammonium halides. The main purpose of the present paper is to examine the fluorescence characteristics of lightly and heavily doped $\text{NH}_4\text{Cl}:\text{Tl}$ phosphors. Attempts have also been made to suggest fluorescence centres for the emissions observed.

Analar grade ammonium chloride powder was obtained from the BDH laboratory, Chemical Division, Glaxo Laboratories, India. Crystallization from aqueous solution was used to prepare microcrystalline $\text{NH}_4\text{Cl}:\text{Tl}$ samples of concentrations 10^{-4} and 10^{-1} m.f. of impurity thallium. The excitation and emission spectra were recorded at room temperature by means of an Aminco-Bowman Spectrophotofluorometer supplied by the American Instrument Co. Inc.

Typical excitation and corresponding emission spectra of pure NH_4Cl and $\text{NH}_4\text{Cl}:\text{Tl}$ specimens with 10^{-4} m.f. and 10^{-1} m.f. of impurities are shown in Fig. 1A and 1B. A comparison of the spectra of pure NH_4Cl , lightly and heavily doped $\text{NH}_4\text{Cl}:\text{Tl}$ specimens brings about the following features:

- (i) Introduction of thallium impurity enhances the fluorescence substantially.

- (ii) The lightly doped $\text{NH}_4\text{Cl}:\text{Tl}$ (10^{-4} m.f. $\geq \text{Tl}$), specimen displays a dominant excitation band at 242 nm with a corresponding emission peak at 380 nm.
- (iii) The excitation band at 242 nm shifts to 246 nm in heavily doped $\text{NH}_4\text{Cl}:\text{Tl}$ (10^{-1} m.f.). The corresponding emission exhibits a new emission in the visible region around 460 nm along with the dominant one at 380 nm.
- (iv) The most striking feature of the heavily doped $\text{NH}_4\text{Cl}:\text{Tl}$ specimen is the appearance of an additional well defined excitation band around 256 nm with corresponding emissions at around 460 and 500 nm. The emission at 380 nm appears as hump.

According to present understanding the luminescent centres comprise of an emitter (inherently present or deliberately introduced impurity) and a

Fig. 1. (A) Emission Spectra, (B) Corresponding excitation spectra. —○—○—○— pure NH_4Cl , lightly doped $\text{NH}_4\text{Cl}:\text{Tl}$ (Tl concentration 10^{-4} m.f.), — and ——— heavily doped $\text{NH}_4\text{Cl}:\text{Tl}$ (10^{-1} m.f. of Tl impurity) for near ultraviolet and visible emissions, respectively.

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trapping site (a point defect in the host lattice). The electron-hole recombination at the emitter without multiple trapping leads to the temperature independent spontaneous emission known as fluorescence. Thus we suppose that the luminescence emission is characteristic of the impurity irrespective of host lattice. It is believed that doping of NH_4Cl with thallium generates a large number of isolated Tl^+ ions, TlCl molecules and $(\text{TlCl}_n)^-$ complexes whose relative concentrations depend on the concentration of the thallium impurity. The introduction of 10^{-4} m.f. of Tl impurity in NH_4Cl causes the prominent 380 nm emission band on 242 nm excitation (Figure 1). As it has been reported that the emissions around 320 nm and 380 nm are associated with Tl^+ ions and TlCl molecules, respectively [3, 7], it is suggested that, like in Tl-activated alkali halides, internal electronic transitions in undissociated TlCl molecules are mainly responsible for the 242 nm excitation and corresponding 380 nm emission in the case of lightly doped $\text{NH}_4\text{Cl}:\text{Tl}$. The mechanism of fluorescence suggested for this emission is an excitation induced electron transfer from

a halide ion (Cl^-) to a neighbouring Tl^+ ion and recombination with it.

It is further suggested that increasing concentrations of thallium create substantial amounts of $(\text{TlCl}_n)^-$ complex ions along with TlCl molecules, influencing the TlCl molecules and causing the shift in the 242 nm excitation band to 246 nm (Figure 1B). On the other hand, the heavily doped specimens should display new emissions associated with the $(\text{TlCl}_n)^-$ complex ions themselves. The appearance of the 460 and 500 nm emissions along with the dominant 380 nm emission strengthens this expectation. Figure 1 (dashed lines) demonstrates the favourable excitation band at 256 nm for the 460 and 500 nm visible emissions. It is proposed from the present experimental results that both the TlCl molecule and $(\text{TlCl}_n)^-$ complex ions are present in $\text{NH}_4\text{Cl}:\text{Tl}$ phosphor and that internal electronic transitions in the complex ions $(\text{TlCl}_n)^-$ are mainly responsible for the visible emissions. The fluorescence mechanism for the visible emission is more or less similar to that suggested for the 380 nm emission.

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