

ELECTRON TRANSPORT AND ELECTRON-ION RECOMBINATION IN  
NON-POLAR LIQUIDS AND SOLIDS AS STUDIED BY A X-RAY  
PULSE CONDUCTIVITY METHOD

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The electron mobility,  $\mu_e$ , is one of the most important quantities that describe the interaction between an excess electron and the molecules of the medium, and thus  $\mu_e$  has been measured for a large number of non-polar liquids. Nevertheless, the behavior of electrons in non-polar liquid is not sufficiently understood. Since  $\mu_e$  in the solid phase, however, has never been extensively measured, the examination of the effect of liquid-solid phase change on  $\mu_e$  will be very helpful for understanding the transport mechanism of excess electrons in non-polar media.

We have demonstrated that Febetron 706 is a very attractive electron-pulse accelerator to investigate the behavior of electrons in non-polar liquids and solids.<sup>1,2)</sup> The X-ray pulse obtained from electron pulse of Febetron 706 has a very short pulse-width of a few nsec with very high intensity. The short pulse-width makes it easy to determine the  $\mu_e$  value in high-mobility liquids such as neopentane (NP), and the high intensity enables us to measure the rate constant of electron-ion recombination,  $k_r$ , by controlling the intensity by setting Pb plates in front of the accelerator window.

Previously we measured the values of  $\mu_e$  and  $k_r$  in both liquid and solid NP by using the decay curve analysis method.<sup>1a,2)</sup>

We have recently applied the same method to determine the values of  $\mu_e$  and  $k_r$  in both liquid and solid tetramethylsilane (TMS).<sup>3)</sup> The molecular structure of TMS is similar to that of NP and it has been found that the reduced temperature dependence of  $\mu_e$  is qualitatively similar to each other over the whole liquid range.<sup>4)</sup> It is therefore of interest to compare the effect of the liquid-solid phase change on  $\mu_e$  for TMS with that for NP. It is also interesting to observe the effect of the solid-solid phase change on  $\mu_e$  in TMS since solid TMS has three crystalline forms designated  $\alpha$ ,  $\beta$ , and  $\gamma$  in the temperature region from 155 to 166 K.<sup>5)</sup>

Figure 1 shows the temperature dependence of  $\mu_e$  in both liquid and solid TMS and NP. By taking account of the temperature and the density dependence of  $\mu_e$ , it is found that the behavior of  $\mu_e$  in TMS is in good agreement with that in NP in both the liquid and the solid phases near their triple points (fig. 2), which indicates that the transport mechanism of excess electrons in these media is quite similar to each other in both the liquid and the solid phases. In figs. 1 and 2,  $T$  is the absolute temperature and  $n$  is the number of molecules per  $\text{cm}^3$ .

The measured values of  $k_r$  are, in a way similar to those for NP,<sup>2)</sup> roughly in agreement with those expected by the reduced Debye equation. Therefore the electron-ion recombination process is diffusion-controlled in liquid and solid  $\alpha$  of TMS.

The X-ray pulse dose can be measured by monitoring the temperature of 0.1 mm tungsten foil where the electron pulse is converted to the X-ray pulse. The free ion yield,  $G_{fi}^0$ , and also  $\mu_e$  are determined from the X-ray pulse dose by the peak current method,<sup>6)</sup> which is applied in this experiment to determine the values of  $\mu_e$  and  $G_{fi}^0$  in both liquid and solid cyclohexane (CH).

The transport mechanism of excess electrons in CH has been regarded as different from those for NP and TMS in the liquid phase. It is found that the observed effect of liquid-solid phase change on  $\mu_e$  for CH is quite different from those for NP and TMS (fig. 3), and  $G_{fi}^0$  abruptly decreases as well as  $\mu_e$  on the transition from liquid to solid (fig. 4).

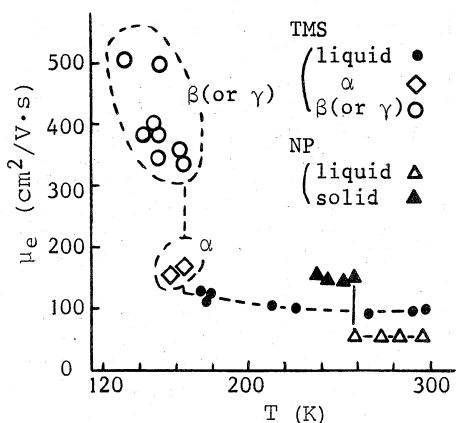


fig. 1; Temperature dependence of  $\mu_e$  in TMS and NP.

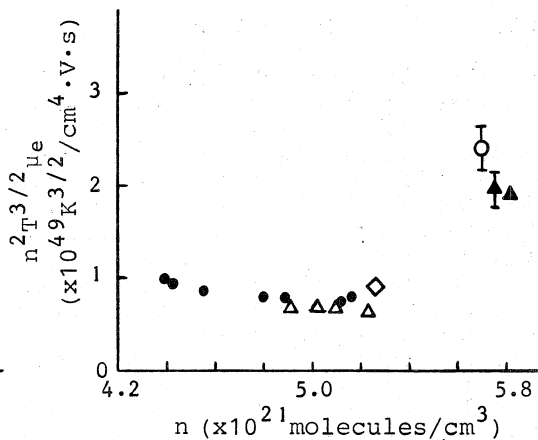


fig. 2; Plots of  $n^2 T^{3/2} \mu_e$  vs.  $n$  for TMS and NP.

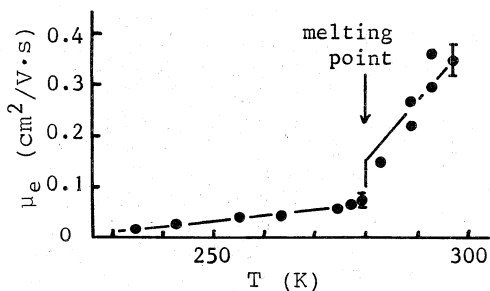


fig. 3; Temperature dependence of  $\mu_e$  in CH.

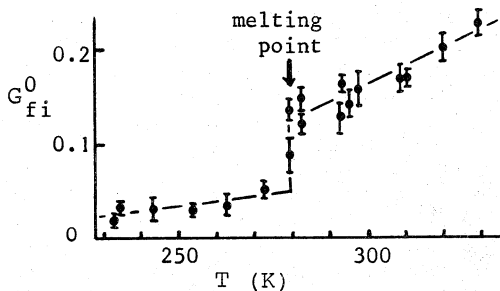


fig. 4; Temperature dependence of  $G_{fi}^0$  in CH.

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- 1) (a) H. Namba, K. Shinsaka, and Y. Hatano, Charge Storage, Charge Transport and Electrostatics with their Applications. Studies in Electrical and Electronic Engineering, Vol. 2, Elsevier, (1979), p. 223; (b) K. Shinsaka, Y. Hatano, T. Wada, K. Mori, and H. Namba, Proc. 1st Symp. on Accelerator Science and Technology, Tsukuba, (1975), p. 54; (c) Y. Hatano, K. Shinsaka, T. Wada, H. Namba, and Y. Nakamura, Proc. 2nd Symp. on Accelerator Science and Technology, Tokyo, (1978), p. 231.
- 2) (a) T. Wada, K. Shinsaka, H. Namba, and Y. Hatano, Can. J. Chem., 55, 2144 (1977); (b) H. Namba, K. Shinsaka, and Y. Hatano, J. Chem. Phys., 70, 5331 (1979).
- 3) Y. Nakamura, H. Namba, K. Shinsaka, and Y. Hatano, Chem. Phys. Lett., to be published.
- 4) N. E. Cipollini and A. O. Allen, J. Chem. Phys., 67, 131 (1977).
- 5) M. Harada, T. Atake, and H. Chihara, J. Chem. Thermodyn., 9, 523 (1977).
- 6) M. G. Robinson and G. R. Freeman, Can. J. Chem., 52, 440 (1974).