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Observation of Blocking Contacts at Mo-Amorphous GeSe-Mo Sandwiches

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Not very much is known about the properties of the contacts between a metal and amorphous semiconductors. In some cases the contacts are expected to be of low resistance because a high density of states near the middle of the gap will pin the Fermi level (1). On the other hand there are experiments indicating the existence of blocking contacts (2 to 4). In a recent paper (5) the frequency dependence of both conductance and capacitance of Mo-amorphous-GeSe-Mo sandwiches was explained by means of a simple equivalent circuit including a frequency independent capacitance C_C and a frequency independent conductance G_C (Fig. 1) describing the properties of a blocking contact region and determining the behaviour of the equivalent circuit at low frequencies. In order to yield more information about the contact properties we have measured the temperature dependence of conductance and capacitance of such samples at different frequencies.

The GeSe films were prepared by rf sputtering on cooled glass substrates. The film thickness varied from 0.1 to 2.0 μm. Measurements of the parallel conductance and capacitance of the samples were made with a differential measuring bridge in the frequency range of 4.0×10^2 to 4.0×10^5 Hz. During the measurements the sample soldered on a copper holder was placed in a vacuum system. The temperature of the holder was changed from 273 to 343 K.

Fig. 2 shows for a representative sample a semilogarithmic plot of the experimental results against the reciprocal temperature. Although similar characteristics as the measured ones depicted in Fig. 2a are usually interpreted in terms of band and hopping conduction (2, 6 to 8), the significant strong increase of the capacitance with increasing temperature at low frequencies cannot be explained with these mechanisms since hopping conduction, and thus the hopping capacitance, is only slightly temperature dependent (9).

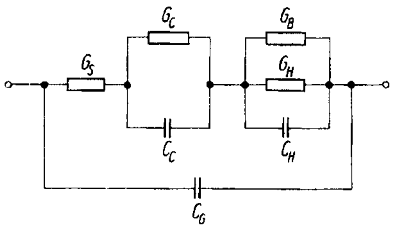

Fig. 1. Equivalent circuit for amorphous semiconductors with blocking contacts from (5); $G_H = A\omega^s$, $C_H = G_H \omega^{-1} \tan(s\pi/2)$. For the symbols the reader should also refer to (5)

An extremely temperature dependent capacitance has been predicted by Simmons et al. (10) whose treatment involves metal-insulator-metal systems in which the insulator is highly doped and in which Schottky barriers exist at the metal-insulator interface with the barriers being represented by a frequency and temperature independent capacitance in an equivalent circuit similar to that of Fig. 1 .

The good fit of the experimental characteristics of Fig. 2 achieved by using the equivalent circuit of Fig. 1 and accounting the total conductance and capacitance of this circuit as a function of the temperature T at different frequencies suggests that the concept of Schottky barriers gives a reasonable explanation for the phenomena observed so far at our samples. For generating the curves of Fig. 2 the temperature dependence of G_B and G_H (i.e. also that of C_H, see Fig. 1) was assumed according to

$$G_B = G_{Bo} \exp(-\Delta E/kT) , \tag{1}$$

$$G_H = G_{Ho}(T + T_1)/T_2 , \tag{2}$$

where G_{Bo} and G_{Ho} denote reference parameters for the band and hopping conductance, respectively, ΔE is the activation energy, k the Boltzmann constant, and T_1 and T_2 are temperature parameters for fitting the slope of the curves at low temperatures. It should be emphasized that there was no necessity of supposing any form of temperature and frequency dependence of G_C and C_C, and that all curves of Fig. 2 were calculated with the same parameters.

The activation energy of 0.7 eV used for the approximation agrees with the value of Bobe and Fritzsch (11) obtained from dc measurements. From G_{Bo} a corresponding preexponential factor for the conductivity of about $0.5 \times 10^4\ \Omega^{-1}\mathrm{cm}^{-1}$ can be estimated which is close to the Stuke rule (12).

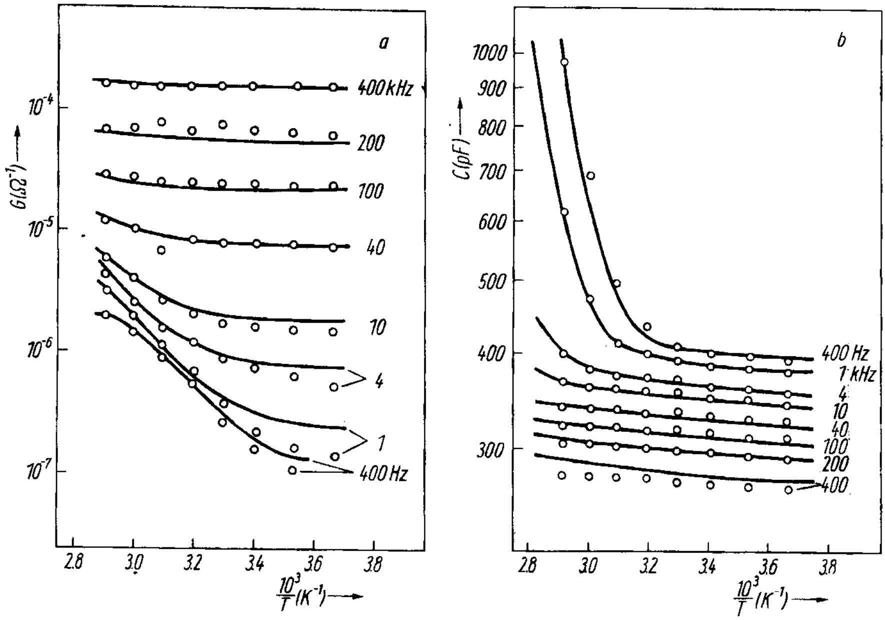

Fig. 2. Semilog plots of a) the conductance and of b) the capacitance vs. reciprocal temperature for sample 120/2 at different frequencies. Circles: measured values. The full lines are calculated assuming a temperature dependent G_B and G_H according to equations (1) and (2) respectively. $G_{Bo} = 1.17 \times 10^{5}\ \Omega^{-1}$; $G_C = 0.92 \times 10^{-6}\ \Omega^{-1}$; $G_{Ho} = 8.1(\omega)^{0.94} \times 10^{-11}\ \Omega^{-1}$, ($\omega$ in s); $G_S = 0.55 \times 10^{-2}\ \Omega^{-1}$; $\Delta E = 0.7$ eV; $T_1 = 523$ K; $T_2 = 866$ K; $C_C = 1.77 \times 10^{3}$ pF; $C_G = 2$pF

The hopping conductance G_H is nearly temperature independent. Such a temperature dependence would be evidence for correlated hopping (9). Following Rockstad's treatment (13) a density of states at the Fermi level of about 10^{18} to 10^{19} $cm^{-3}eV^{-1}$ is obtained. On the other hand a total density of charged (say donor) states of about 3×10^{18} cm^{-3} is obtained from C_C using the conventional formula for the capacitance of a Schottky barrier (14) assuming $\varepsilon_r = 8$ for the relative dielectric constant (11) and $V_D = 0.5$ V for the diffusion voltage (15), but the uncertainty of these values is too large for conclusions to be drawn about the energy diagram of the system.

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