POSSIBILITY OF ANDERSON TRANSITION IN LIQUID Se AND As IN THE REGION OF HIGH TEMPERATURES AND PRESSURES

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Conductivity of selenium and arsenic at high temperatures, 2000°C, and supercritical pressures has been measured. With the density decrease the conductivity was found to drop rapidly from the $\sim 10^2\ \Omega^{-1}\ cm^{-1}$ level corresponding to the minimal conductivity estimated by Mott. This is accounted for by the Anderson localization of electrons and confirmed by the calculations presented.

The level of metallic conductivity is of great importance in the study of the metal–nonmetal transition with density decrease, in liquid metals and semiconductors. It is of interest to look for objects where the Anderson transition can be demonstrated [1].

From this point of view liquid Se may be considered because of the values of the conductivity, $\sigma \sim 1 \times 10^2 - 3 \times 10^2\ \Omega^{-1}\ cm^{-1}$, observed in refs. [2–6], which are close to the minimal metallic conductivity estimated by Mott [6].

For the comparison As has been chosen since its critical parameters are close to those of Se and it was interesting to compare temperature dependences of the conductivity for these elements in the transition region [7].

Since the critical parameters of As [1] and Se [5,8] have not been precisely determined the measurements of conductivity were at pressures and temperatures significantly exceeding the critical ones to avoid the boiling region.

These measurements for Se and As were performed using the same type of beryllium oxide cells with four electrodes (two current and two potential). The temperature was measured with W–Re thermocouples. These cells have been described before in ref. [4] and the experiments were carried out on the installation of the type described in ref. [9].

Fig. 1 shows the conductivity of As and Se at supercritical temperatures and pressures.

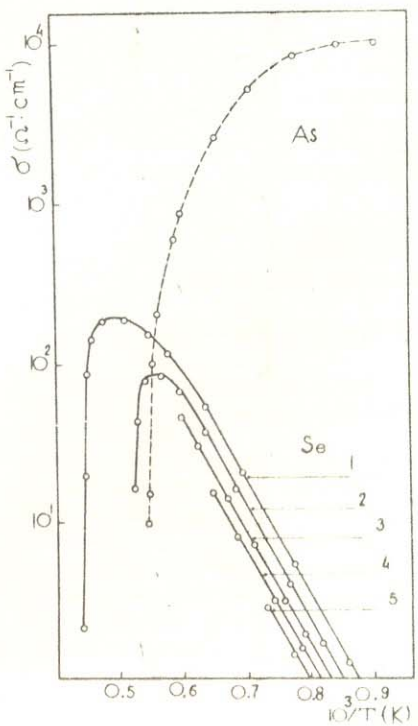

Fig. 1. Temperature dependence of the electric conductivity of arsenic and selenium at different pressures: ○ experimental points; —— selenium, 1: 1000 atm, 2: 500 atm, 3: 165 atm, 4: 103 atm, 5: 47 atm; – – – arsenic, 330 atm.

The sharp decrease in the electric conductivity of selenium after the plateau can be explained as due to the total Anderson localization. As seen from the plot, localization of the Anderson type starting from $\sigma \sim 100\ \Omega^{-1}\ \mathrm{cm}^{-1}$ seems to be possible also for arsenic. Up to this level the effect of localization can be shunted by the metallic channels with conductivity equal to or greater than the minimal metallic one as in the case of a supercritical region in Cs and Hg [10], where the conductivity is due to a percolation [10,13].

The total localization of electrons in the Anderson model [1] occurs when W/V achieves the critical value $(W/V)_c$ (here W is the spread of the energy levels of electrons on atoms, V is the amplitude of the electron transitions from atom to atom). This ratio obviously increases with the temperature density decrease. Near the transition temperature T_c we can write:

$$W(T)/V(T) \approx (W/V)_c + B(T - T_c)/T_c,$$

because in the supercritical metal there are no reasons for the W/V ratio to be a non-analytic function of the temperature.

According to Mott's estimates the metallic conductivity near the Anderson transition [6] (minimal metallic conductivity) was found to be:

$$\sigma_{\min} = (8\pi^3 e^2/\hbar a)(V/W)_c^2,$$

where a is the average interatomic distance.

In our experiments the density has been estimated to be $\sim 5 \times 10^{22}\ \mathrm{cm}^{-3}$, i.e. $a \approx 2.7 \times 10^{-8}$ cm. Thus it seems possible that starting from the conductivity level of $\sim 100\ \Omega^{-1}\ \mathrm{cm}^{-1}$ both for Se and As the condition for the Anderson localization of the electrons is satisfied and this results in a jump-like transition [6] from metallic to hopping conductivity $\sigma \ll \sigma_{\min}$. The hopping regime was not observed in these experiments. Hopping conductivity near the mobility edge has the form [6]:

$$\sigma \approx \sigma_h \exp\{-(a^3/R_{loc}^3)(W/T)\},$$

where R_{loc} is the localization radius of the electronic wave functions:

$$R_{loc} \approx a \left| \frac{(W/V) - (W/V)_c}{(W/V)_c} \right|^{-\nu},$$

where ν is the critical exponent defined only by the space dimensionality [11] coinciding with the correlation-length exponent of the second-order phase transition with the zero-component order parameter [12].

In three-dimensional space $\nu = 0.6$ [1]. Thus for $T \gtrsim T_c$ we have

$$\ln(\sigma/\sigma_h) \sim -((T - T_c)/T_c)^{3\nu}.$$

The observation of the hopping conductivity in Se at $T \gtrsim T_c$ would be of great interest due to the possibility of experimental determination of the exponent ν.

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