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CONDUCTIVITY OF SELENIUM IN SEMICONDUCTOR-METAL TRANSITION REGION AT HIGH TEMPERATURES AND PRESSURES

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Abstract. - Electrical conductivity of Selenium has been measured in semiconductor metal transition region at pressures up to 0.4 GPa and temperatures up to 2100 K. It was observed that the origin of semiconductor-metal transition shifted to lower temperatures and metallic conductivity region was expanded. With pressure increasing the metallic conductivity level gradually increases from $10^2 \Omega^{-1} \text{cm}^{-1}$ at 0.1 GPa to $10^3 \Omega^{-1} \text{cm}^{-1}$ at 0.4 GPa. On the other hand the metal-isolator transition shifts apparently to higher temperatures with pressure increasing. These data are compared with results on metal-nonmetal transition in arsenic and mercury. The character of semiconductor-metal and metal-isolator transitions is discussed.

Our research on liquid selenium in the critical and super-critical region carried out in 1975 allowed us to suppose that selenium was a most interesting object for study of the metal-nonmetal transition at high temperatures and pressures /1/.

These measurements showed for the first time the transition from the semiconductor temperature dependence of electrical conductivity to the metallic one with the occurrence of a saturation sector ("plateau") of order $100 \Omega^{-1} \text{cm}^{-1}$ at a pressure 0.1 GPa.

The following experiments /2-5/ discovered the sharp decrease in the electrical conductivity after "plateau" when temperature increased.

This effect was interpreted as the Anderson transition /2-5/ when the system passed from the metallic conductivity to the hopping one with the next temperature dependence

$$I_n \frac{\sigma}{\sigma_h} \sim \left[\frac{T - T_c}{T_c} \right]^{3\nu}$$

where T_c - transition temperature
 ν - critical index

The research of the liquid selenium conductivity in this work were performed with the aim of investigating the pressure dependence of the "plateau" level up to pressure 0.4 GPa. Due to using of boron nitride container for selenium we could trace the "plateau" shift up to the temperatures of the order of 2100 K.

The measurements were performed with the high pressure installation of the type described before /2/. Clean argon was used as the medium transmitting

pressure. The measuring cell containing the investigated substance was heated by a graphite heater. The cell design is analogous to the cell made from beryllium oxide described before /2/. Current and potential electrodes were made from graphite. WRe 5/WRe20 - thermocouples were used for temperature measuring. The experimental data on the selenium conductivity at various pressures up to 0.4 GPa and temperatures up to 2100 K are shown on figure 1.

It was noted that the maximum electrical conductivity value increased when the pressure was raised achieving almost $1000 \Omega^{-1} \text{cm}^{-1}$ and shifting to the low temperature side. One can see also that there is tendency to saturation of this value with increasing pressure. At higher pressures an Anderson transition is not observed. The metallic conductivity minimum is almost the same as that predicted by Mott /7/.

The metallic conductivity level in /3,4/ exceeds our results, however our results agree well with data of work /6/.

The comparison of selenium with some liquid semiconductors shows that in some liquid semiconductors the level of metallic conductivity is higher ($5 \cdot 10^3 \Omega^{-1} \text{cm}^{-1}$) than selenium /8,9/. It is possible that the low selenium density is the reason for this difference. It is of interest to compare all presently known metal-nonmetal transitions for expanded metals and semiconductors with use of reduced temperatures. Fig. 2 shows that there are many common properties of these transitions.

In spite of a different level of metallic conductivity in the far supercritical region the most sharply decreasing conductivity is observed beginning from $10^2 \Omega^{-1} \text{cm}^{-1}$ at almost the same reduced temperature.

Figure 3 shows "reduced temperature - reduced density" relations for selenium, arsenic, cesium, mercury and other materials. One can see that this relation is the same one for mercury and arsenic, and that selenium is analogous in this sense to such dielectric materials as CO_2 , Ar and others.

For this analysis we used the following parameters :

mercury : $T_c = 1786 \pm 15\text{K}$, $P_c = 1730 \pm 30$ bar

$$\rho_c = 5.9 \pm 0.2 \text{ g/cm}^3 \text{ /11/}$$

cesium : $T_c = 2033 \pm 20\text{K}$, $P_c = 116 \pm 5$ bar

$$\rho_c = 0.40 \pm 0.02 \text{ g/cm}^3 \text{ /12/}$$

selenium : $T_c = 1766\text{K}$, $P_c = 286$ bar, $\rho_c = 1,235 \text{ g/cm}^3$
/13/

arsenic : $T_c = 1673 \pm 25\text{K}$, $P_c = 220 \pm 50$ bar,

$$\rho_c = 2.6 \pm 0.2 \text{ g/cm}^3 \text{ /10/}$$

References

- /1/ V.A. Alekseev, V.G. Ovcharenko, Yu.F. Ryzhkov and A.A. Andreev, Program and Abstract Vth Int. Confer. on amorphous and Liquids Semiconductors, Leningrad, USSR, Publ. ("Nauka", L. (1975) and Structure and Properties of non-crystalline semiconductors, Ed. B.T. Kolomiets. (Publ. "Nauka") (1976).
- /2/ V.A. Alekseev, V.G. Ovcharenko, Yu. F. Ryzhkov and M.V. Sadovsky, Sov. Phys. JETP Lett. 24 (1976) 214.
- /3/ H. Hoshino, R.W. Schmutzler and F. Hensel, Ber. Bunsenges Physic Chem. 80 (1976), 27.
- /4/ H. Hoshino, R.W. Schmutzler, W.W. Warren and F. Hensel, Phys. Mag. 33 (1976), 255.
- /5/ V.A. Alekseev, V.G. Ovcharenko, Yu. F. Ryzhkov and M.V. Sadovsky, Phys. Lett. 65A, (1978) 173.
- /6/ R. Fisher and R.W. Schmutzler, The Physics of Selenium and Tellurium Ed. E. Gerlach and P. Grosse (Springer - Verlag, Berlin Heidelberg New-York) (1979) 225.
- /7/ N.F. Mott, Metal -Insulator Transition (Taylor and LTD London) 1974.
- /8/ A.A. Andreev, T. Turgunov and V.A. Alekseev, Pizika Tverdogo Tela 16 (1974), 3660.
- /9/ V.A. Alekseev, A.A. Andreev and M.V. Sadovsky Soviet Physics Uspekhi 132 (1980) 100.
- /10/ V.A. Alekseev, V.G. Ovcharenko, Yu. F. Ryzhkov, L.A. Niselson and V.K. Zakharov-Cherenkov, High Temp.- High Press. 7(1975)675.
- /11/ I.K. Kikoin, A.P. Senchenkov, S.P. Naurzakov and E.B. Gelman, "V International Conference on high pressure and technology" (Moscow, 1975 M., "Nauka") (1975), 152; Preprint IAE-2310, (1973).
- /12/ V.A. Alekseev, V.G. Ovcharenko, Yu. F. Ryzhkov and A.P. Senchenkov, Zh. Eksp. Teor. Fis. Pisma Red 12 (1970) 207 (JETP Lett. 12 (1970) 000.)
- /13/ V.J. Rau, Chem. Therm., 6 (1974), 525.