anisotropic and the antiferromagnetic coupling along the c axis is much stronger than the ferromagnetic coupling in the plane perpendicular to c; this has been observed experimentally in $KCuF_3$ [6]. Further, it follows from the developed theory that $T_s/T_{orb} \sim J/U$; usually $J/U \simeq 0.1$ [3]. In $LaMnO_3$ we actually have $T = 100°K$ and $T_{orb} \simeq 900°K$. A more detailed consideration of these questions, as well as all the details of the derivation of the results, will be published later.

Let us discuss the relation of the proposed mechanism to the ordinary Jahn-Teller effect. Generally speaking, these two mechanisms do not contradict each other: it is possible that the local distortions near the cation are determined by the Jahn-Teller effect, and their cooperative ordering by the superexchange considered above. In this case the ordering picture would be somewhat closer to the picture of Wojtowicz [7] (a transition of the order-disorder type) than to that of Kanamori [2].

It is possible that the mechanism considered here operates in substances with a different structure, for example in tetragonal spinels [1], and also in a number of rare-earth metal compounds (CeSb, DySB [8], $DyVO_4$ [9]), where a lattice transition has been observed at $T > T_s$.

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[1] J.B. Goodenough, Magnetism and Chemical Bond, N.Y.-London, 1963.
[2] J. Kanamori, J. Appl.Phys. Suppl. 31, 145 (1960).
[3] P.W. Anderson, Phys. Rev. 115, 2 (1959).
[4] L.R. Roth, Phys. Rev. 149, 306 (1966).
[5] V.L. Pokrovskii and G.V. Uimin, Zh. Eksp. Teor. Fiz. 61, 859 (1971) [Sov. Phys.-JETP 34, 457 (1972)].
[6] K. Hirakawa and Y. Kuragi, Progr. Teor. Phys. (Suppl), No. 46, 147 (1970).
[7] P.J. Wojtowicz, Phys. Rev. 116, 32 (1959).
[8] F. Levy, Phys. Kondens. Mater. 10, 86 (1969).
[9] A.H. Cooke et al., Sol. St. Commun, 8, 689 (1970).

SWITCHING MECHANISM IN AMORPHOUS SEMICONDUCTORS

S.M. Ryvkin
A.F. Ioffe Physico-technical Institute, USSR Academy of Sciences
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The switching effect in amorphous semiconductors, which has been under intense study in recent years (see, e.g., [1 - 3]), has not yet been uniquely and convincingly explained [4].

We propose here a switching mechanism that should take place in amorphous semiconductors if the model of [5] is valid for them.

According to this model, an amorphous (vitreous) semiconductor constitutes a system in which strong fluctuations in the spatial distribution of the charge give rise to such powerful fluctuations of the potential and of the potential energy of the electrons, that the corresponding bending of the energy bands turn out to be of the order of the width of the forbidden band of the superconducting material.

It is easily seen that under these conditions the semiconductor constitutes alternating n- and p-type regions, i.e., a system comprising a large number of

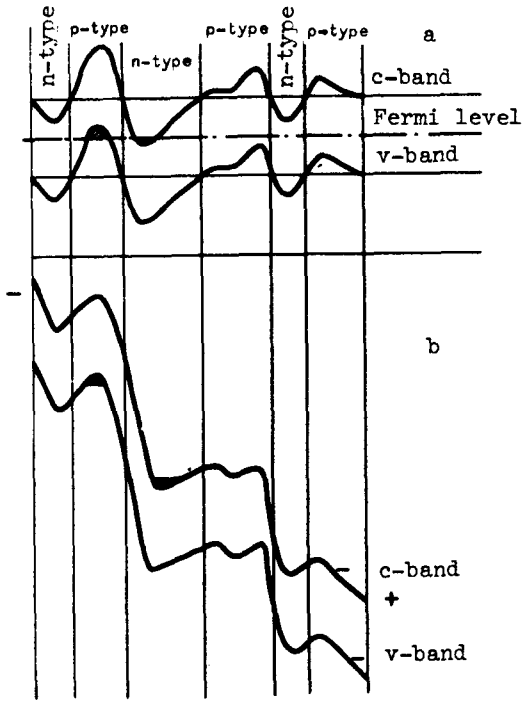

Fig. 1

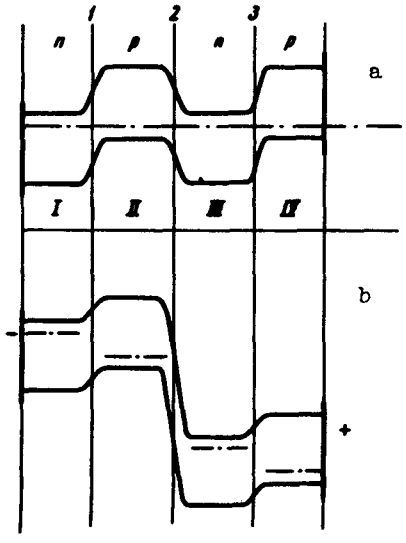

Fig. 2

Fig. 1. Section of energy scheme of an amorphous semiconductor: a - in equilibrium, b - after application of the voltage.

Fig. 2. Energy scheme of four-layer n-p-n-p structure: a - at equilibrium, b - after application of a voltage.

n-p junctions (Fig. 1a).

Such a system of series-connected n-p junctions, however, should have an S-shaped current-voltage characteristic when a voltage is supplied to it (Fig. 1b), i.e., it should exhibit a switching effect (with respect to current). Indeed, for a system consisting, say, of four regions (i.e., n-p-n-p structure characteristic of "tyristors" (Fig. 2a)), this is well known [6]. In such a structure, when a sufficiently strong voltage is applied (Fig. 2b), an instability sets in and leads to a switching into a state with a higher value of the current. Indeed, the barrier (3) for the holes in the right-hand junction is lowered by the charge of the electrons injected in the left-hand n-p junction (1) which pass through the p-region and enter the n-region III with their charge. This increases the injection of the holes from region IV into region III, and subsequently into region II. The holes in region II lower in turn the barrier (1) for the electrons, etc. The process terminates with a transition into a state with lower resistance and is characterized by an S-shaped current-voltage characteristic.

An analysis of the current-voltage characteristic for structures containing more than four alternating n- and p-regions, performed in a number of studies (see, e.g., [7]), has shown that they too retain an S-shape characteristic.

An amorphous semiconductor, of course, is not the strictly periodic planar structure for which the S-shaped current-voltage characteristic has been deduced.

However, the qualitative character of the switching effect in an amorphous semiconductor (i.e., for a random distribution of the dimensions and shapes of the alternating n- and p-regions) remains of course the same, except that the role of the barrier overcome by the electrons (holes) upon injection is assumed by the energy distance from the Fermi level (or edge of the band) to the corresponding "percolation levels."

It should also be noted that since each electrode of the amorphous switching element is in contact with both n- and p-regions, the closest analog of the amorphous structure should be taken to be the well-known multi-layer devise with symmetrical characteristic, called "symmistor" or "triac" [8].

Real amorphous switching elements are characterized by a great variety of characteristics. This is apparently connected to a considerable degree with the fact that the pinching of the current, which occurs in the case of an S-shaped characteristic, leads to effects (sometimes irreversible) connected with heating of the semiconductor.

It seems to us, however, that the primary mechanism of switching is not connected with heating and has the electronic nature described above.

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[1] J.F. Dewald, A.D. Pearzon, W.R. Northover, and W.F. Peck, J. Electrochem. Soc. 109, 243C (1962).
[2] B.T. Kolomiets and A.E. Lebedev, Radiotekhnika i elektronika 8, 2097 (1963).
[3] S.P. Ovshinsky, U.S. Patent 3,271,591 (1966); Phys. Rev. Lett. 21, 1450 (1968).
[4] N.F. Mott, Phil. Mag. 24, 911 (1971).
[5] H. Fritzsche, J. Non-Cryst. Sol. 6, 49 (1971); B.I. Shklovskii, ZhETF Pis. Red. 14, 397 (1971) [JETP Lett. 14, 269 (1971)]; B.I. Shklovskii and A.L. Efros, Zh. Eksp. Teor. Fiz. 62, 1156 (1972) [Sov. Phys.-JETP 35, No. 3 (1972)].
[6] J.L. Moll, M. Tanenbaum, J.M. Croldey, and N. Holonyak, Proc. of IRE 44, 1174 (1956).
[7] I.V. Grekhov and L.S. Kostina, Fiz. Tekh. Poluprov. 4, 1462 (1970) [Sov. Phys.-Semicond. 4, 1250 (1971)].
[8] F. Gentry et al., Semiconductor Controlled Rectifiers, Prentice-Hall, 1964.