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This Week's Citation Classic®

Mott N F. Conduction in non-crystalline materials. III. Localized states in a pseudogap and near extremities of conduction and valence bands. *Phil. Mag.* 19:835-52, 1969.
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This is one of a series of papers, starting in 1966, that set out an interpretation of the observed electrical properties of noncrystalline materials. This paper was the first to show in detail that, in noncrystalline materials, some of the states in the conduction band turn into traps and that a sharp energy, denoted by E_c (or, the mobility edge), separates the conductivity states from the traplike states. The paper also introduces the 8-N rule, which shows why certain conducting glasses cannot be doped. [The *SCI*® indicates that this paper has been cited in over 910 publications.]

The Mobility Edge and the 8-N Rule

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Several things attracted me to this subject. There was P.W. Anderson's paper on the absence of diffusion in certain random lattices,[1] J.M. Ziman's theory of conduction in liquid metals,[2] my own study with W.D. Twose of impurity conduction in semiconductors,[3] and, above all, the observations of the Leningrad school under B.T. Kolomiets showing that the chalogenide glassy semiconductors could not be doped.[4]

A number of the ideas that I put forward in 1967[5] and 1968, such as the mobility edge, which was given that name when it was reintroduced in 1969,[6] have stood the test of time and are still used today. Others, such as a minimum metallic conductivity, have not, although they suggested good subsequent experiments, which is the real purpose of theories. There have been many attempts to describe the way conductivity behaves for a degenerate electronic gas, for example, in a heavily doped semiconductor—how it approaches the condition when the Fermi energy (E_f) approaches E_c. Here, however, there remain controversies. I have summarized my opinions on this subject on several occasions.[7,8]

There are several new ideas in the paper cited here, and I do not know which has lifted the paper to its eminent position. I guess, however, that it is my explanation of Kolomiets's results, namely, that in a glass, each atom will have, in the state of lowest free energy, as many neighbours as there are outer electrons (for example, two for tellurium, three for arsenic, and four for germanium and silicon). All electrons are thus in bonds; none are loosely bound. This phenomenon is known as the 8-N rule and has been verified experimentally.[9] This rule shows why certain conducting glasses cannot be doped.

The 8-N rule appears to be valid in most glasses, but not in deposited films, for example, in amorphous silicon. In a glow discharge in SiH_4, doping is possible by adding a substance such as PH_3. While some of the phosphorus goes in with three silicon neighbours, according to a modified 8-N rule, which treats the three p electrons in silicon as the relevant ones, the remaining electrons go in with four coordination as in the crystal, thus giving a donor center.

It hardly needs to be said that lack of belief in the 8-N rule, at least for deposited silicon, was extremely fortunate, and it has led to an industry with a great future in the production of solar cells based on doped amorphous silicon.

1. **Anderson P W.** Absence of diffusion in certain random lattices. *Phys. Rev.* 109:1492-505, 1958. (Cited 1,580 times.)
2. **Ziman J M.** A theory of the electrical properties of liquid metals—the nonvalent metals. *Phil. Mag.* 6:1013-34, 1961. (Cited 705 times.)
3. **Mott N F & Twose W D.** The theory of impurity conduction. *Advan. Phys.* 10:107-63, 1961. (Cited 670 times.)
4. **Kolomiets B T.** Vitreous semiconductors (I). *Phys. Status Solidi* 7:359-72, 1964. (Cited 130 times.)
5. **Mott N F.** Electrons in disordered structures. *Advan. Phys.* 16:49-144, 1967. (Cited 895 times.) [See also: **Mott N F.** Citation Classic. (Thackray A, comp.) *Contemporary classics in physical, chemical, and earth sciences.* Philadelphia: ISI Press, 1986. p. 96.]
6. **Cohen M H, Fritzsche H & Ovshinsky S R.** Simple band model for amorphous semiconducting alloys. *Phys. Rev. Lett.* 22:1065, 1969. (Cited 510 times.)
7. **Mott N F & Kaveh M.** Metal insulator transitions in non-crystalline systems. *Advan. Phys.* 34:329-401, 1985. (Cited 65 times.)
8. **Mott N F.** *Conduction in non-crystalline materials.* Oxford, England: Clarendon Press, 1987. 128 p.
9. **Bienenstock A.** Threefold coordinated model structure of amorphous germanium sulfide, germanium selenide, and germanium telluride. *J. Non-Cryst. Solids* 11:447-58, 1973. (Cited 35 times.)

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