

Jonscher A K. Electronic properties of amorphous dielectric films. *Thin Solid Films* 1:213-34, 1967. [Physics Department, Chelsea College of Science and Technology, London, England]

The paper discussed several aspects of the subject as perceived at that time, in particular the properties of low-mobility solids with special reference to high-field conduction phenomena such as the Schottky and Poole-Frenkel effects; the power-law current-voltage dependence in many of these materials; and the alternating-field (ac) conduction in amorphous solids. [The SC^{ρ} indicates that this paper has been cited in more than 260 publications.]

Towards the Significance of Disorder

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This paper was written 23 years ago in the heyday of interest in the electrical and structural properties of amorphous semiconductors, with the subject of amorphous dielectrics being taken as a natural extension of the former.

Nearly a quarter of a century later, it is interesting to note that many of the fundamental processes attributable at that time to the amorphous nature of these materials are now seen as being more generally applicable. We now realize that the necessary condition for the Poole-Frenkel effect is the low mobility of carriers,¹ which happens to be a by-product of the amorphous nature of materials. It may be found in, for example, layered crystalline materials normal to the planes, which may also show this behavior. However, in higher mobility solids, the prevailing process is avalanche multiplication.

In recent years, the once "heroic" struggle to distinguish between the Schottky and Poole-Frenkel effects appears to have been relegated to the attic of not very important unresolvable questions, while many more pressing ones demand attention. With regard to the very strong voltage dependence of current, this is seen in crystalline or polycrystalline ceramics as much as in amorphous materials. And, there does not yet appear to exist a convincing theory of this phenomenon, though it forms the basis of an impor-

tant industry of lightning protection elements.

The observed alternating-field (ac) conductivity had already been mentioned at that time as being probably not confined to amorphous materials. Today we know that it is a manifestation of a much wider phenomenon called the "universal" dielectric response^{2,3} whose theoretical interpretation is once again not yet definitively resolved but which almost certainly involves many-body interactions as its principal foundation.

We are thus confronted with a paradox: an interest in the properties of amorphous materials spawned experimental work which appeared to give relatively simple results. However, we found that the significance of these results was a good deal more complicated and hid much more profound processes.

One of the fundamental properties of all dielectric material is their ultimate breakdown under sufficiently high electric fields. This process was not, as such, the subject of the original paper under review, but high-field phenomena were. Once again, the very good progress in the understanding of the nature of breakdown made since these early days owes a good deal to our studies on amorphous materials.

One of the long-term conclusions from our early studies of amorphous dielectric and semiconducting materials is the present realization of the fundamental significance of disorder, which lies at the basis of all dielectric responses, regardless of whether the host material itself is crystalline or amorphous—the operative property being the disorder inherent in the orientation of the dipoles or in the positions of localized charge carriers. This, in turn, leads to the application of modern mathematical analysis of long-tailed random distributions and fractal phenomena which promise to shed fresh light on the understanding of these relaxation processes.

We are thus able to see the evolution of a completely new approach to the understanding of the phenomena of transport in a wide range of materials, starting from the early "ball and stick" models of amorphous solids and going all the way to the latest theory of fractal and stochastic processes. The driving force in all this has been the realization of the "universality" of the dynamic responses² in the frequency- and time-domains.

1. Jonscher A K. Free carrier Poole-Frenkel effect in crystalline solids. *J. Phys. C—Sol. State* 3:L159, 1970.
2.------. *Dielectric relaxation in solids*. London: Chelsea Dielectrics Press, 1983. (Cited 190 times.)
3.------. Dielectric response of polar materials. *IEEE Trans. Elect. Insul.* 25:622-9, 1990.