Letters to the Editor

DOES PERCOLATION OF PHONOS EXIST?

СУЩЕСТВУЕТ ЛИ ПЕРКОЛЯЦИЯ ФОНОНОВ?

J. BIELEK[1], Š. BARTA[1], Bratislava, L. VESELÝ[2], Brno

The term percolation was first introduced in 1956 by the English mathematicians S. R. Broadbent and J. M. Hammersley [1, 2] for the statistical description of system composed of a large number of mutually bound and interacting objects. Depending on the number of these objects and their bonds in such a system, there either exists – or does not – the long range interaction with a well distinct transition between these two cases: the percolation threshold.

Aggregates of objects for some arrangements close to the percolation threshold were studied by rigorous statistical methods by J. W. Essam [3] and S. Kirkpatrick [4]. On the basis of these works the percolation of electrons was experimentally studied and confirmed in electrically conductive heterogeneous systems. A further study of this phenomenon confirmed that it belongs to the category of cooperative phenomena. Using a theoretical approach of model nets and later also experiments, the critical indices of electron percolation were determined for some types of planar and spatial structures [5].

Consequently, there arises the question whether there exists the percolation of pohonons and how such an effect could be confirmed?

The aim of our contribution is to give information about a valuable experimental result obtained during an investigation of the thermal properties of polyolefins modified by mineral filling [6, 7]. By measuring the concentration dependence of the effective thermal conductivity coefficient – λ_{eff} of the composite polymeric system: compact polyethylene – $CaCO_3$ at room temperature $T_0 = 298.15$ K, it was experimentally confirmed that the rule of material balance for thermal conductivity breaks at a certain critical bulk concentration $CaCO_3$ – n_{vc} ($n_{vc} = 0.3$) and λ_{eff} strongly increases with increasing bulk concentration. The measured dependence of λ_{eff} is shown in Fig. 1.

The dependence $\lambda_{eff} = f(n_v;\ T = T_0)$ apparently exhibits the percolation threshold at a concentration of 30 vol. % $CaCO_3$, although of a different character than that known from electrical measurements. There cannot be realized an ideal thermal insulator ($\lambda = 0$). Consequently, a finite (non-zero) thermal conductivity is obtained also at $n_v < n_{vc}$.

Since the investigated composite polymeric system is electrically non-conducting, the only possible heat transport is that caused by phonos. We therefore interpreted the measured $\lambda_{eff} = f(n_v;\ T = T_0)$ dependence by means of the percolation of phonons [8]. For this purpose the following measurement fit was used

$$|\lambda_{eff}(n_v) - \lambda_{eff_m}(n_v)| = \alpha |n_v - n_{vc}|^{\beta}, \tag{1}$$

[1] Dept. of Physics, Electrotechnical Faculty, Slovak Technical University, Gottwaldovo nám. 19, 812 19 BRATISLAVA, Czechoslovakia.

[2] Research Inst. of Macromolecular Chemistry, Tkalcovská 2, 656 49 BRNO, Czechoslovakia.

where α is the constant of proportionality, n_{vc} is the critical bulk concentration of $CaCO_3$ (percolation threshold), and β is the critical exponent. This dependence is plotted in Fig. 2. In this manner the critical indices of this cooperative phenomenon were determined, namely

$$n_{vc} = 0.3; \quad \beta = 1.70. \tag{2}$$

These critical indices are in very good agreement with those obtained in the study of the percolation of electrons [5] for a wide range of spatial structures.

We believe the presented experimental data to show and confirm the percolation of phonons.

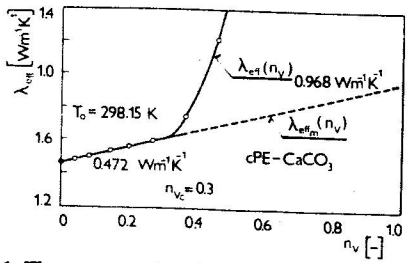

Fig. 1. The concentration dependence of effective thermal conductivity coefficient of composite polymeric system: compact polyethylene Liten, type 5850 – $CaCO_3$, at standard temperature $T_0 = 298{,}15$ K

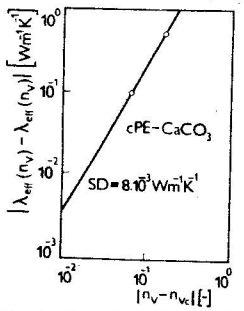

Fig. 2. The concentration dependence of phonons percolation contribution to the effective thermal conductivity coefficient in composite polymeric system: compact polyethylene Liten, type 5850 – $CaCO_3$, at standard temperature $T_0 = 298{,}15$ K

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Received October 28th, 1981