

# Thermal Conductivity of Composite Materials Based on Crystallizing Polymers

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## ABSTRACT

The lack of a theory of thermal conductivity of polymer composite polymers and homopolymers makes it difficult to predict the thermophysical characteristics of newly created polymer materials. Therefore, the issue of experimental study of heat transfer processes in polymers and materials based on them is relevant. The accumulation of experimental data on the thermophysical characteristics of new polymeric materials differing in nature and structural features contributes to the acceleration of the creation of the theory of their thermal conductivity. In this regard, this work presents an approach to solving this problem by increasing the spectra of experimental methods and their theoretical interpretation.

**KEYWORDS:** *thermophysical properties (TPP); the nature of the thermal movement; heat transfer mechanism; polymer composite material (PCM); filler; fluctuation; dispersed phase; polymer matrix; thermal conductivity; electrical conductivity; phonon mechanism*

The development and production of new composite materials with a set of specified properties is defined as one of the most important tasks of modern science. A special place belongs to polymer composite materials (PCM), which often have a number of such important performance characteristics that traditional materials for structural and other purposes do not possess [1].

One of the most important tasks of modern thermal physics and molecular physics is to establish the relationship between thermophysical properties (TPP), in particular thermal conductivity ( $\lambda$ ) of polymeric materials with their structure at its various levels organization and the thermal motion nature. This relationship knowledge makes it possible to more deeply and comprehensively analyze the heat transfer mechanism in polymer composite materials (PC), which will help accelerate the solution to the polymer materials obtaining problem with predetermined TPPs. Providing polymer materials for the growing needs of various industries and, first of all, mechanical engineering, as well as the electrical industry, radio electronics and other branches of technology.

Knowledge of TPP PCM allows us to evaluate the products behavior made of these materials in various operation modes, thereby increasing the service life and increasing the reliability of such products. Thermophysical characteristics of PCM and their components are the basis for the scientific approach to thermal equipment

calculations and technology for obtaining PCM and their processing into products.

These materials use in the national economic sectors complex engaged in the production, processing and operation of PCM products, as well as the results of studying these materials TPP, ultimately saves the material and energy resources of the country.

Among the fluorine-containing polymers class, there are those that are characterized by significantly higher performance properties than polytrifluorochlorethylene (PTFCHE), and therefore, are widely used now in various sectors of the national economy. Such polymers are polyvinylidene fluoride (PVDF) and its modification - modified polyvinylidene fluoride (PVDF-M).

These polymers are characterized by high resistance to ionizing radiation, chemically aggressive media, and high temperature resistance, good dielectric and mechanical properties. Moreover, these materials have a relatively simple molecular structure, a sufficiently high regularity of the main molecular chain, and crystallize well, thus forming sufficiently perfect crystal structures. The crystallinity degree ( $\alpha$ ) and the crystalline formations size can be varied within a fairly wide range. In addition, the structure at its various levels organization and the molecular mobility of unfilled PVDF are well studied [2-4]. Based on this, it can be concluded that these polymers are promising as a binder for creating PCM.

The fillers effect on TPP polymer material is manifested in two ways. First, the presence of dispersed fillers particles in a polymer significantly affects its structure formation at its various levels organization.

In two-component composite material case, an important factor is the quantitative relationship between the volumetric content of polymer and filler in PCM. Volume content of filler in PCM:

$$\varphi = \frac{V_n}{V_n + V_p} \quad (1)$$

Where  $V_n$  and  $V_p$  - is the filler and polymer volume in the composition, respectively. If the filler content in the composition is within,  $0 < \varphi < 0,5$ , then in this case the polymer acts as a forming medium. That is, the polymer can be considered as a dispersion medium in which dispersed filler particles are embedded.

In the non-interacting components case of such a composite material, both components in them will be geometrically equal [1]. This means that the effective conductivity (in this case, thermal conductivity) of such

materials does not change and remains invariant when the places of the components change, i.e.

$$\lambda_{eff} = f(\lambda_1, \lambda_2) = f(\lambda_2, \lambda_1), \quad (2)$$

where  $\lambda_{eff}$  - is an effective thermal conductivity PCM;  $\lambda_1, \lambda_2$  - is thermal conductivity of the polymer and filler, respectively.

If the PCM has a filler content of  $0,5 < \varphi < 1$  by volume, then the polymer is the binder. That is, in such a material, the volume bulk is occupied by filler, which particles are interconnected by a thin layer of polymer [2]. A distinctive feature of the structure of such a PCM model is that the components in it are not geometrically equal, i.e.

$$\lambda_{\varphi\phi} = f(\lambda_1, \lambda_2) \neq f(\lambda_2, \lambda_1) \quad (3)$$

A number of works, including [3; 4-7], are devoted to the experimental study of the thermal PCM conductivity based on crystallizing polymers and dispersed fillers. Reviews of experimental and theoretical works available in the literature devoted to this problem are carried out in [2-9].

As is known [2; 5; 8], the main physicochemical characteristics of polymer fillers are: the filler type, the filler particles shape,

dispersion, specific surface area of the particles and this surface state.

These features are decisive in the polymer structure formation, and hence its properties, including thermal conductivity [1; 2].

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