# Study of the physico-chemical characteristics of reinforced composite polymer materials

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**Abstract.** One of the important properties of reinforced composite polymer materials is their physico-chemical properties. Their structure plays an important role in assessing the physico-chemical properties of composite materials. Research objectives - to study the physico-chemical properties of high-strength polymer composite materials.
Experiments were carried out at 100 and 400-fold magnification in an optical microscope to study the morphology and structural changes of various parts of high-strength polymer composite materials with a polymer binder - ED-20 and nitrone fibers. IR spectroscopic studies were also carried out to study the interaction of nitron fibers with an epoxy binder - ED-20 during the formation of high-strength polymer composite materials.
The data obtained in the study of various sections of polymer composites revealed a linear structure characteristic of nitron fibers coated on all sides with a polymer binder - ED-20, and structural changes in morphology at 100 and 400-fold magnification. Infrared spectral studies showed that the intermolecular interaction between hydroxyl and amide groups was established as a result of the interaction of the nitrile groups of the nitrone fiber and ED-20 with PEPA. Based on the analysis of the results obtained, it can be concluded that the developed composite materials based on epoxy binders with nitrone fibers can be considered as a new class of composite materials designed to operate under high stress conditions.

## 1 Introduction

In the 21st century, scientists and practitioners are wondering about modern engineering materials [1]. The rapid development of science and technology makes it difficult to predict: six decades ago there was no widespread use of polymer engineering materials, and only a narrow circle of specialists knew about true composites. Engineering materials will be created on the same raw material basis, but with the use of new recipes of components and technological methods, which will increase the performance properties and, accordingly, ensure their durability and reliability [2, 3].

A promising direction in the creation of machine-building composite materials is the reinforcement of materials with whiskers, which, due to their small diameter, are practically

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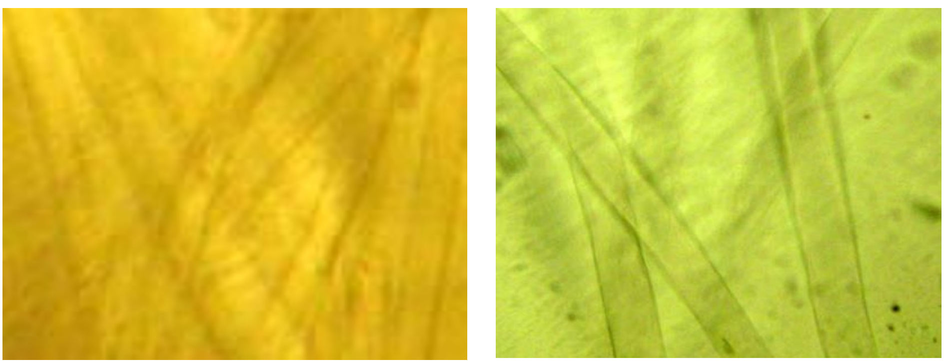
devoid of defects present in larger crystals and have high strength. Thus, we investigated the creation of new machine-building composite materials based on a polymer binder - ED-20 and nitron fibers [4]. The physicochemical properties of the developed composite materials were investigated.

## 2 Objects and methods of research

One of the important properties of the developed reinforced composite materials, which determine the possibility of their use as high-strength materials, is the physico-chemical characteristics [5, 6]. When assessing the physico-chemical properties of composite materials, their structure plays an important role. In this regard, the structural features of the developed reinforced composite materials based on epoxy binders - ED-20 and nitrone fibers were studied by a microscopic method. Microscopic studies of various fragments of samples of the polymer composition were carried out on an optical microscope with photographing their sections.

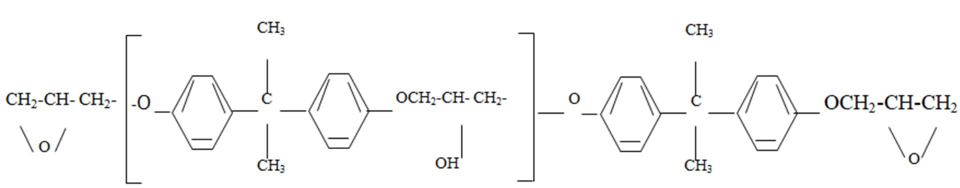
Microscopic examinations were carried out using a Nicon optical microscope (Great Britain) connected to a computer (Fig. 1). The magnification of the optical microscope is 100x and 400x.



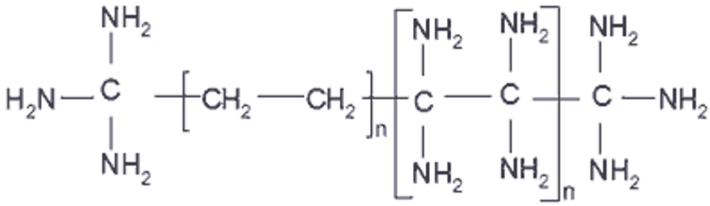
***a*** ***b***

**Fig. 1.** Micrographs of sections of various fragments of reinforced composite materials: a - 100-fold increase; b - 400 times increase

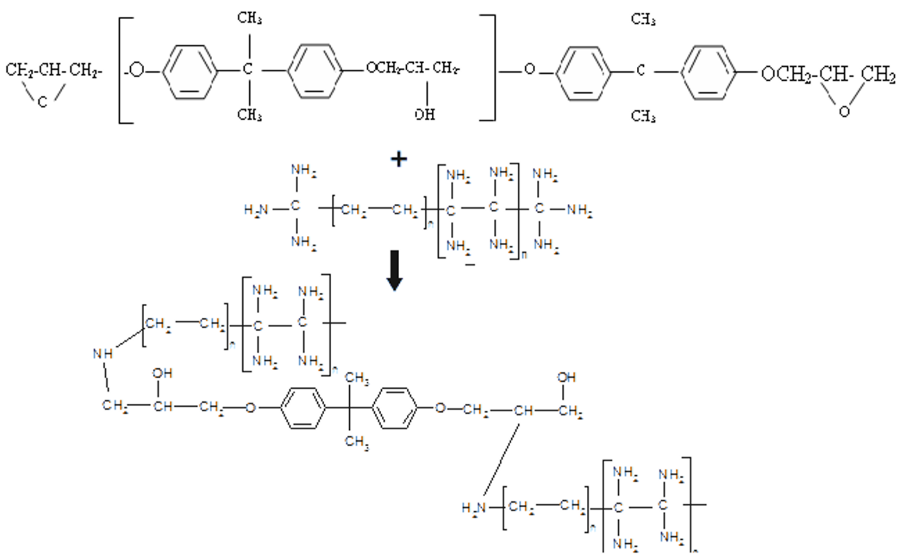
The following studies of the IR spectrograms of the obtained samples were taken on Speccord-75-IR and Perkin-Elmer Instrument spectrometers in the range of 400-4000 $cm^{-1}$ (Fig. 2), which indicate the interaction of nitron fibers with an epoxy binder during the formation of reinforced composite materials. As is known [7,8], an epoxy binder is a liquid reactive oligomeric product based on diphenylolpropane diglycidyl ether. Epoxy binder - ED-20 has only 2 epoxy groups




The greater the degree of polymerization, the thicker the resin [9,10]. The lower the number in the brand of epoxy resin, the more epoxy groups in the resin. If the number of epoxy groups is approximately 25, then the epoxy will be a hard plastic at room temperature. Epoxy resins with a small amount of epoxy groups must be cured with hardeners. For curing ED-20, we used polyethylenepolyamine (PEPA), which is a viscous dark brown liquid. Having tertiary amide groups, it performs well at room temperatures. PEPA has the following chemical structure



When an epoxy resin interacts with a hardener, the following reaction takes place:



Tertiary amide groups, which are located at the ends of the curing agent molecules, react with the epoxy resin to cure it. These groups are the most mobile, they more easily enter into the curing reaction. The tertiary amide groups of any hardener will react with the epoxy groups of the resin. A fixed network structure of the cured resin is formed. Epoxy resin becomes plastic, solid. The more epoxy groups in the resin, the more "branches" will appear during the reaction, which will create a plastic polymer, interacting with each other using various chemical bonds [11, 12]. This plasticizer mixes well with epoxy resin, various proportions are acceptable (from 1 to 20 parts by weight and more; usually it is 5-10 parts by weight).

## 3 Results and their discussion

Experiments were carried out at 100 and 400-fold magnification in an optical microscope to study the morphology and structural changes of various parts of reinforced composite materials with a polymer binder - ED-20 and nitrone fibers.

In microscopic sections of the samples, a criss-crossing arrangement of nitrone fibers is found. An optical microscope also confirms the general linearity of fragments of nitrone fibers (Fig. 1). The data obtained from studies of various fragments of polymer compositions in the form of sections quite clearly show the linear structure inherent in nitrone fibers, coated on all sides with a polymer binder - ED-20. These structural changes in morphology are more clearly manifested at magnifications of 100 and 400 times.

Thus, the analysis of the obtained micrographs of the polymer compositions indicates the presence of a binder component and a reinforcing fiber, which indicates the specificity of their morphology.

To evaluate the colors of the components in the developed composite materials, the IR spectroscopy method is used. We have studied the method of IR spectroscopy of the interaction of a mixture (ED-20 + PEPA + DBP) with nitron fiber (Fig. 2). At the same time, there is a sensation of the functional group of the mixture of nitrile fibers [13, 14].

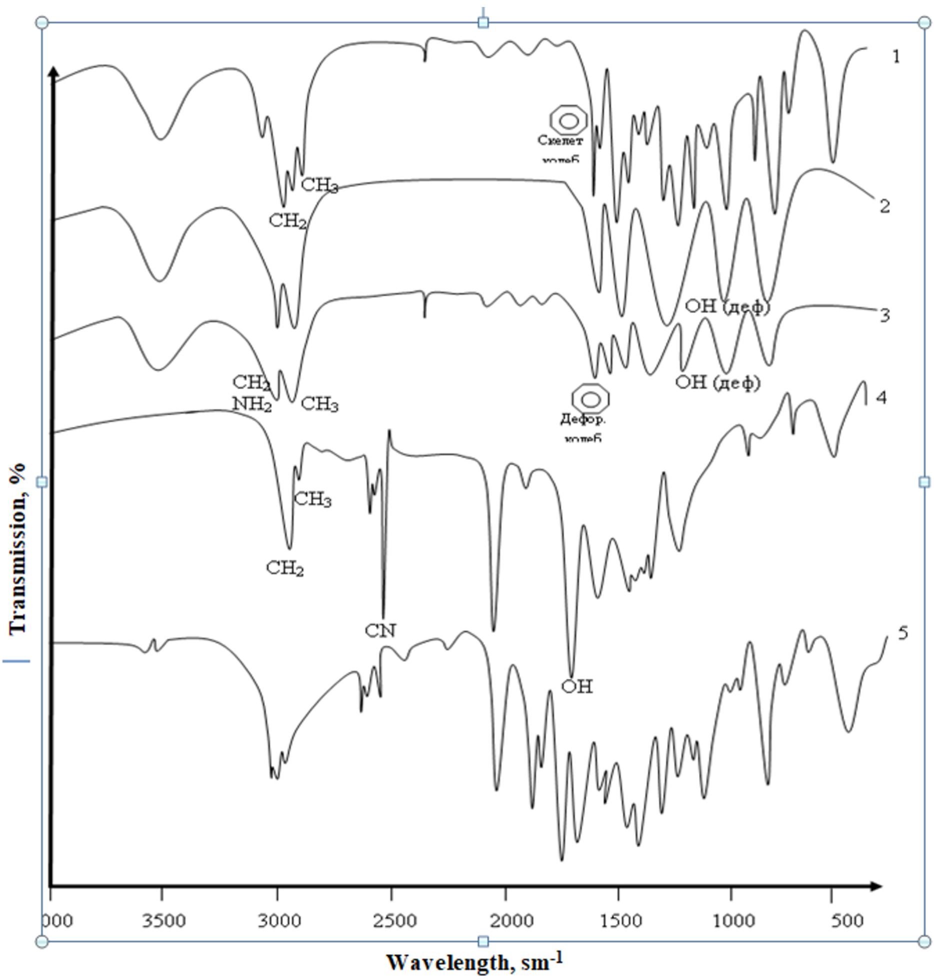



**Fig. 2.** IR - spectrum of reinforced epoxy composite materials: 1-ED-20; 2-PEPA; 3-ED-20+PEPA; 4-nitron fiber; 5-received composite material

As can be seen from fig. 2, in the IR spectrum of the ED-20 + PEPA + DBP mixture, absorption bands of the free unbound (non-associated) OH hydroxyl group (3450 cm$^{-1}$) and the product of the chemical interaction of the ED-20 epoxy resin with the PEPA hardener are observed. The absorption bands at 2923 $cm^{-1}$ should be assigned to the stretching vibrations of the $CH_3$ groups, and at 2853 $cm^{-1}$ to the stretching vibrations of the $CH_2$ groups. On the IR spectrum of the original nitrone fiber, there is a characteristic intense band of the stretching vibration of the C≡N, $\nu_{CN}$ group at 2245 $cm^{-1}$.

In the IR spectrum of the ED-20 + PEPA + DBP mixture in the region of 1800-2800 $cm^{-1}$ there is a transparency window where the bands of the mixture components do not fall. Therefore, in our case, it is convenient to use it to observe the appearance of a band characteristic of a nitrone fiber [15,16]. In the IR spectrum of the reinforced composite material, the stretching vibration bands of the ─C≡N, $\nu_{CN}$ at 2243 $cm^{-1}$. The interaction of a mixture of ED-20 + PEPA + DBP with nitrone fiber can be carried out on the nitrile groups of the fiber and the hydroxyl and amide groups of the product of the interaction of ED-20 with PEPA.This is confirmed by the disappearance of intense absorption in the region of 3450 $cm^{-1}$ of free hydroxyl groups and a decrease in the intensity of the band of vibrations of the ─C≡N bond, which indicates the consumption of nitrile groups. vibrations of the group >C=N[17]. Information on the intermolecular interaction of nitron fiber molecules with a mixture of ED-20+PEPA+DBP cannot be fully obtained by IR spectroscopy[18], since the spectra of these substances partially overlap.

Thus, the presence of intermolecular interaction between the nitrile groups of the fiber and the hydroxyl and amide groups of the product of the interaction of ED-20 with PEPA was established.

## 4 Conclusions

Structural characteristics of reinforced composite materials filled with nitron fibers have been studied using IR spectroscopic and microscopic analysis methods. It has been established that in the IR spectrum of the ED-20 + PEPA + DBP mixture, absorption bands of the free hydroxyl group OH (3450 $cm^{-1}$) and the presence of intermolecular interaction between the nitrile groups of the fiber and the hydroxyl and amide groups of the product of the interaction of ED-20 with PEPA are observed.

Summarizing the studies of the physicochemical properties of reinforced composite materials [19, 20], we can conclude that the developed reinforced composite materials can be considered as a new class of composite materials designed to operate under high voltage conditions.

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