EFFECT OF UHF MODIFICATION ON THE
PROPERTIES OF FIBRE FILLERS AND
CATION-EXCHANGE FIBRE MATERIALS

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The expediency of modifying polypropylene and basalt fibres to increase the SEC of cation-exchange fibre materials (CEFM) made from them due to increasing the activity of the UHF-treated fibres was demonstrated.

Polymer composite materials (PCM) have penetrated so deeply into different sectors of industry, transportation, and daily life that the degree of their utilization has become a criterion of the level of scientific and technical progress [1]. PCM with chemisorption properties based on fibre fillers occupy a special position among them.

Polyacrylonitrile and polypropylene fibres are currently primarily used to obtain composite chemisorbents by polycondensation filling. At the same time, the actively developed basalt fibres and yarns, which are distinguished by elevated properties, modern production technology, and growing production volumes, are being increasingly used in the reinforcing fibre materials sector [2].

We determined the effect of ultrahigh-frequency treatment on the structure and properties of reinforcing fillers of different chemical nature and the phenol-formaldehyde cation-exchange fibre materials (CEFM) made from them.

Polycondensation filling technology for CEFM is based on the principle of intercalation of monomers in the structure of the filler followed by synthesis of the polymer binder directly from the monomers inside and on the surface, which ensures uniform distribution of the polymer in the bulk of the material [3]. The efficiency of the reaction of the synthesized oligomers with the fibres is higher than in traditional PCM production technology.

Basalt (Bf) and polypropylene (PPf) fibres were investigated. To increase the efficiency of utilizing the fibres, modifying them with UHF radiation, a modern physical method of purposeful control of the structure and properties of polymers, was proposed.

The published data [4, 5] shows that UHF treatment causes amorphization of the polymer and should probably result in deeper diffusion of the monomers into the bulk of the fibre in polycondensation filling, an increase in the proportion of cation-exchange matrix, and an increase in the static exchange capacity (SEC) of the CEFM synthesized from them.

A preliminary experiment on modification of these fibres showed (Table 1) that in UHF treatment, the reinforcing properties of PPf and Bf are almost totally preserved, while the SEC of the CEFM obtained increases 30-60%.

The use of mathematical experimental design allowed determining the optimum parameters of the UHF treatment for these fibres, where the SEC reached 1.62 meq/g for PPf CEFM and 1.4 meq/g for Bf CEFM (Fig. 1).

Infrared spectroscopy was used to evaluate the effect of UHF radiation on the structural characteristics of these fibres (Fig. 2).

The study of the absorption spectra of PPf showed [6] that intensive absorption bands characterizing vibrations of the main carbon chain of the polypropylene macromolecules with symmetrically positioned CH₃ groups is characteristic of the initial fibre (curve 1). The closely positioned absorption maxima in the 1456-1378 cm⁻¹ region correspond to CH₂ and CH groups. The 2942-2839 cm⁻¹ region is characteristic of stretching vibrations of a CH₃ group and the 1370-1200 cm⁻¹ region is

TABLE 1. Properties of Modified Polypropylene and Basalt Fibres and CEFM Made from Them

<table>
<thead>
<tr>
<th>UHF treatment parameters</th>
<th>linear density, tex</th>
<th>tenacity, cN/tex</th>
<th>elongation at break, %</th>
<th>Static exchange capacity of CEFM, meq/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>power, W</td>
<td>duration, sec</td>
<td>PPf</td>
<td>Bf</td>
<td>PPf</td>
</tr>
<tr>
<td>With no treatment</td>
<td>280</td>
<td>1335</td>
<td>19.4</td>
<td>12.1</td>
</tr>
<tr>
<td>450</td>
<td>30</td>
<td>276</td>
<td>1290</td>
<td>19.6</td>
</tr>
<tr>
<td>750</td>
<td>30</td>
<td>283</td>
<td>1301</td>
<td>18.7</td>
</tr>
</tbody>
</table>

Fig. 1. Effect of parameters of UHF modification of polypropylene (■) and basalt (□) fibres on the static exchange capacity of CEFM made from them.

characteristic of fan and twisting vibrations of CH groups. The absorption bands in the 1200-800 cm\(^{-1}\) region are caused by the interaction of CH\(_3\) and CH\(_2\) group pendulum vibrations with the stretching vibrations of the carbon skeleton. The study of the IR spectrum of PP fibre after UHF treatment (curve 2) shows a decrease in the peak of the =CH—CH\(_3\) vibrations, and spectral changes are also characteristic of the 900-1700 cm\(^{-1}\) region. All of the above indicates the structural changes that take place in the polymer under the effect of UHF modification.

The analysis of the IR spectra of the initial and UHF-treated basalt fibres (curves 3, 4) showed that absorption bands at 3440 cm\(^{-1}\) caused by stretching vibrations of the OH groups forming hydrogen bonds with each other and with other groups are characteristic of them. However, the intensity of this absorption band decreases as a result of the UHF treatment, which probably indicates a decrease in the number of free OH groups in the modified fibre capable of forming hydrogen bonds with each other and with other groups in the structure. The intensity of the absorption bands in the 2920-2850 cm\(^{-1}\) region characteristic of stretching vibrations of molecules of crystallization water bound by hydrogen and donor-acceptor bonds with cations of different nature is increased in the UHF-treated fibre. The maxima at 2320-2350 cm\(^{-1}\) which reflect stretching vibrations of OH groups in [O\(_3\)Si—OH]\(^3\) anions disappear in the IR spectra of the modified fibres. The maximum at 1640-1650 cm\(^{-1}\) is due to deformation vibrations of molecules of crystallization water \(\delta_w\).

As a result, the IR spectra of the Bf in the 3500-2300 cm\(^{-1}\) region can be used to evaluate the character and proportion of bound crystallization water, whose content is increased in the modified fibres.

The analysis of the IR spectra of fibrous basals in the 1500-500 cm\(^{-1}\) region is of the greatest interest. The intense broad maximum in the 1150-1000 cm\(^{-1}\) region reflects the stretching vibrations of the SiO bond in chain and ribbon silicon-oxygen structures. There was a small increase in the intensity of these peaks in the modified Bf. The stretching vibrations of the SiO bond in silicon-oxygen ring structures characteristic of the 780-790 cm\(^{-1}\) region almost do not change after modification. The 740-540 cm\(^{-1}\) region reflects the presence of the oxides of such metals as Al, Fe, Ca, and Mg. The maximum in the 518 cm\(^{-1}\) region is probably due to deformation vibrations of Si—O—Si bridges.