dening in normal temperature and damp conditions and 10÷25 kg/m^3 at warm damp processing. Similar law is characteristic also for sodium sulphate. Potassium nitrate is forbidden to be applied in concrete and the solutions which are exposed to thermal processing or periodic heating to temperatures above 70 °C. Besides, at application of any of chemical the additives accelerating a set of durability of concrete and building mortar it is necessary to provide the actions lowering temperature of the prepared mix and preventing formation of cracks.

FDM PRINT MATERIALS APPLIED IN THE MICROWAVE RANGE

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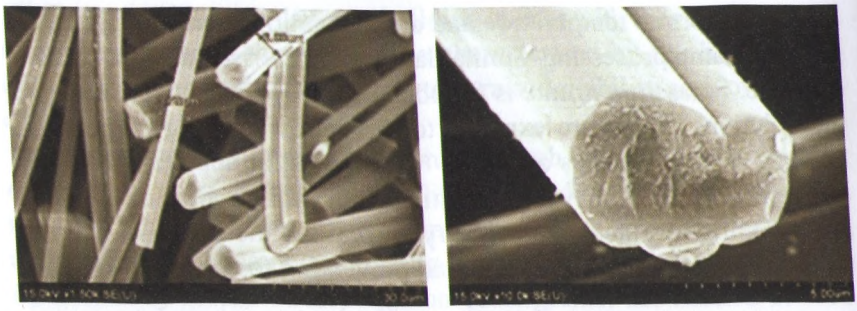
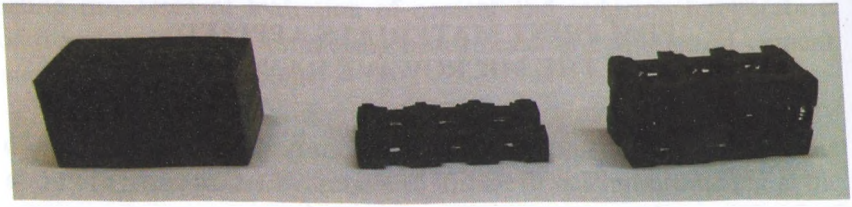
Obtaining materials with desired electromagnetic properties suitable for 3D printing is an important task of modern materials science and solid state physics. Carbon inclusions of various morphology (carbon nanotubes, graphene nanoplates, carbon fibers, etc.) have proven themselves as fillers in the manufacture of polymer composite materials. Composites with carbon and nanocarbon inclusions are especially attractive as absorbers of electromagnetic radiation in the development of technology to reduce the visibility of the radar. The use of carbon fibers with a regular cylindrical shape and a high ratio of transverse dimensions, and high electrical conductivity allows you to create composites based on them with a high absorption coefficient at a concentration of inclusions below the percolation threshold. The use of such materials in 3D printing allows you to create screening elements of any configuration.

The production of ABS filaments with a different content of carbon filler was carried out using the method of melt blending on a twin-



a



b

Fig. 1. Carbon filler (*a*), three-dimensional structures printed by FDM technology (*b*)

screw extruder in several stages: the preparation of the compound, the preparation of the filament from the compound. The following polymers were used in the work: ABS MG47F (PTR 5.6 g / 10 min). Wastes from the carbon filament production of SvetlogorskKhimvolokno OJSC (Fig. 1, *a*). The content of the filler is 6; 9; 12; 15 wt.%. Then, using FDM printing (nozzle diameter 0.4 mm, layer thickness 0.2 mm), experimental samples were obtained in the form of parallelepipeds, as well as three-dimensional structures in the form of Ashby cells (Fig. 1, *b*).

The electromagnetic properties of the samples obtained in the frequency range 12–18 GHz are investigated. For carrying out the experiments, a vector analyzer of R4M circuits manufactured by Mikran and a waveguide path of 16x8 mm were used. The dielectric constant spectra were obtained from experimentally measured.

S-parameters according to the methods described in [1].

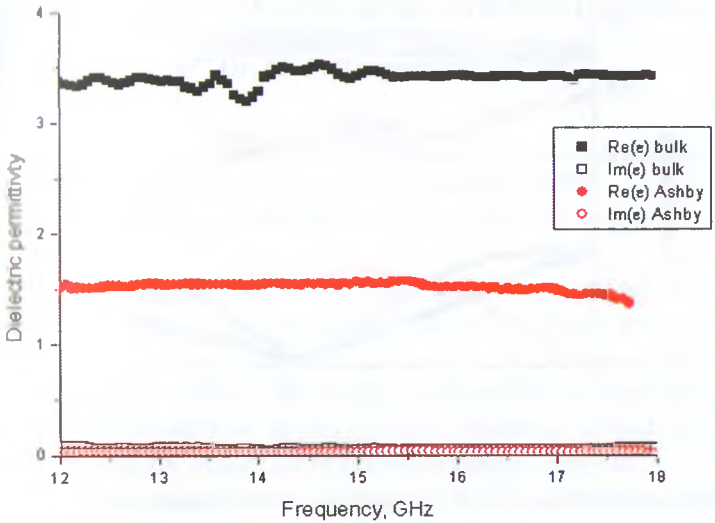


Fig. 2. Frequency dependences of the complex dielectric constant of samples with full filling (bulk) and Ashby grids

Fig. 2 shows the frequency dependences of the complex dielectric constant of the samples obtained.

An analysis of Fig. 2 shows that the effective complex dielectric constant of the materials under study is practically independent of frequency. The ε values for the Ashby lattices are approximately 2 times smaller than the ε values for the samples with full filling.

The dependences of the amplitudes of the transmitted S_{21} and the reflected S_{11} signals on the frequency for samples of different thickness (consisting of 1–4 layers containing one Ashby cell) are shown in Fig. 3.

From Fig. 3 it is clearly seen that the structures under consideration pass through a significant part of the incident microwave radiation. Varying the thickness of the samples (the number of Ashby elementary cells located along the direction of wave propagation) leads to a shift in the apparent interference peaks in the S-parameter spectra and can be used to obtain structures transparent to the radiation of a given frequency.

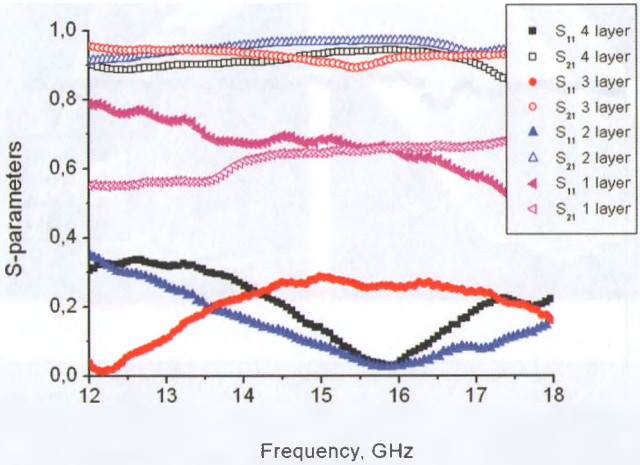


Fig. 3. Frequency dependences of the amplitudes of the transmitted S21 and reflected S11 signals for samples of different thickness (consisting of *1–4* layers containing one Ashby cell)

The results obtained allow us to consider carbon microfibers as a cheap alternative to nanocarbon fillers for various applications [3]. To obtain large absorption values in the structures under consideration, it is necessary to increase the content of the filler in the polymer martix. This will allow increasing the values of the imaginary part of the effective complex dielectric constant and thus will lead to an increase in absorption in the structures under consideration due to ohmic losses.

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