Mechanical Characteristics of Nanocomposite Materials Based on Polytrifluorchlorethylene

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Introduction

Features of molecular and supramolecular structure of polytrifluorochloroethylene (fluoroplastic (FP)) enable the implementation of a unique combination of its strength, tribological, anti-corrosion, thermal, and other operational characteristics in various products and, in particular, in working parts of equipment. Various fillers (fibers and particles) successfully reduce fluoroplastic wear by several orders of magnitude, but they also impair some other useful thermal and chemical properties that make these polymers attractive for use. The use of carbon nanofillers eliminates many of the limitations inherent in traditional fillers. At the same time, low concentrations of nanoparticles lead not only to improvements in the characteristics of mechanical properties, such as strength, Young's modulus, deformation before the destruction of polymer matrices but also make the composite material electrically conductive.

In this work, expanded graphite was used as a nanoscale form of the carbon filler to create nanocomposite materials based on the FP. The large specific surface area of expanded graphite particles, their plasticity, the ability to deform and exfoliate permit it to be effectively used to create electrically conductive nanocomposite materials with improved characteristics.

Experimental Results

In this work elastic and strength properties of polymer composites with a polytrifluorochloroethylene matrix and an expanded graphite (EG) filler have been evaluated using the microindentation method. The influence of dispersion and filler concentration on the mechanical characteristics of nanocomposite materials (NCM) has been studied. It has been established that the microhardness of the NCM decreases with increasing the filler concentration. Growth of filler particles sizes for NCM with a filler concentration of 3 vol.% led to an increase of microhardness and Young's modulus. As for NCM with a 10 vol.% of the filler, increasing of EG particles dispersity up to 180 μm showed a similar change of the mechanical characteristics. However, a further increase in the average particle size of EGs caused a decrease in Young's modulus and the microhardness of the composites. The reason for that might be a different degree of structuring of the polymer and the formation of different orientational order of the filler.

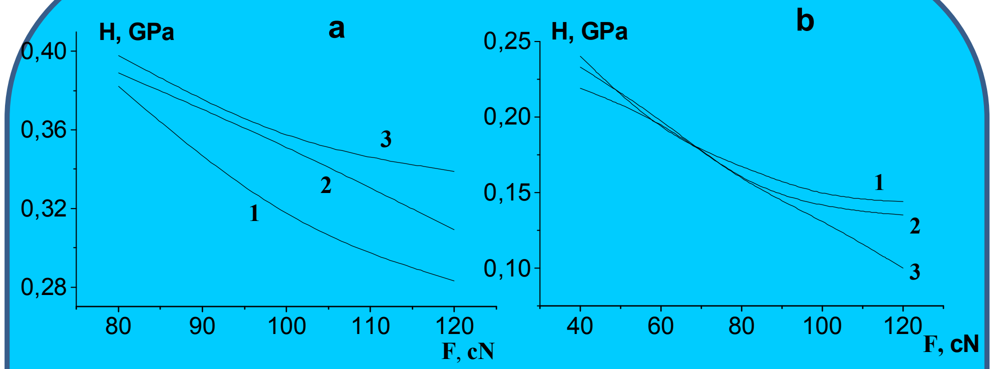

Fig. 1. Dependence of microhardness on the loading on the indenter: **a** - for samples FP-EG, C (EG) = 3 vol.%, d = 40 (1), 80 (2), 260 (3) μm; **b** - for pure FP (1) and NCM C (EG) = 10 vol.%, d = 120 (2), 500 (3) μm.

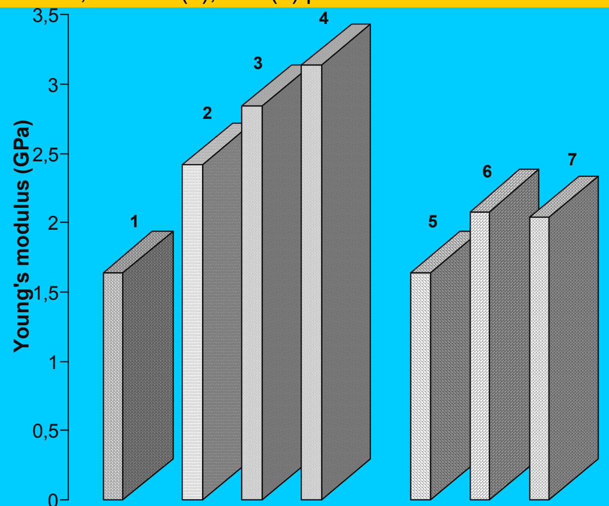

Fig. 2. Young's modulus for samples of FP (**1**) and NCM FP-EG. The concentration of EG is 3 vol.% (**2, 3, 4**) and 10 vol.% (**5, 6, 7**) and the dispersion of its particles 40 (**2**), 80 (**3**), 120 (**5**), 180 (**6**), 260 (**4**) and 500 (**7**) μm.

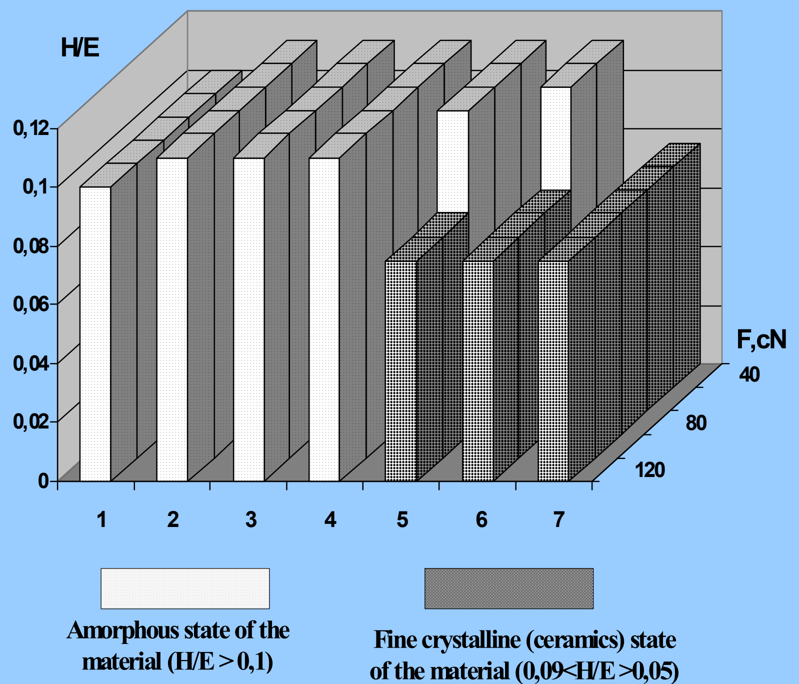

Fig. 3. Dependence of the *H/E* ratio at different degrees of load for samples of FP (**1**) and NCM FP-EG with a concentration of EG 3 vol.% (**2, 3, 4**) and 10 vol.% (**5, 6, 7**) and dispersion of its particles: 40 (**2**), 80 (**3**), 120 (**5**), 180 (**6**), 260 (**4**), 500 (**7**) μm.

As Fig. 3 shows, at low concentration of the filler (*C(EG)* = 3 vol.%), the *H/E* value is 0.1, which corresponds to the amorphous behavior of the sample, whereas at a higher filling of NCM (*C(EG)* = 10 vol.%), the behavior under loading is changing from the amorphous to crystalline or ceramic type. This indicates a growing influence of the composite carbon component on the mechanical characteristics, the *H/E* value decreases to 0.07. The microhardness measurement results have also been used to calculate and plot the dependence of the ultimate strength upon the microhardness for the FP-EG samples (Fig. 4).

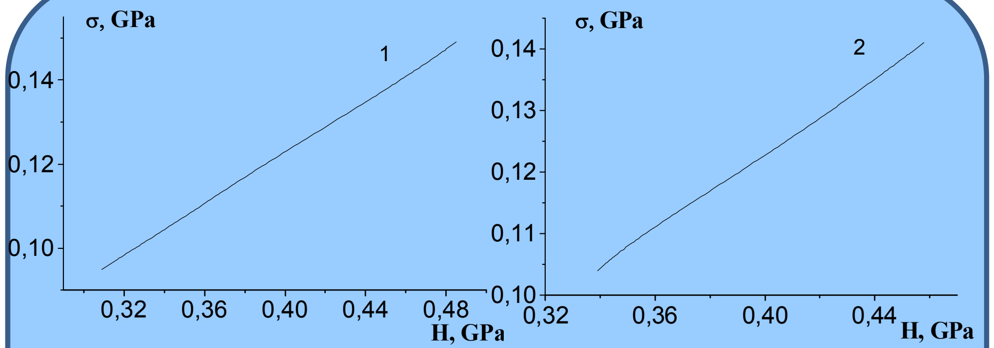

Fig. 4. Dependence of the magnitude of the stress, which corresponds to the onset of plastic deformation of the material under tension on the microhardness obtained using the Micron-gamma device for the FP-EG samples (*C* (EG) = 3 vol.%, *d* = 40 μm (**1**), 260 μm (**2**)).

Conclusion

A variety of microindentation methods allows solving a wide range of issues in physical nanomaterial science, which are part of more complex tasks. In particular, indentation methods make it possible to determine the mechanical properties, dynamics, and deformation mechanisms of a wide variety of materials, including polymer nanocomposites. The method of measuring microhardness was used to evaluate the elastic and strength properties of an amorphous-crystalline composite with a polytrifluorochloroethylene matrix. It was shown that the microhardness of NCM FP-EG decreases with increasing filler concentration. The observed changes in Young's modulus and the *H/E* ratio indicate a change in the amorphous-crystalline behavior of the composite to that which is characteristic for fine-crystalline materials and depends on the dispersion of the EG. This may be due to the different degrees of structuring of the polymer and the formation in the polymer structure of different orientational order.