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Abstract

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ON THE ROLE OF SUPRAMOLECULAR STRUCTURES IN THE DESTRUCTION OF POLYMERS IN AN ULTRASONIC FIELD

(Presented by Academician V. A. Kargin, April 13, 1964)

In connection with the use of ultrasound for processing polymer materials ([1–5]), it is of interest to study the influence of ultrasonic action on the physical properties of polymers and, above all, on their structure and mechanical properties.

Amorphous films of polyvinyl chloride and crystalline films of polyethylene and polypropylene* were subjected to ultrasonic irradiation. Ultrasonic vibrations with a frequency of 22 kHz were focused on the film by means of an exponential intensifier. The intensity of the vibrations at the center of the beam reached 15-18 W/cm^2. During irradiation of the films, the condition of their surface was observed. The films were subjected to ultrasonic action until defects visible to the naked eye appeared on them. The irradiation time for the amorphous polyvinyl chloride films was 30 min, and for the other types of films, 10 min. Since the intensity of the ultrasonic action** was maximal at the center of the film and decreased toward its periphery, successive stages of destruction could be observed on one film at a given irradiation time.

The study of structural changes in the films after their irradiation in an ultrasonic field was carried out on an MP-7 polarization microscope in transmitted polarized and nonpolarized light.

Ultrasonic action, if secondary phenomena accompanying ultrasonic vibrations in a liquid medium are not taken into account, creates tensile and compressive stresses in the polymer film. Such action, depending on the character of the supramolecular structures of the polymer, leads to different mechanisms of destruction.

Damage to an amorphous polyvinyl chloride film*** in an ultrasonic field begins with the appearance of cracks located in one direction. Then the cracks grow in arbitrary directions with the formation of a network, and the cracks propagate into the depth of the polymer (Fig. 1).

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* The polyethylene and polypropylene films were kindly provided by Yu. Glazkovskii (VNIISV).

Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

** Irradiation of the films with ultrasound was carried out in distilled water.

*** The amorphous films were obtained from a solution; the crystalline films, from a melt under pressure. Film dimensions: 20×18 mm. Film thickness: 40-70 μ.

Fig. 1. Network of cracks in a polyvinyl chloride film irradiated with ultrasound.

Fig. 2. *a* —network of cracks in a fine-crystalline polypropylene film irradiated with ultrasound (300×); *b* —a single crack in a polyethylene film irradiated with ultrasound. Micrograph in nonpolarized light (1020×).

Fig. 3. *a* —cracks along the boundaries of spherulites in a polypropylene film irradiated with ultrasound. Micrograph in polarized light (750×); *b* —spherulitic regions destroyed under the action of ultrasound in a polypropylene film with a nonuniform crystalline structure. Micrograph in nonpolarized light (100×).

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Fig. 1

Fig. 2

Fig. 3

Destruction is completed by the spalling and knocking-out of polymer particles along the cracks, with the formation of a hole in the film.

The growth of a network of cracks under the action of ultrasound was observed in polyethylene film (Fig. 2a), and also in polypropylene film (Fig. 2b) that did not possess large crystalline formations (for example, spherulites). Thus, amorphous films and crystalline films with small structural elements are destroyed in an ultrasonic field with the formation of individual cracks that grow in arbitrary directions and form a network.

Fig. 3

Figure 3: Fig. 3

Fig. 4

Figure 4: Fig. 4

Ultrasonic action in the case of crystalline polypropylene films possessing a large-spherulitic structure leads to the formation and development of cracks along the boundaries of the spherulites (Fig. 3a). Apparently, this is connected with the fact that the stresses arising in the films under the action of ultrasound are concentrated at the boundaries of the spherulites. Irradiation with ultrasound of polypropylene films having a sharply inhomogeneous crystalline structure (alternation of regions with a very fine crystalline structure and with distinctly different spherulites*) leads to destruction only of the spherulitic regions along clearly expressed boundaries (Fig. 3b). The unequal effect of ultrasonic action in this case can be explained by the fact that the regions with small structural elements are more resistant to ultrasound, since in them a smaller part of the cross section proves to be overstressed than in coarse-grained (spherulitic) regions.

From Fig. 4, which gives the dependence of the strength of polypropylene films with different supramolecular structure on the duration of ultrasonic irradiation, the substantial influence of the sizes of the structural elements on the strength and on the process of disintegration of the film in an ultrasonic field is clearly seen.

Fig. 4. Change in the strength of polypropylene films of different structures under the action of ultrasound: 1 —finely crystalline, 2 —large-spherulitic, 3 — inhomogeneous crystalline

The strongest, but also the least resistant to irradiation, proved to be films with minimum sizes of crystalline formations (curve 1). Films with larger (curve 2) and with spherulites inhomogeneous in size (curve 3) proved to be less strong, but relatively more resistant to ultrasonic vibrations.

Thus, the process of destruction of crystalline polymers in an ultrasonic field is regulated by the sizes of the elements of supramolecular structures and, probably, also depends on the internal structure of these elements.

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* Such films were obtained by very rapid cooling of the melt in a press mold.

Note: Figure translations are in progress. See original paper for figures.