Investigation of heating of nanomodified polymers under the action of microwave radiation

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Abstract. The article presents the study of heating nanomodified polymers under the action of microwave radiation. Modification of polyethylene was carried out using CNTs synthesized on Co-Mo / Al₂O₃-MgO catalysts. The influence of CNTs concentration on the temperature regime of polymer heating is investigated. The study of interaction with microwave radiation was carried out at the emitter power of 800 W in 2 minute increments for 8 minutes.

1. Introduction
The use of carbon nanotubes (CNTs) as polymer modifiers opens up new technological prospects in the creation of materials with functional properties [1-2]. CNTs can have dual functionality, i.e. provide microwave heating and improve electrical conductivity and mechanical properties. Thus, it is possible to develop polymer products with improved mechanical and electrical properties and functionality providing such possible technological operations as selective welding.

In this regard, it is important to study the influence of the nature of carbon materials on the interaction with microwave radiation in polymer matrices.

We studied the effect of the area of carbon particles on the interaction with microwave radiation. According to the results of studies it was concluded that the morphological characteristics of carbon had a strong influence on their properties under the influence of microwave heating. Studies carried out in [3] have shown that the efficiency of heating soot particles increases when the surface area of the particle is higher. In [4] the authors proposed a mechanism in which residual metals (Fe) of the catalyst for CNTs synthesis could influence the effect of microwave perception. However, other studies have shown the independence of the microwave effect from residual metals in CNTs [5].

In the article [6] polypropylene was chosen as a polymer matrix and nanocomposites were prepared by mixing in the melt using a twin-screw extruder. The efficiency of the heating process was tested taking into account the dispersion of CNTs in the polymer matrix, which allowed assessing the effect of dispersion as the main factor on heating.

In work [7] researches of dispersion of the polypropylene filled with 1% CNTs were carried out. Nanocomposites were obtained by compounding in the melt in a rotary twin-screw extruder. Processing parameters such as screw speed, screw configuration, and feed technology have been

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modified to analyze their effect on carbon nanotube dispersion. According to the research, the question remains related to the uniformity of heat release and the influence of CNTs concentration on the heating dynamics of the nanomodified polymer.

However, the studies [3-7] do not fully reflect the influence of CNTs on the effects of interaction with microwave radiation, especially the influence of CNTs concentration in the polymer matrix.

The research objectives included:

1. Identification of the influence of CNTs concentration on the mode of polymer heating under the action of microwave.
2. Detection of exposure time under the action of microwave radiation to heat samples of different concentrations.

2. Methods and Materials

Polyethylene is used as a polymer matrix. Modification of polyethylene was carried out using CNTs synthesized on Co-Mo / Al2O3-MgO catalysts. The concentration of CNTs in the polymer reached 15%, other concentrations were wt.0.3 and 0.5 %. CNTs morphology was studied using scanning (SEM) and transmission electron microscope (TEM) “Hitachi H-800” (Hitachi, Japan). The Mooney polymer was mixed in a mixer. Further, the resulting material was extruded on a single-screw extruder with a drive motor power of 1.5 kW. The study of interaction with microwave radiation was carried out at the emitter power of 800 W with different time delay up to 8 minutes in increments of 2 minutes. The temperature field distribution on the composite surface was investigated using a Testo 875 thermal imager (Black Forest, Germany).

3. Results and Discussion

CNTs (Figure 1) have an outer diameter of about 25-35 nm and an inner diameter of 10-15 nm. CNTs having an outer diameter of 5-15 nm, have an inner diameter of 5-7 nm.

![SEM CNTs](image.png)

Figure 1. SEM CNTs
Nanomodified polymers obtained using an extruder, are shown in Figure 3.

Figures 4 - 6 show thermograms with the heat release of samples under the influence of microwave radiation.
The first experience showed (Figure 4) that the sample with the highest CNTs content was heated to 53.8 °C.

In Figure 5 it is possible to observe an increase in temperature to 56.4 °C of the third sample containing 15% CNTs. However, there is also a slight heating of the first and second samples.
The maximum temperature of the first and second samples is in the 40 °C zone (Figure 6).

![Thermogram of the samples (8 minutes)](image)

**Figure 7.** Thermogram of the samples (8 minutes)

The fourth stage of the experiment showed a large increase in temperature to 76.3 °C (Fig. 7). This is due to the fact that at this stage – the longest duration of the experiment 8 minutes. During this time, the samples gain the largest possible amount of thermal energy. At this concentration there is a peak of heat release in the Central region with a decrease in temperature to the ends of the sample.

Figure 8 shows the dynamics of temperature regime change for a sample with wt. 15 % CNTs.

![Dynamics of temperature change for the sample with wt. 15 % CNTs](image)

**Figure 8.** Dynamics of temperature change for the sample with wt. 15 % CNTs

The sharp temperature peak of 76.3 °C at 8 minutes can be explained by the fact that the heating occurred in the volume of the material over time, those CNTs that were located more deeply due to heat transfer gave their thermal energy to the upper layer of the polymer. Due to this, it is possible to explain the uneven temperature dynamics during microwave heating. This feature should be taken into account when long-term heating, as it is possible to ignite the polymer, due to excessive temperature increase of the inner layers.

**4. Conclusion**

Studies have shown how the concentration of CNTs in polymers affects the dynamics of heating depending on the time of exposure to microwave radiation. The highest temperature corresponded to the sample with a CNTs concentration of 15 % and was 76.3 °C. At this concentration, there is a peak of heat release in the Central region with a decrease in temperature to the ends of the sample.
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