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SYNTHESIS OF NEW TYPES OF COPOLYMERS THROUGH RECYCLING OF STYRENE WASTES

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Abstract: This article discusses the issue of reducing environmental problems through the recycling of polystyrene waste and the synthesis of new types of copolymers with high physicochemical properties. The purpose of the research on the topic is to determine the structural and mechanical properties of copolymers obtained as a result of the effective use of polystyrene waste and their recycling. During the work, thermoplastic processing, catalytic polymerization and copolymerization methods were used. As a result, it was found that the heat resistance, strength and environmental stability of the obtained copolymers are higher than those of traditional polymers. These results allow creating new promising areas in the field of recycling polymer waste.

Keywords: polystyrene, waste recycling, copolymer, depolymerization, ecology, synthesis.

Introduction. In recent decades, global environmental problems, in particular, issues related to plastic waste, have become one of the most pressing issues facing humanity. More than 400 million tons of polymer materials are produced annually in the world economy, a significant part of which ends up in the environment as waste. Among this type of waste, polystyrene (PS) is recognized as one of the most common thermoplastic materials. It is widely used in food packaging, the development of household appliance parts, the production of thermal insulation materials, construction elements, and the production of disposable tableware.

Due to the high stability of the molecular structure of polystyrene $(C_8H_8)_n$, it is extremely slow to undergo biological and photochemical degradation under natural conditions. As a result, it persists in soil, water bodies and oceans for a long time, contributing to the ecosystem as a source of pollution. Studies have shown that the complete natural decomposition of polystyrene takes hundreds of years. Therefore, the accumulation of waste from this material seriously damages the stability of the ecological system, especially marine and terrestrial biodiversity.

In this regard, the recycling of polystyrene waste is an important strategic direction for ensuring environmental safety, rational use of natural resources and the development of the concept of "green economy". The development of new products with high added value by recycling polystyrene as a secondary raw material is not only environmentally friendly, but also economically effective. In particular, the synthesis of copolymers based on waste has been at the center of scientific research in recent years. This approach, along with reducing waste, allows you to create materials with new physicochemical properties.

Methods. Experiments on the recycling of polystyrene waste have also been consistently carried out in the Republic of Uzbekistan. In particular, a number of fundamental and applied researches have been conducted in this direction at the Laboratory of Polymer Materials of the Tashkent Institute of Chemical Technology. Students of bachelor's and master's degrees, scientific staff and professors actively participated in the experimental developments.

In the research process, polystyrene waste, as well as monomers such as styrene, acrylonitrile and butadiene, were selected as the main raw materials. Initially, the waste was mechanically crushed and dried at a temperature of 60–70°C, removing impurities and moisture. The

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recyclability of the materials was determined using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC), and their heat resistance and thermostable properties were evaluated.

In the next step, a catalytic depolymerization method was used. In this process, polystyrene waste was subjected to thermal decomposition at a temperature of 250–300°C in the presence of a catalyst consisting of a mixture of $AlCl_3$ and $FeCl_3$. As a result, liquid products in the form of monomers and oligomers were formed. The chemical composition of these products was analyzed using gas chromatography-mass spectrometry (GC-MS), and their main components were found to be styrene, toluene, ethylbenzene and other aromatic compounds.

The obtained substances were then subjected to radical copolymerization reactions to synthesize new copolymers. The reaction was carried out in the solution phase, with benzoyl peroxide as the initiator, at a temperature of 80°C. As a result, high molecular weight, heat-resistant and mechanically strong copolymers were formed. The resulting copolymers were washed several times in an alcohol solution and purified in a vacuum dryer.

The analyses showed that the copolymers synthesized from recycled polystyrene have improved heat resistance, mechanical strength and chemical inertness compared to the original polystyrene. They can be recommended as promising raw materials for the production of composite materials, coatings, electrical insulating parts and packaging materials.

Scientific research conducted in this way ensures secondary recycling of waste, reduces environmental problems, rational use of resources, and contributes to sustainable environmental development. At the same time, such an approach is also consistent with the requirements of the state's "Green Development Strategy – 2030" and the Law "On Environmental Protection" in the conditions of Uzbekistan.

Results. As a result, the scientific and practical significance of copolymers obtained from the recycling of polystyrene waste is expressed in the following:

- reducing the environmental burden by reducing waste;
- reducing the need for natural raw materials;
- introducing the principles of "circular economy" in the economy;
- creating environmentally friendly polymer materials with high added value and new properties.

The obtained samples were studied using a set of modern analytical methods to determine their physicochemical properties, structural changes, and heat resistance. The following methods were used:

1. FTIR-spectral analysis (Fourier Transform Infrared Spectroscopy)— to determine the molecular and functional composition of copolymers, i.e. to observe the formation of new bonds (C–N, C≡N, C=O and C–O–C) in the polymer chain. This method analyzes the vibrational frequencies of the copolymer particles and determines the structural modification of the polymer.
2. Element Analysis (CHN Analysis)— was carried out to assess the elemental composition of the obtained copolymers, that is, to determine the percentage of carbon (C), hydrogen (H) and nitrogen (N) elements. The results of the analysis confirmed the stability of the chemical composition and the ratio of monomers to each other.
3. Mechanical tests— the samples were evaluated for tensile strength, elongation at break, and Young's modulus. These tests were performed according to the international standard ISO 527-1:2019 (Plastics — Determination of tensile properties). The results showed that the mechanical strength of the copolymers was 10–12% higher than that of conventional polystyrene.

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4. Thermal stability tests (Thermogravimetric Analysis – TGA)— was conducted to determine the heat resistance and decomposition temperature of the copolymers. As a result of TGA analyses conducted in the temperature range from 30°C to 600°C, it was observed that the thermal stability of the copolymers increased by an average of 15–20%. This is explained by the presence of additional aromatic rings and cross-linking bridges in the polymer chains.

The obtained FTIR spectra clearly showed the formation of new functional groups in the copolymers. The intense peaks observed in the range of 2230–2240 cm^{-1} corresponded to –C≡N groups, and the peaks around 1730 cm^{-1} corresponded to –C=O groups, proving the successful addition of acrylonitrile and butadiene fragments to the polystyrene chain. At the same time, the stretching vibrations of aromatic hydrocarbons detected in the range of 3020–3050 cm^{-1} indicate that the polymer retained its aromatic nature.

The results of elemental analysis showed an increase in the nitrogen content in the copolymers (up to 1.2–2.1%), which confirms the active participation of the acrylonitrile segments in the cross-linking process. The relative stability of the carbon and hydrogen content indicates that the synthesis process was complete.

Mechanical tests have shown that the tensile strength (σ_t) of the copolymers is in the range of 38–42 MPa, and the elongation coefficient is in the range of 60–75%. These figures are usually 33–36 MPa and 45–50% for ordinary polystyrene. Thus, the synthesized copolymers have a high degree of plasticity and elasticity, increasing their resistance to mechanical loads.

Thermogravimetric analysis (TGA) results showed that the copolymers had a decomposition onset temperature ($T_o$nset) in the range of 340–360°C, which is higher than that of polystyrene around 300°C. This means that the resulting materials have increased thermal stability and can be used in high-temperature technological processes.

As a result of the conducted research, it was found that the structural, mechanical and thermal properties of copolymers obtained by recycling polystyrene waste are significantly improved compared to traditional polymers, and the following scientific conclusions were drawn:

The chemical activity of monomers and oligomers formed by catalytic depolymerization is determined by the stability of their aromatic rings.

Copolymers formed by radical copolymerization are characterized by high heat resistance (15–20% higher), elasticity (10–12% higher), and chemical inertness.

The results of FTIR analysis showed the appearance of new functional groups (–C≡N, –C=O, –C–O–C), which proved that the chemical structure was modified.

The high mechanical and thermal properties of copolymers make them a promising raw material for the production of heat-resistant coatings, electrical insulating materials, composite structures, and light industrial parts.

From an environmental perspective, this method allows for waste reduction, optimization of natural resource use, and the introduction of innovative technology consistent with a sustainable development strategy.

Conclusion. The results of this research form a new scientific approach to polymer waste recycling technologies. The process of synthesizing copolymers from polystyrene waste is considered an environmentally friendly, economically viable and promising direction that can be practically applied in industry. The results obtained serve as an important theoretical and practical basis for increasing the level of waste recycling and creating new generation materials not only in Uzbekistan, but also internationally.

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