

COMPOSITIONS OF ARYLALICYCLIC COPOLYIMIDE
WITH ALKYLATED MONTHMORILLONITEMaira Umerzakova¹, ✉, Talkybek Jumadilov¹, Ruslan Kondaurov¹, Rakhima Sarieva¹<https://doi.org/10.23939/chcht17.03.601>

Abstract. The results of studies on the preparation and study of the properties of composite materials based on compositions of arylalicyclic copolyimide and alkylated montmorillonite (AMM) modified with polyethylene glycol to increase the affinity of a natural mineral to polymer matrix are presented in the work. It was found that an increase in the compatibility of composition's components is due to the addition to copolyimide solution of previously prepared mixture of alkylated montmorillonite in 5 % and 2 % polyethylene glycol solution in methylpyrrolidone. Based on IR-spectroscopy of the obtained mixtures and literature data, an assumption about specified composition mechanism was made. Compounds of copolyimide compositions with modified montmorillonite were determined. Found that the total content of alkylated montmorillonite and polyethylene glycol should not exceed 12.5 wt. % in the case of copolyimide – 1 wt. % and in case of copolyimide-2 – 4 wt. %. The optimal conditions for obtaining on their basis transparent composite films with a smooth surface by a mechanical mixing method are found. Their basic thermodestructive and mechanical properties were determined. It was shown that the materials have high thermodestructive and strength properties: the temperature of decomposition onset is 409–421°C, the tensile strength is in the range of 140–168 MPa. The best thermodestructive properties and tensile strength are possessed by films obtained from ternary mixtures of the initial composition 87.5 SPI1 + 7 PEG + 5.5 AMM and 97 SPI2 + 2 PEG + 1 AMM, while the elasticity of the material remained at an acceptable level.

Key words: arylalicyclic copolyimide, polyethylene glycol, alkylated montmorillonite, composition, mechanism, film, properties.

1. Introduction

Progress in the field of polymer materials is currently associated with the creation of composite materials,

since as a result of the combination of polymers with inorganic and organic compounds, new polymer compositions are formed with properties that differ from the original components. Their capabilities are wide due to the variety of polymers and fillers, the variability of the compositions of composites based on them. This contributes to a change in the basic characteristics of polymer basis in certain specified directions, for example, improving thermodestructive and mechanical properties of the matrix, obtaining biopolymers, conductors, elastomers, *etc.*^{1–7} A special place among the initial components for polymer composites is occupied by heat-resistant polymers, in particular polyimides, which are processed into composite materials. However, in regard with the growing operational requirements for them in modern conditions, more and more attention is paid to improving of obtaining methods and chemical content of polymer compositions, the development of ways of modifying base polymers with various additives, including those of a polymer nature. Well-studied aromatic polyimides are mainly used for these works.^{8–10} Composite materials based on polyimides acquire improved characteristics at a relatively low concentration of the modifying compound.^{10,11} At the same time, there are data on the use of polyimides with an alicyclic structure to obtain polymer compositions with a high level of technical characteristics.^{12,13}

Modification of the initial copolyimide with montmorillonite particles makes it possible to expand the field of application of composite materials based on it in such promising industries as micro- and nanoelectronics, electrical engineering, integrated optics, as well as in other optical technologies as products with unusual photosensitive, magnetic, heat-conducting properties, effective and selective catalytic systems.¹⁴

The aim of this work is to obtain new composite materials based on copolyimide from dianhydrides of tricyclodecene and diphenyloxide tetracarboxylic acids and diaminodiphenyl ether modified with particles of the alkylated natural mineral montmorillonite, which improves the thermal stability and strength of composite material as a whole.

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2. Experimental

N-methyl-2-pyrrolidone (MP), pyridine was purified according to the procedures.¹⁵

4,4'-diaminodiphenyl ether (DADPE) was purified by sublimation in vacuum at 210°C and 10⁻³ mm Hg. Art., $T_{melt} = 200\text{--}202^\circ\text{C}$.

Dianhydride tricyclo-(4,2,2,0,2,5)-dec-7-ene-3,4,9,10-tetracarboxylic (the adduct of benzene and maleic anhydride, AB) and 3,3',4,4'-diphenyloxide tetracarboxylic (DPHO) acids were purified by heating in vacuum at 10⁻³ mm Hg. Art. at temperatures of 200–230°C, $T_{melt} = 351^\circ\text{C}$ and $T_{melt} = 221^\circ\text{C}$, respectively.¹⁵

Copolyimides were synthesized by the one-stage copolycondensation of dianhydrides of tricyclodecene- and diphenyloxide tetracarboxylic acids with 4,4'-diaminodiphenyl ether at initial ratios of dianhydrides 90:10 mol. % (SPI1) and 85:15 mol. % (SPI2), respectively, in a solution of N-methyl-2-pyrrol (43 wt. %) in the presence of a pyridine catalyst (6 wt. %). The process was carried out with a gradual rise in temperature from 90°C to 140°C, keeping at each temperature, respectively, 0.5 and 3.5 hours.¹⁵

The original montmorillonite (MM) and the alkylated montmorillonite (AMM) were provided by Prof. G.W. Beal (Nanophase Research Center, Texas, USA).

Polyethylene glycol (PEG) from Aldrich (USA), a chemically pure grade with a molecular weight of 2000 was used without additional purification.

Compositions based on SPI1 and SPI2 (43 wt. % solution in MP) with AMM were obtained by the mechanical mixing method by introducing composite solutions of PEG + AMM into the copolyimide solution, obtained by the preliminary mixing of 5 % and 2 % PEG solution in methylpyrrolidone with different amounts of AMM, leading to formation of PEG composition mixtures: AMM = 1 : 1; 0.5; 0.3; 0.2 and 0.5 : 0.7; 0.5; 0.3; 0.1 wt. %. The resulting mixtures were stirred for 1 hour at 40°C.

Films based on copolyimides and their compositions with PEG + AMM were formed by pouring 18–20 % solutions of polymers and polymixtures onto glass surfaces. In order to remove the solvent, the films were preliminarily dried by heating in an oven at a temperature of 90°C for 0.5 h, then additional heat treatment was carried out in air with a stepwise rise in temperature from 90°C to 140°C and up to 275°C, keeping the samples at final temperatures for 1 and 0.3 hours, respectively.

IR spectra of composite solutions and solutions of PEG + AMM mixtures, copolyimide and composite films based on them were recorded on a Nicolet 5700 IR spectrometer manufactured by Thermo Electron Corporation.

The thermodestructive properties of the composite films were determined by thermogravimetry (TGA) and calorimetry (DSC) on MettlerToledo TGA/SDTA 851c and FP85 TA Cell instruments at a constant heating rate 4 and 8°C/min, respectively.

The mechanical properties of the films - tensile strength (σ_{break}) and relative elongation, for specimens 6-8x1.0 cm² in size, 0.1-0.05 cm thick were studied on a Com-Tem Testing Equipment (USA) tensile testing machine.

3. Results and Discussion

One of the main tasks in obtaining composite materials with the inclusion of a layered mineral, for example, montmorillonite, is its compatibility with the polymer matrix, which is possible when the surface of the mineral is modified with appropriate reagents. The authors¹⁶ show that the modification of nanoparticles of an inorganic filler (silicon, Zr₂O) with an organic silicon-containing compound (3-aminopropyl-, *m*-aminophenyl-3-methoxysilane, respectively) makes it possible to increase the affinity of nanoparticles to the polymer matrix. Previously, to improve compatibility in compositions based on alicyclic polyimide and alkylated montmorillonite by the reaction mixing, we used a filler in a modified 3-aminopropyl-3-methoxysilane form, which contributed to the preservation of clay particles in the reaction solution during polycondensation with the formation of polyimide.¹⁷

Our studies have also shown that as a result of polyimide modification with polyethylene glycol, a composite material with a higher thermal stability was obtained in comparison with the original polyimide. The observed effect may be due to the well-known property of polyethylene glycols to form intermolecular crosslinks, which leads to the appearance of a thermally more stable polymer structure.¹⁸

In addition, in preparation of polymer compositions for the effective combination of filler particles with a polymer medium, the adsorptive modification of the filler with the help of surfactants is used. By forming firmly fixed layers of oriented molecules due to adsorption on the surface of solid phase particles, surfactants make it possible to bring the nature of the filler closer to the polymer medium, improve the wetting of filler particles and their distribution in the polymer. Shown that the use of PEG, molecular weight 1500, is promising for improvement of structural and physicomachanical properties of composites.¹⁹

In the work, to obtain composites based on SPI1, SPI2, and AMM by mechanical mixing, we undertook a preliminary modification of alkylated montmorillonite with polyethylene glycol. This should increase the solubil-

ity of the filler and its affinity for the polymer component, since AMM, like the initial mineral montmorillonite, does not dissolve in organic solvents, including N-methyl-2-pyrrolidone used for synthesis, and does not exhibit the compatibility with the copolymers under study.

In this regard, the work was carried out to obtain double mixtures of various initial ratios of polyethylene glycol and alkylated montmorillonite: PEG : AMM = 1 : 1; 0.5; 0.3; 0.2 and 0.5 : 0.7; 0.5; 0.3; 0.1 wt. %. For this experiment, a calculated amount of AMM was added in a dry form to a 5 % or 2 % solution of PEG in N-methylpyrrolidone. For the mixture with components ratio PEG : AMM = 1 : 1; 0.5; 0.3; 0.2 wt. %, the specificity of dissolution of AMM in a PEG solution was revealed. As AMM content increases, the resulting mixture solutions change from an ideal state (with an AMM amount of 0.2 wt. % and 0.3 wt. %) to the formation of a colloid: at 0.5 wt. % AMM, the solution slightly opalescent, and with a mixture ratio of 1 : 1 wt. % the solution becomes white. For the ratios PEG : AMM = 0.5 : 0.7; 0.5; 0.3; 0.1 wt. % showed better solubility, possibly due to greater dilution of the reaction solution and, as a result, greater mobility of the mixture molecules.

The resulting mixtures were investigated by IR spectroscopy. IR spectroscopic studies revealed that the characteristic band of stretching vibrations of PEG, corresponding to C-O groups, in a solution of methylpyrrolidone is prescribed at 1685 cm^{-1} .¹⁸ When a small concentration of AMM (0.2 wt. %) is added to 1 wt. % PEG solution, the IR spectrum of the mixture shifts this band to the low frequency region of 1682 cm^{-1} (Fig. 1, spectrum 1). An increase in the concentration of AMM to 0.3 wt. %, the characteristic PEG band shifts to 1678.7 cm^{-1} (Fig. 1, spectrum 2). For the ratio PEG : AMM = 1 : 0.5 wt. %, this band broadens and shifts to 1693.2 cm^{-1} (Fig. 1, spectrum 3). When the ratio of the components in the solution is 1 : 1 wt. %, the characteristic PEG band is displaced, and its shape changes (a small shoulder appears at the peak) and is recorded in the region of $1693.2\text{--}1667.7\text{ cm}^{-1}$ (Fig. 1, spectrum 4). Also, in these spectra, with an increase in the mineral content, there is a noticeable change in the absorption bands in the region of $3100\text{--}3650\text{ cm}^{-1}$, in which OH-groups are prescribed. Apparently, as AMM is added to the binary composition, a complex is formed between the oxyethylene oxygen of PEG and the hydrogen of the hydroxyl group of crystalline hydrate water of alkylated montmorillonite (general formula $\{\text{Al}_2\text{O}_3 \cdot (\text{H}_2\text{O})_x \cdot \text{Si}(\text{OCH}_3)_4\}$,¹⁷) as a result of this there is a fixation of a part of the polyethylene glycol on the surface of the filler and partial penetration of PEG into the interlayer space of the mineral.

The fact that both the adsorption of PEG on the surface and its penetration into the interlayer space of montmorillonite occur is evidenced by the fact that the

characteristic PEG band, as AMM is added to its solution, first shifts to the low-frequency region (Fig. 1, spectrum 2), then - to the high-frequency (Fig. 1, spectrum 3), and when the ratio polymer : filler is 1 : 1 its appearance changes (Fig. 1, spectrum 4). In contrast to the interaction in the PEG – alicyclic polyimide composition with the formation of H-bonds, where as the PEG concentration increases, the characteristic bands in the spectra shift in one direction. Analysis of the spectra of composite mixtures with lower concentrations of AMM (0.7-0.1 wt. %) and PEG (0.5 wt. %) indicates their analogy with those described.

Thus, based on the data of the work²⁰ and our studies, we assume that the PEG-modified alkylated montmorillonite is transferred to a dissolved state. This is due to the fact that PEG, as a nonionic surfactant, is adsorbed through polar centers on the inner and outer surfaces of the layered filler, forming organophilic layers, thereby facilitating the dissolution of the alkylated montmorillonite and, ultimately, its compatibility with the copolyimide matrix.

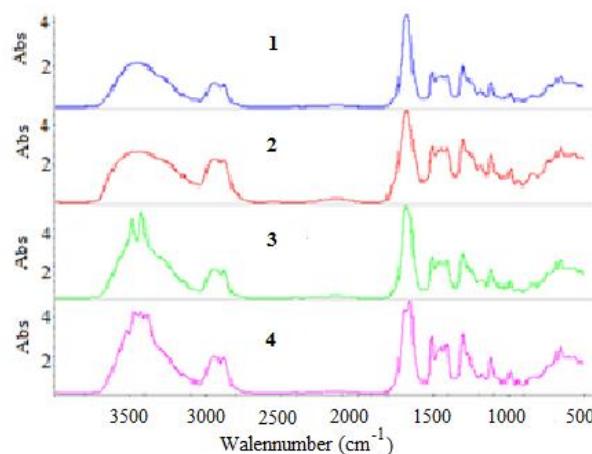


Fig. 1. IR spectra of compositions based on PEG : AMM at various ratios of components: 1 : 1 (4); 1 : 0.5 (3); 1 : 0.3 (2); 1 : 0.2 (1) wt. % in the solution (on KBr glasses)

At the next stage, studies were carried out to select the optimal conditions for obtaining compositions based on SPI1 and SPI2 and alkylated montmorillonite by the method of mechanical mixing. Found that for these mixtures of various compositions PEG + AMM are added to a 43 % solution in methylpyrrolidone and the resulting composite mixtures are stirred for 1 h at 40°C to achieve a homogeneous solution. Higher mixing temperatures are undesirable. Its increase can lead to gelation in the composite solution as a result of intermolecular reactions between the copolymer and the final hydroxyl groups of PEG,¹⁸ which do not participate in the process of adsorption on the filler surface.

It was found that in the case of SPI1 the ratio of PEG : AMM per 100 wt. % of ternary compositions is 7 : 7; 3.5; 2; 1.4 and 3.5 : 4.9; 2.8; 0.7 wt. %. Composite films were formed from the mixtures obtained (18–20 % solutions in MP) by casting onto glass substrates. The composite films were dried in an oven in air at a temperature of 90°C for 0.5 h, then with a stepwise rise in temperature from 90 to 140 and 275°C, holding at each temperature for 1 and 0.3 h, respectively. The resulting composite films have a transparent smooth surface. However, a film of a ternary composition containing a modified filler AMM : PEG = 7 : 7 wt. % acquires a whitish hue and brittleness, but AMM in the form of individual particles on the surface of the composite film is not observed. This, apparently, can be explained by the fact that PEG, as noted above, partially adsorbed with the help of active sites on the surface of alkylated montmorillonite prevents coagulation of AMM on the surface of the composite film.

It was found that the heat treatment of composite films based on SPI1 with a low concentration of the introduced components (3.5 wt. % PEG + 4.9–0.7 wt. % AMM) at $T = 275^\circ\text{C}$ does not lead to their delamination and brittleness. Possibly, in this case, a good compatibility of the modified AMM with the polymer is observed, and the filler particles are uniformly distributed in the polymer matrix, without hindering the more complete cyclization of the remaining amido acid groups in SPI1 (Fig. 2). From the analysis of the spectra of the indicated composite films, it follows that the stretching vibrations of the bands corresponding to the imide cycle in the copolymer were revealed at 1708.7 cm^{-1} . It is well known that the imide cycle is prescribed in the region of $1720\text{--}1780\text{ cm}^{-1}$ by a doublet. Apparently, in the studied ternary compositions, this characteristic band shifted and doublet bands were superimposed due to the presence of additives. In this case, another band, which is responsible for the vibrations of the imide cycle in the region of 1380 cm^{-1} , is clearly defined and its intensity increases upon heat treatment of the films (Fig. 2, spectra 1–4). This confirms the further occurrence of cyclization of the remaining amido acid groups.

Similar studies with SPI1 were carried out to obtain composite materials based on SPI2 and PEG + AMM. The preparation of solutions of the compositions SPI2 + PEG + AMM and the formation of a film on their basis were carried out under the same conditions (composition, duration, temperature) as indicated above for SPI1. All films, regardless of their composition, have delaminated (they acquire a whitish tint) and are fragile. It is assumed that an excess of the AMM + PEG mixture appears on their surface upon heat treatment of the composite films. Apparently, in the initial composition, from which the films are formed, the amount of residual amide acid groups in SPI2 (AB : DPO = 85 : 15 wt. %) is not suffi-

cient for complexation with the modified filler. The lower content of amide acid groups in SPI2 in comparison with SPI1 is associated with diphenyloxide dianhydride, which is more reactive than AB, which, at this ratio, is greater than in SPI1. It was found by TGA (DTA) that the content of amide acid groups in SPI2 corresponds to $\sim 8.9\%$ of the sample weight, in contrast to SPI1, where their amount reaches $\sim 13\%$. Presumably, less than 8 % of AMM + PEG additives should be added to SPI2.

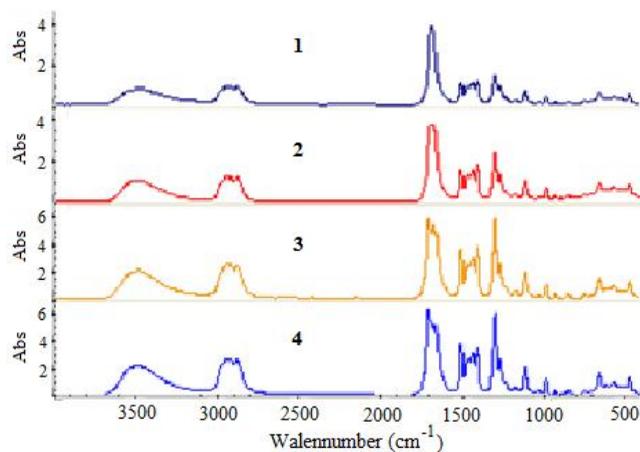


Fig. 2. IR-spectra of composite films based on ternary mixtures, wt. %: 91.6SPI1 + 3.5PEG + 4.9AMM (4); 93SPI1 + 3.5PEG + 3.5AMM (3); 93.7SPI1 + 3.5PEG + 2.8AMM (2); 95.8SPI1 + 3.5PEG + 0.7AMM (1) during heat treatment of films at 275°C

In addition, it should be taken into account that polyimides based on diphenyloxide tetracarboxylic acid have a more regular structure, *i.e.*, they contain regions with a crystalline structure,²¹ in contrast to amorphous alicyclic polyimide. Apparently, this can also reduce the compatibility of the components in a given mixture. In this regard, a search was carried out for the optimal content of AMM + PEG for compositions based on SPI2. It was established that for the preparation of an optimal ternary composition, a solution of a filler modified with polyethylene glycol should be preliminarily prepared by adding a calculated amount of AMM in the solid state to 2 % solution of PEG in methylpyrrolidone so that, when converted to 100 wt. % of the composition, the ratio of PEG: AMM is 2–3 : 0.2–1 wt. %. Moreover, their total content in the ternary mixture was no more than 4 %, *i.e.*, less than expected by the content of residual amido acid groups. From composite solutions based on 96–97.8 wt. % SPI2 + 2–3 wt. % PEG + 0.2–1 wt. % AMM, transparent, smooth films without defects are formed.

Based on the spectral analysis of the obtained composite mixtures and films based on SPI2 and PEG + AMM, it was confirmed (Fig. 3) that the formation of the composite material occurs similarly to SPI1 (Fig. 2). In

this case, the modified montmorillonite particles also do not interfere with the cyclization of amido acid groups, having the necessary adsorbed amount of PEG on their external and internal (interlayer space) surfaces to maintain solubility.

As noted above, the modification of the polymers with various additives is carried out in order to improve the main characteristics of the polymer matrix, in our case, its heat resistance and strength. Therefore, the main thermdestructive and mechanical properties of the obtained composite films based on SPI1 (SPI2) + PEG + AMM of optimal compositions were studied.

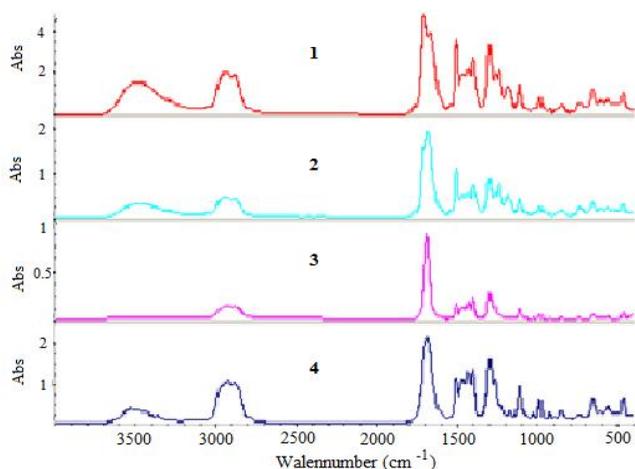


Fig. 3. IR-spectra of films heat-treated at 275°C and compositions in a MP solution (in KBr glasses) of various compositions, wt. %: 97.5SPI2 + 2PEG + 0.5AMM (2 and 3); 96SPI2 + 3PEG + 1AMM (1 and 4), respectively

Fig. 4 shows the thermal analysis data for composite films based on SPI1, PEG, and AMM. The diagrams of the change in the mass of the studied films under the influence of temperature, as is well known, reflect the processes taking place in them. The jumps in the TGA curve are due to changes in the internal energy of chemical bonds of the components in the composite sample, which are transformed as a result of these processes.²² In alicyclic polyimides, first of all, thermal destruction of the tricyclodecene imide fragment occurs (with the decomposition onset temperature $T = 380^{\circ}\text{C}$, in air) with the formation of maleimide and benzene or its derivatives. At temperatures above 460°C , deeper destructive processes occur, accompanied by the release of CO , CO_2 , H_2O and H_2 .

As follows from Fig. 4, in the initial sections of the thermogravimetric analysis diagrams for all compositions when exposed to temperatures up to 200°C , the change in mass is associated with the release of water residues from the sample. The second section on the TGA curve in the range from 200 to $\sim 390^{\circ}\text{C}$ indicates the release of solvent

residues from the film and imidization of undercyclized amido acid units in the alicyclic copolyimide. Further exposure of the sample to temperature leads to the decomposition of imide cycles ($T = 409\text{--}421^{\circ}\text{C}$). At temperatures above 550°C (with a sample weight loss of over 50%), deeper destructive processes occur. For thermogravimetric analysis of samples based on SPI2 + PEG + AMM of various compositions, a similar picture is characteristic.

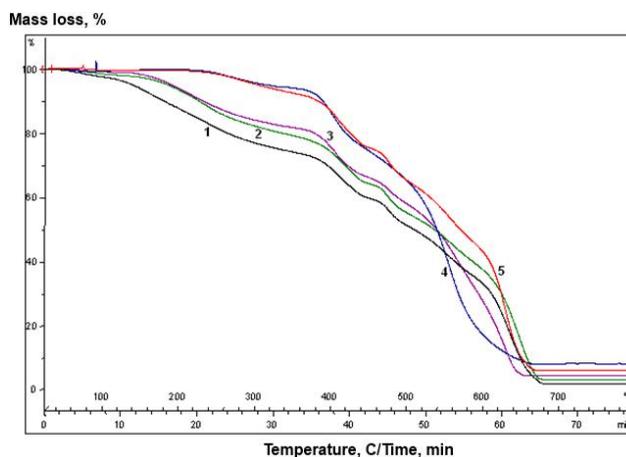


Fig. 4. Diagrams of thermogravimetric analysis of composite films based on mixtures of various compositions, wt. %: 91.6SPI1 + 7PEG + 1.4AMM (1); 91SPI1 + 7PEG + 2AMM (2); 89.5SPI1 + 7PEG + 3.5AMM (3); SPI1 (4); 87.5SPI1 + 7PEG + 5.5AMM (5)

When carrying out studies on the calorimetric analysis of composite films, it was found that the diagrams of the change in heat capacity versus the temperature of composite films at ratios of 87.5 wt. % SPI1 + 7 wt. % PEG + 5.5 wt. % AMM and SPI2 + 2 (3) PEG + 1 (0.65) AMM have 2 jumps – the first jump with a smooth inflection in the temperature range from 150 to 400°C and the second with a sharp increase in heat capacity at 500°C . The gentle character of the first inflection in the heat capacity diagram with a wider temperature range indicates the integrity of the composite film and the compatibility of its components, caused by partial crosslinks during heat treatment of the residual amide acid groups of the SPI with the terminal hydroxyl groups of PEG. The second jump in the heat capacity at 500°C corresponds to the mineral particles in the composite material, which for these concentrations is associated with the decomposition of the organic part of the filler introduced into the polymer matrix. This explains the absence of the glass transition temperature at the maximum content of PEG and AMM for compositions based on SPI1 and SPI2 (Table).

At a lower AMM content in the investigated composite films, the DSC diagrams have only one jump in the

heat capacity in the region of 500°C, and the main part of the diagrams has a smooth change in the heat capacity with the increasing temperature, which corresponds to a single glass transition temperature (t_g) and indicates the thermodynamic compatibility of the components in the film.

The results of the carried studies for determination of the main thermodestructive and physicomechanical properties of composite films based on mixtures SPI1 (SPI2) + PEG + AMM are presented in Table. The found values of thermodestructive characteristics and strength of composite films, as follows from Table, exceed the values corresponding to the initial copolymers. It was shown that films obtained from mixtures of the initial composition 87.5SPI1 + 7PEG + 5.5AMM and 97SPI2 + 2PEG + 1AMM have the best thermodestructive properties and

tensile strength (σ_{break}). Films with a lower AMM content (1.4 wt. % in the case of SPI1, 0.2 and 0.5 wt. % in case of SPI2) have the highest elasticity (elongation l).

Based on the obtained results, it can be said that with an increase in the concentration of AMM to 5.5 wt. % in the composite mixture SPI1 + 7 wt. % PEG + AMM, the heat resistance of the material based on it increases in comparison with films from the original copolymers. This, apparently, can be explained not only by cross-linking along the amide acid groups of copolyimides with terminal hydroxyl groups of PEG, which occurs under the influence of temperature on the sample, but also by an increase in the concentration of montmorillonite particles in the composite mixture, which contribute to an increase in the thermal stability of the film, as well as an improvement in strength.^{14,16}

Table. Thermal and physicomechanical properties of composite films based on SPI1 (SPI2), AMM and PEG

Composition based film, ratio components, wt. %	t_g , °C	$t_{start\ of\ decomposition}$, °C (on air)	σ_{break} , MPa	l, %
91.6SPI1 + 7PEG + 1.4AMM / 96.8SPI2 + 3PEG + 0.2AMM	393/385	409/406	145/140	26/27
91SPI1 + 7PEG + 2AMM / 96.5SPI2 + 3PEG + 0.5AMM	392/387	412/408	158/143	24/25
89.5SPI1 + 7PEG + 3.5AMM / 96.35SPI2 + 3PEG + 0.65AMM	390/-	416/410	164/146	22/24
87.5SPI1 + 7PEG + 5.5AMM / 97SPI2 + 2PEG + 1AMM	-/-	421/414	168/150	21/23
SPI1 / SPI2	388/383	405/406	137/138	20/21

4. Conclusions

An accessible and technological method was developed – mechanical mixing, obtaining composite films with a good compatibility of the mineral modified with polyethylene glycol with a polymer matrix with a maximum content of alkylated montmorillonite particles up to 5.5 wt. % (in the case of arylalicyclic copolyimide SPI1) and 1 wt. % (SPI2). It is shown that composite films with improved thermodestructive properties by 2-16°C and 2-31 MPa strength properties compared to the initial copolyimides were obtained from ternary mixtures SPI1 (SPI2) + PEG + AMM. Films obtained from ternary mixtures of the initial composition 87.5SPI1 + 7PEG + 5.5AMM and 97SPI2 + 2PEG + 1AMM have the best thermodestructive properties and tensile strength, while the elasticity of the material remains at an acceptable level.

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КОМПОЗИЦІЇ АРИЛАЛІЦІКЛІЧНОГО КОПОЛІМІДУ З АЛКІЛЬОВАНИМ МОНТМОРИЛОНІТОМ

Анотація. У роботі наведено результати досліджень з отримання та вивчення властивостей композиційних матеріалів на основі композицій арилаліциклічного кополіміду й алкільованого монтморилоніту (АММ), модифікованого поліетиленгліколем, для підвищення спорідненості природного мінералу до полімерної матриці. Встановлено, що підвищення сумісності компонентів композиції відбувається завдяки додаванню до розчину кополіміду попередньо приготованої суміші алкільованого монтморилоніту в 5% та 2%-ному розчині поліетиленгліколю в метилпіролідоні. На основі ІЧ-спектроскопії отриманих сумішей і літературних даних зроблено припущення щодо певного механізму формування композиції. Визначено сполуки кополімідних композицій з модифікованим монтморилонітом. Встановлено, що загальний вміст алкільованого монтморилоніту та поліетиленгліколю не повинен перевищувати 12,5 мас. % у разі кополіміду – 1 мас. %, а у випадку кополіміду-2 – 4 мас. %. Знайдено оптимальні умови отримання на їхній основі прозорих композитних плівок з гладкою поверхнею методом механічного змішування. Визначено їхні основні термодеструктивні та механічні властивості. Показано, що матеріали мають високі термодеструктивні та міцнісні властивості: температура початку розкладу становить 409-421°C, а міцність на розрив лежить у межах 140-168 МПа. Найкращі термодеструктивні властивості та міцність на розрив мають плівки, отримані з потрійних сумішей вихідного складу 87,5 SPII + 7 PEG + 5,5 АММ та 97 SPII + 2 PEG + 1 АММ, при цьому еластичність матеріалу залишилася на прийнятному рівні.

Ключові слова: арилаліциклічний кополімід, поліетиленгліколь, алкільований монтморилоніт, композиція, механізм, плівка, властивості.