



**INFLUENCE OF MODIFIERS ON THE PHYSICAL AND MECHANICAL PROPERTIES OF  
COMPOSITE MATERIALS BASED ON POLYAMIDE-6**

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**Annotation**

The article shows the improvement of the physical and mechanical properties of composite materials based on polyamides as a result of the addition of dispersed fillers.

**Introduction**

At present, the demand for polymer composite materials is growing annually in the world due to high rates of population growth and industrial production. At the same time, high demands are placed on polymer composite materials in the automotive industry and construction. However, the low resistance to combustion, inherent in polymers of composite materials based on polyethylene, significantly limits the scope of their application. [1;6]

On a global scale, it is necessary to substantiate the following problems of scientific solutions for the production of new composite materials based on polymers: the choice of various organic modifiers for micro- and nanosized mineral layered silicates that are added to polymers; selection of finishing agents for polymer modification with the use of dispersed and fibrous particles; improving the physico-mechanical properties of the resulting polymer composite materials through the use of adhesion promoters of the surface of mineral dispersed particles from the surface of polymers; create materials with enhanced performance characteristics and increased resistance to combustion. [1;2]



### Experimental Part

In this work, basalt from the Asmansay deposit in the Jizzakh region of the Republic of Uzbekistan was used as a filler, which has the composition shown in Table 1 below [3].

Table 1. The chemical composition of basalt from the Asmansay deposit

Component	Content, % wt.
	basalt
Silicon oxide $\text{SiO}_2$	47,0
Magnesium oxide, $\text{MgO}$	16,3
Aluminum oxide $\text{Al}_2\text{O}_3$	11,2
Iron oxide $\text{Fe}_2\text{O}_3$	10,3
Calcium oxide, $\text{CaO}$	8,94
Sodium oxide, $\text{Na}_2\text{O}$	1,53
Potassium oxide, $\text{K}_2\text{O}$	0,33
Iron oxide $\text{FeO}$	0,16
Titanium oxide $\text{TiO}_2$	0,57
Manganese oxide $\text{MnO}$	0,19
Sulfur oxide, $\text{SO}_3$	less 0,05
Other rock impurities	2,04

And also, vermiculite, a mineral from the group of hydromicas with a layered structure, was used as a nanofiller in the work.

In our republic, vermiculite has not yet found wide application. This is explained by the fact that until recently the raw material base has not been sufficiently studied. Surveys of recent years have shown that Uzbekistan has large reserves of this mineral, and they are located in Tebinbulak, near Nukus, 16 km to the north-west of the populated village of Karatau. The total amount of vermiculite reserves of the Tebinbulak deposit is 1332620 tons.

Table 2 The chemical composition of vermiculite

Component	Content, % wt.
Silicon oxide $\text{SiO}_2$	38-49
Magnesium oxide, $\text{MgO}$	20-23,5
Aluminum oxide $\text{Al}_2\text{O}_3$	12-17,5
Iron oxide $\text{Fe}_2\text{O}_3$	5,4-9,3
Calcium oxide, $\text{CaO}$	0,7-1,5
Sodium oxide, $\text{Na}_2\text{O}$	0,8
Potassium oxide, $\text{K}_2\text{O}$	5,2-7,9
Iron oxide $\text{FeO}$	1,2
Titanium oxide $\text{TiO}_2$	1,5
Manganese oxide $\text{MnO}$	0,1-0,3
Sulfur oxide, $\text{SO}_3$	0,5
Other rock impurities	0,2

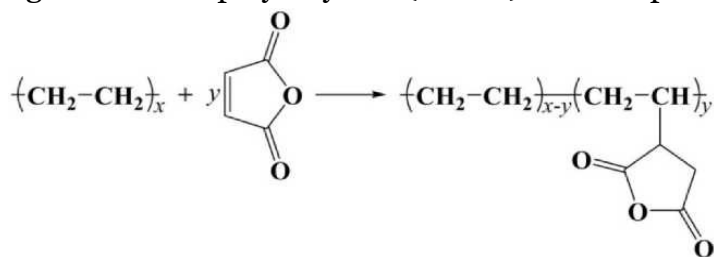


The development of the first vermiculite deposit in Uzbekistan opens up new prospects for the development of the industry and the possibility of their use in various industries [4].

As a nanofiller, we also used wollastonite, a mineral from the class of silicates, natural calcium silicate with chemical

formula  $\text{Ca}_3(\text{Si}_3\text{O}_9)$ . The color of wollastonite is white with a grayish or brownish tinge. The mineral is distinguished by its chemical purity, contains a small amount of impurities in the form of oxides of manganese, iron and titanium. The composition of wollastonite includes calcium oxide (CaO) - 48.3%, silicon dioxide ( $\text{SiO}_2$ ) - 51.7%. [5]

In some cases, tetraethylammonium stearate (TEAS) was used to increase adhesion between the filler and the polymer matrix. The modifier was obtained by shaking an aqueous solution containing tetraethylammonium bromide and sodium stearate in a 1:1 molar ratio. The resulting dispersed solution was filtered with a water pump, washed with distilled water, and dried at  $40^\circ\text{C}$  for 2 hours in an oven. [6] We used low molecular weight maleated polyethylene (PEMA) as a compatibilizer.



1. Scheme. The formula of the unit of maleized polyethylene.

Low molecular weight maleated polyethylene is a viscous liquid (1.9 Pa.s at 323K) with an acid value of 65 mg (potassium hydroxide)/g.

The residual content of maleic anhydride in low molecular weight maleated polyethylene is about 0.3 wt.%. [7;8]

## Results and its Discussion

The article presents the results of the analysis of the structure and some properties of the modifier, and also discusses the structural and rheological characteristics of polyamide-6 modified with low molecular weight maleated polyethylene (PEMA), which are compared with the characteristics of modified tetraethylammonium stearate (TEAS).

The melt flow index determines the processing conditions for composite materials, in particular, the melt temperature and formation pressure. Their study allows you to choose the appropriate method and mode of processing. As the research results show, the values of the melt flow index with an increase in the content of fillers up to 30 wt. % changes insignificantly, and at a concentration of 40 wt. % the melt flow rate of the composites is increased.

At the same time, the MFR of the compounds does not depend on the type of filler. Therefore, the optimal degree of filling of PA-6 with fillers should be considered 30 wt. %.(tab.3.)



As can be seen from the data obtained in Table 4, the introduction of maleated polyamide-6 and TEAS has a greater effect on reducing the MFI of the compositions. At the same time, it was found that an increase in the degree of exfoliation of the layered aluminosilicate affects the decrease in the MFR of the compositions.

Table 3 Change in the melt flow index (MFR) of compositions based on PA-6 fillers at a temperature of 2200C depending on its composition

The composition of the composition	Particle size, $\mu\text{m}$	The amount of nanoadditives in the compositions (wt.%)			
		100	80/20	70/30	60/40
PA-6		0,32	-	-	-
PA-6 / Vermiculite	1	-	0,33	0,4	0,6
	3		0,5	0,7	0,8
	5		0,55	0,8	0,9
PA-6 / Basalt	1	-	0,4	0,5	0,8
	3		0,5	0,7	0,8
	5		0,6	0,75	0,9
PA-6 / wollastonite	1	-	0,33	0,4	0,5
	3		0,5	0,6	0,7
	5		0,6	0,7	0,8

Table 4 Change in the melt flow rate of compositions based on PA-6 at a temperature of 2200C depending on the concentration of the modifier

The composition of the composition	The amount of the modifier in the compositions per wt.h of the filler (wt.%)				
	TEAS				
	0	0,5	1,0	1,5	2,0
PA-6 /Vermiculite	0,4	0,35	0,3	0,3	0,3
PA-6 /PEMA/ Vermiculite	0,35	0,3	0,2	0,2	0,2
PA-6 / Basalt	0,5	0,4	0,3	0,3	0,3
PA-6 / PEMA /Basalt	0,4	0,3	0,2	0,2	0,2
PA-6 / wollastonite	0,4	0,35	0,3	0,3	0,3
PA-6/PEMA / wollastonite	0,35	0,3	0,2	0,2	0,2

Table 5 shows the comparative physical and mechanical properties of composites obtained from polyamide-6 modified maleated polyethylene and tetraethylammonium sterate. Comparative data are presented for all studied compositions of modified PA-6 with the introduction of fillers.

As can be seen from the table, compositions with PA-6/PEMA/TEAS/Basalt have greater impact strength and tensile strength compared to compositions containing PA-6/PEMA/TEAS/Vermiculite and PA-6/PEMA/TEAS/Wollastonite



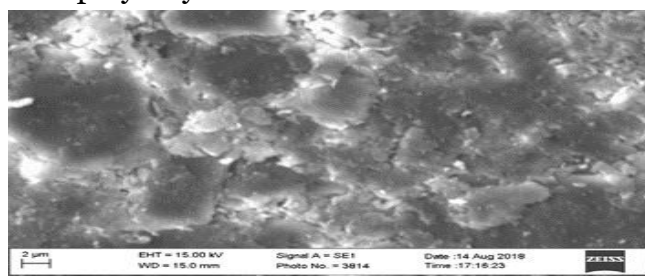
Table 5 Comparative data of PA-6 compositions with fillers

The composition of the composition	Impact strength, kJ/m <sup>2</sup>	bending $\sigma$ , MPa	fracture $\sigma$ , MPa	Elongation, %	Shrinkage, %
	GOST 4647-80	GOST 4648-80	GOST 14236-81	GOST 14236-81	GOST 8599-21
PA-6	100	90	80	150	3
PA-6/Vermiculite	96	85	73	74	2,7
PA-6/TЭAC/Vermiculite	120	96	86	70	2,8
PA-6/ PEMA/TEAS /Vermiculite	128	108	98	55	2,2
PA-6/ Basalt	97	87	78	78	2,6
PA-6/ TEAS / Basalt	122	98	84	64	2,8
PA-6/ PEMA/TEAS / Basalt	131	110	96	56	2,3
PA-6/ Wollastonite	96	86	74	76	2,8
PA-6/ TEAS / Wollastonite	121	97	88	63	2,0
PA-6/PEMA/TEAS / Wollastonite	130	109	98	40	2,2

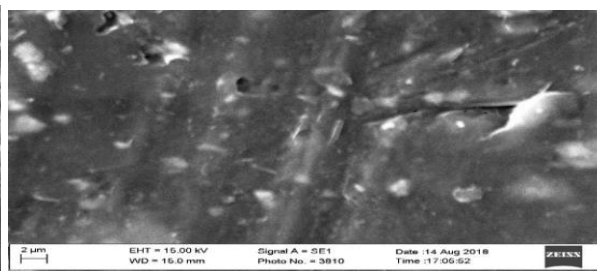
When adding the TEAS modifier, it was found that its small concentration of 1.0 wt. % increases the impact strength of PA-6 with fillers compared to composites without modifier. When maleated polyethylene with TEAS modifier is added to PA-6, impact strength increases, which is especially noticeable when the content of TEAS modifier is 1.0 wt. % and 30 wt. % Vermiculite and basalt. In this case, the impact strength has a maximum value and increases from 100 for the original PA-6, to 120 kJ/m<sup>2</sup> and 128 kJ/m<sup>2</sup> for the composition PA-6/TEAS/Vermiculite and PA-6/PEMA/TEAS/Vermiculite, as well as up to 122 kJ/m<sup>2</sup> and 131 kJ/m<sup>2</sup> for the composition PA-6/TEAS/Basalt and PA-6/PEMA/TEAS/Basalt

Modifiers play a significant role in improving the physical and mechanical properties of composites based on them. Possibly, this occurs due to their interfacial interaction with the polymer matrix.

On fig. Figure 1 shows a snapshot of the nanocomposite, which shows a fairly uniform distribution of fillers in the polyethylene matrix.



A



B



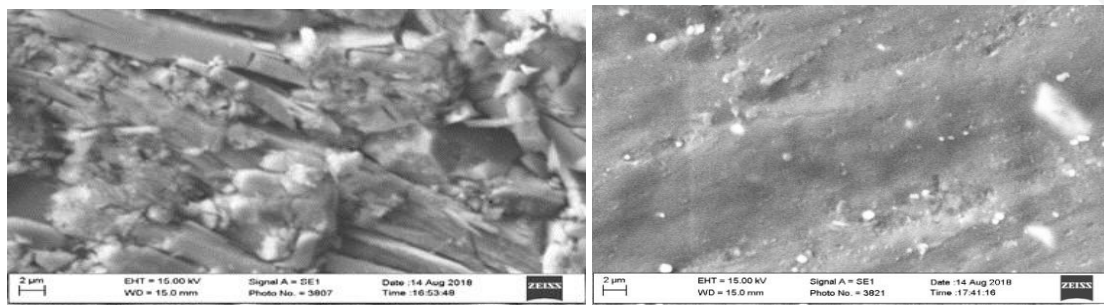


Figure 1. SEM image of dispersed Vermiculite (a), image of PA6/PEMA/TEAS/Vermiculite composite (b), dispersed basalt (c), image of PA-6/PEMA/TEAS/Basalt composite (d)

## Conclusions

1. The possibility of creating composite materials with a complex of improved technological and operational characteristics based on PA-6 with the introduction of nanoadditives of various shapes and concentrations is shown.
2. It has been proven that the use of low molecular weight maleated polyethylene improves the compatibility and distribution of nanoadditives in PA-6, which leads to an increase in the performance of composites.

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