Morphology and physicomechanical properties of antifriction polymer nanocomposite

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Introduction

The formation of the nanostructured state of technological polymer coatings is an effective way to achieve a high level of their physical, mechanical and antifriction properties. To obtain coatings with improved adhesion and cohesion properties, the nanodisperse organosilicon modifier synthesized *in situ* by the sol-gel method was introduced into a matrix based on anhydride cured epoxy resin. Molybdenum disulfide was added to improve the mechanical and antifriction properties.

Methods

The study of the structure and elemental composition of the samples was carried out on an EVO 50XVP scanning electron microscope (Carl Zeiss, Germany), the resolution of which when using a tungsten cathode is 3 nm [1].

Composites were studied by thermomechanical analysis (TMA) [2] on a TMA Q400EM analyzer (TA Instruments, USA). The TMA curves were obtained in the mode of penetration of the indenter into the composite sample, which is identical to its deformation. Samples were cut from composite plates in the form of squares with a side size of 6 mm; the thickness of the samples was 0.3–0.4 mm. The samples were heated at a constant rate of 5 °C/min. The TMA curves were recorded in the temperature range 25–160 °C.

The viscoelastic properties of the composites were determined by dynamic mechanical analysis (DMA) [3] using a Q800 dynamic analyzer (TA Instruments, USA) with a heating rate of 3 °C/min in the temperature range 20–200 °C. The viscoelastic characteristics – the tangent of the angle of mechanical losses tan δ and the dynamic modulus of elasticity *E′* were measured in the tensile strain mode at a frequency of 10 Hz.

The adhesive tensile strength ($\sigma_{tensile}$) was determined in accordance with [4]. The adhesive shear strength (τ_{shear}) was determined in accordance with [5].

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Results

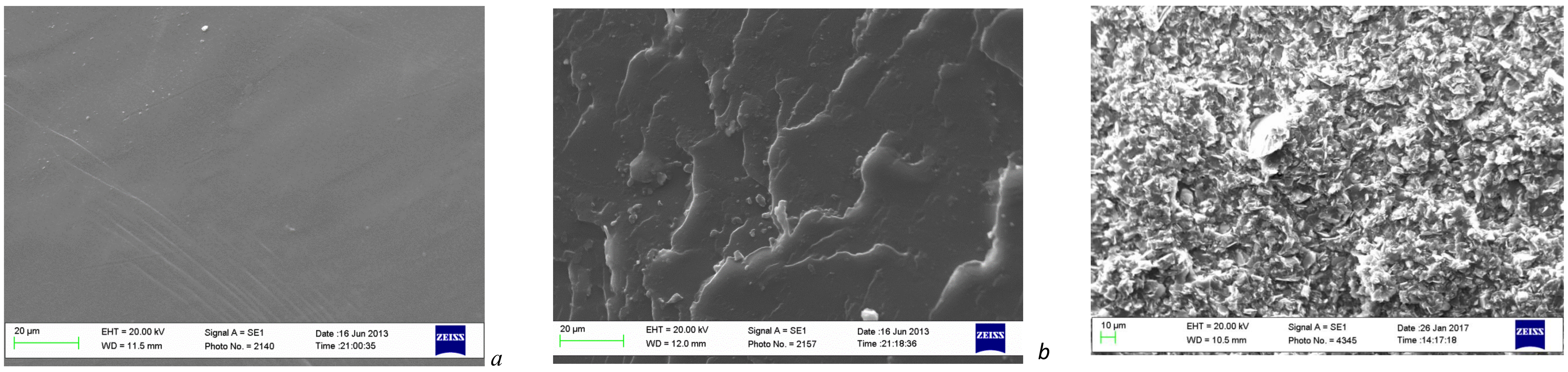

Fig. 1. Transformation of the structure of an epoxy polymer (*a*), with the introduction of polysiloxane particles into it (*b*), followed by the addition of molybdenum disulfide (*c*)

The data obtained by scanning electron microscopy indicate a homogeneous single-phase structure of the initial polymer (Fig. 1 *a*). The introduction of the modifier causes the formation of regions with a pronounced layered morphology (Fig. 1 *b*), and the addition of MoS_2 leads to a decrease in the grain size of the matrix and the formation of a heterophase layered structure with a uniform distribution of phases (Fig. 1 *c*). This significantly improves the mechanical properties of the nanocomposite.

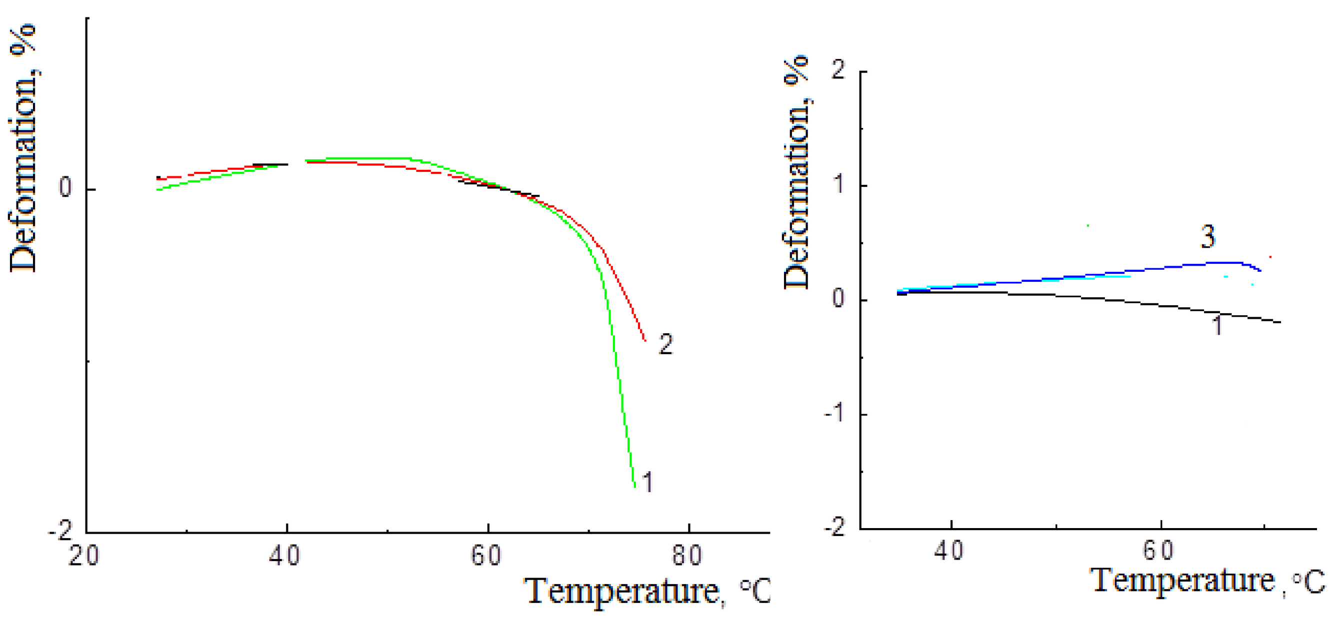

Fig. 2. TMA curves below the glass transition temperature of an epoxy polymer (1), with the introduction of polysiloxane particles into it (2), followed by the addition of molybdenum disulfide (3)

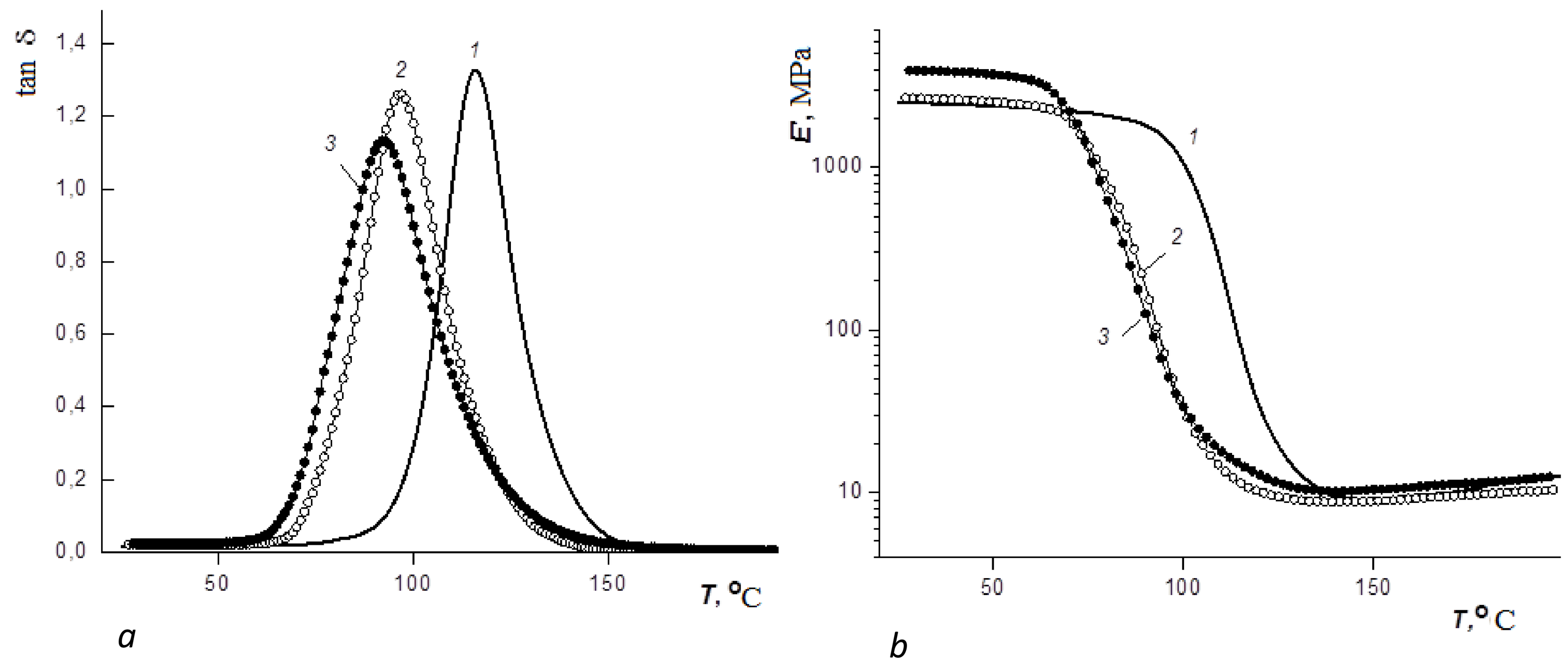

Fig. 3. Temperature dependences of the tangent of the angle of mechanical losses tan δ (*a*) and the dynamic modulus of elasticity E′ (*b*) of an epoxy polymer (1), with the introduction of polysiloxane particles into it (2), followed by the addition of molybdenum disulfide (3)

Table. Viscoelastic characteristics of epoxy composites

N	T_g, °C	tan δ_{max}	$E'_{T=25°C}$, MPa	$E'_{T=150°C}$, MPa
1	115	1.33	2500	9.1
2	96	1.24	2670	8.8
3	92	1.13	3960	10.4

The results of TMA (Fig. 2) and DMA methods (Fig. 3) indicate that the incorporation of 1 wt. % of modifier leads to plasticization of the composite, which is expressed in a decrease in the glass transition temperature caused by a decrease in the effective crosslink density of the epoxy-anhydride matrix (Table). At the same time, this results in the increase of: tensile strength of the adhesive joints of D16 aluminum alloy by the composite – by 35 %, stress at break – by 14 %, Young's modulus – by 17 %.

When MoS_2 is added to the specified composition, the value of the highly elastic deformation of the composite decreases by 46 %, the dynamic modulus of elasticity increases by 48 %, and the mechanical loss tangent decreases by 15 %.

Conclusion

The developed antifriction nanocomposite is a promising coating for friction pairs.

References

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