
**POLYMERS
AND LIQUID CRYSTALS**

Preparation and Investigation of the Composite Based on Superhigh-Molecular Poly(ethylene) and WO_3

G. N. Churilov^{a*}, N. G. Vnukova^a, G. E. Selyutin^b, and I. V. Osipova^a

^a *Kirensky Institute of Physics, Siberian Branch, Russian Academy of Sciences,
Akademgorodok 50, build. 38, Krasnoyarsk, 660036 Russia*

^{*}*e-mail: churilov@iph.krasn.ru*

^b *Institute of Chemistry and Chemical Technology, Siberian Branch, Russian Academy of Sciences, ul. Karla Marksa 42,
Krasnoyarsk, 660049 Russia*

Received July 8, 2008

Abstract—A composite based on superhigh-molecular poly(ethylene) and tungsten trioxide nanoparticles has been synthesized using the activation method. Tungsten nanoparticles have been prepared using the plasma-chemical method and then oxidized in air. The particle size is 48 ± 7 nm. It has been established that the addition of tungsten nanoparticles to superhigh-molecular poly(ethylene) brings about changes in the arrangement of hydrocarbon chains in the structure, which leads to an improvement of the strength characteristics of the products.

PACS numbers: 81.05.Lg, 82.35.Np

DOI: 10.1134/S1063783409040398

1. INTRODUCTION

An increase in the strength, plasticity, impact toughness, and other physicochemical properties of materials is an important problem of modern materials science. Materials satisfying these requirements are in large demand for new fields of mechanical, power, and chemical engineering industry [1]. Moreover, a demand has arisen for the replacement of steel and nonferrous metal products by polymers because metal products are subjected to chemical corrosion and possess a relatively high friction coefficient.

One of advanced polymers satisfying these requirements is superhigh-molecular poly(ethylene) (SHMPE), because this material possesses not only a low friction coefficient but also a high resistance to corrosive media [2].

It is expected that the introduction of modifiers (metal powders and their oxides in the form of nano-products) will increase the wear resistance and thermal stability of the material and, in some cases, can lead even to a decrease in the dielectric loss. The use of a modifier in the form of nanoparticles will make it possible to achieve a uniformity of its distribution in the polymer and to accomplish cross-linking of the polymer molecules owing to the active surface of nanoparticles.

2. SPECIMEN PREPARATION AND EXPERIMENTAL TECHNIQUE

The composite was prepared using a tungsten oxide powder synthesized by a plasma-chemical method in an apparatus described in our previous paper [3]. Sputtering was performed by a dc arc discharge at a high frequency (44 kHz) in an in-phase transverse magnetic field. The discharge was ignited in a water-cooled chamber between two electrodes. The inductor electrode was fabricated in the form of a coil of the copper water-cooled pipe. A tungsten rod was used as the second electrode. Owing to the specially developed supply

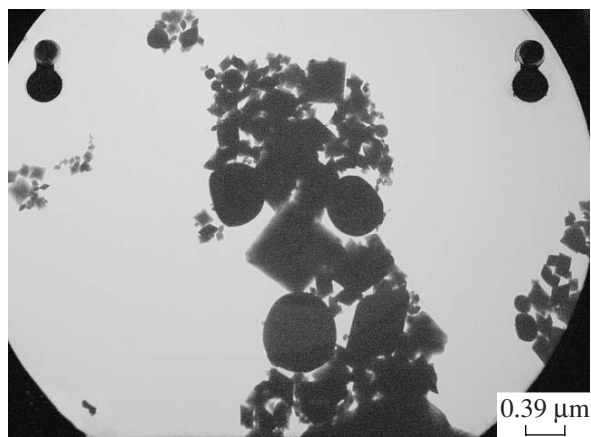


Fig. 1. Electron microscope image of oxidized tungsten nanoparticles.

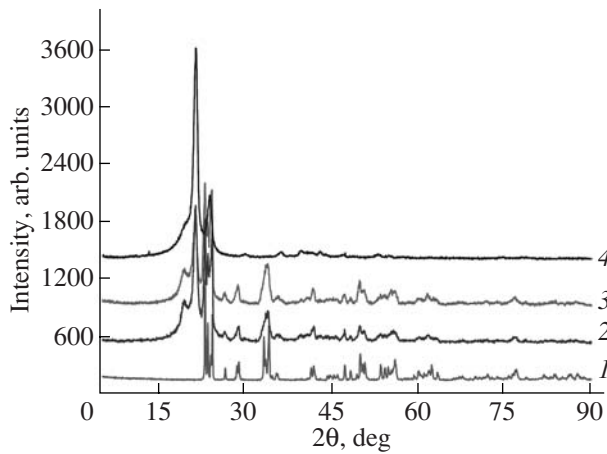


Fig. 2. X-ray powder diffraction patterns of (1) WO_3 and (2–4) superhigh-molecular poly(ethylene) composites with different WO_3 contents of (2) 7, (3) 14, and (4) 0 wt %.

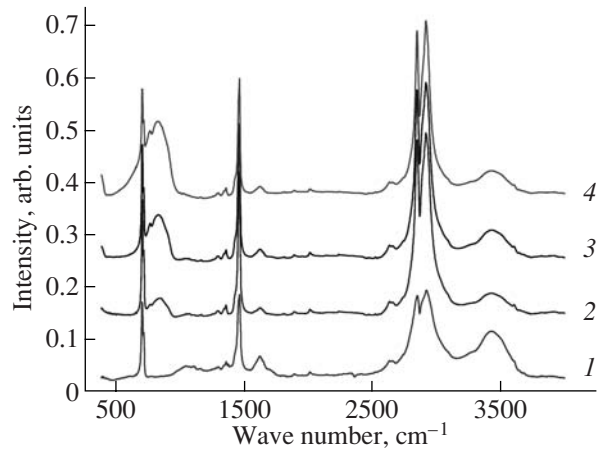


Fig. 3. IR spectra of the superhigh-molecular poly(ethylene) specimens with different WO_3 contents of (1) 0, (2) 2, (3) 7, and (4) 14 wt %.

circuit, this rod was sputtered with the subsequent oxidation in air. Figure 1 presents the electron microscope image of oxidized tungsten nanoparticles.

The powder of oxidized tungsten particles was mixed with a superhigh-molecular poly(ethylene) powder in an AGO-2 mechanical activator (the rotational velocity of drums was 1820 min^{-1}). The percentage of tungsten oxide varied from 2 to 14 wt %. The time of the joint activation was 4 min.

The strength characteristics of the material were investigated using a disk fabricated from the composite under cold pressing with the subsequent hot pressing at a specific pressure of 100 kg/cm^2 and a temperature of 200°C . The abrasion tests were performed in a “disk (steel 45)–test specimen” pair on an MI-2 machine according to the GOST (State Standard) 426-77. The friction area of the specimen was 100 mm^2 , the linear velocity was 12 m/min , and the time of each test was 30 min.

3. RESULTS AND DISCUSSION

The X-ray powder diffraction analysis has established that tungsten sputtered in the plasma and then oxidized in air is the orthorhombic modification of tungsten trioxide WO_3 with an average particle size of $48 \pm 7 \text{ nm}$. Figure 2 presents the X-ray powder diffraction patterns of the WO_3 oxide and the composite containing 7 and 14 wt % WO_3 . The X-ray powder diffraction data indicate that the structure of the polyethylene remains unchanged upon introduction of the WO_3 nanodisperse powder.

The results of the abrasability tests are presented in the table.

Figure 3 shows the IR spectra of the composite specimens with different WO_3 contents.

The analysis of the IR spectra of the composite specimens has revealed a band (800 cm^{-1}) corresponding to the C–H bending vibrations. The presence of these vibrations in the structure of the material can be explained by stresses generated at the SHMPE– WO_3 nanoparticle interface, which in turn, possibly, leads to an increase in the strength characteristics.

The measurements of the permittivity ϵ in the range from 5 to 500 MHz have shown that the superhigh-molecular poly(ethylene) has $\epsilon = 2.3$ and the composite containing 7 wt % WO_3 has $\epsilon = 2.57$.

According to the Raman scattering data, WO_3 reacted with the superhigh-molecular poly(ethylene) and was partially reduced.

Therefore, the introduction of WO_3 nanoparticles into superhigh-molecular poly(ethylene) leads to

Results of tests for abrasability of the initial SHMPE specimen and the SHMPE specimen with 7 wt % WO_3

Material	Force, kg					
	4.5		13.5		22.0	
	Δm	ΔT	Δm	ΔT	Δm	ΔT
SHMPE	9.3	16	CW		CW	
SHMPE + 7 wt % WO_3	0.6	7.2	1.8	24.9	4.1	29.9

Note: Δm is the change in the weight, ΔT is the change in the temperature, CW is the catastrophic wear (abrupt increase in Δm by a factor of several hundreds).

changes in the arrangement of hydrocarbon chains in the structure, which affects the improvement of the strength characteristics of the products.

ACKNOWLEDGMENTS

We would like to thank A.S. Krylov and N.A. Drokin for performing the permittivity measurements and Raman scattering investigations.

This study was performed within the framework of the Interdisciplinary Integration Project (decision no. 55, project no. 12).

REFERENCES

1. N. V. Novikov, *Poroshk. Metall.*, No. 5, 8 (1993).
2. I. N. Andreev, E. V. Veselovskaya, E. I. Nalivaiko, A. D. Pechenkin, V. I. Bukhgalter, and A. V. Polyakov, *Superhigh-Molecular Poly(ethylene) with a High Density* (Kimiya, Leningrad, 1982) [in Russian].
3. G. N. Churilov, N. G. Vnukova, N. V. Bulina, A. V. Marachevskii, G. E. Selyutin, V. A. Lopatin, and G. A. Glushchenko, *Nauka—Proizvod.*, No. 5, 52 (2003).

Translated by N. Korovin