ФІЗИКА І ХІМІЯ ТВЕРДОГО ТІЛА
Т. 14, № 3 (2013) С. 615-618

PHYSICS AND CHEMISTRY OF SOLID STATE
V. 14, № 3 (2013) P. 615-618

УДК 621.891:620.178.1.002

ISSN 1729-4428

L.M. Soltys, H.O. Sirenko

The Influence of the Nano- and Microroughness of Surface of the Solid on the Physic-Chemical Contact Facts (Review)

Vasyl Stefanyk' Precarpathian National University,
57, Shevchenko Str., Ivano-Frankivsk, 76025, Ukraine
Tel. (0342) 77.64.15; (096) 813.93.53, e-mail: orijant@gmail.com

Article deals with the physico-chemical phenomena on microrough surfaces of the polymer composite and metal in dynamic contact. Review of sources which describe methods, parameters and mathematical and physical models of description of nanometrical and micrometrical roughness of surface of solid states.

Key words: polymer composite, metal counterface, carbon fibers, roughness of surface, moments of spectral density, friction, intensity of wear, metallization, selective transport of copper.

Стаття поступила до редакції 15.01.2013; прийнята до друку 15.06.2013.

Introduction

The aim of research: the scientific search of dependence of the physic-chemical processes, speed of chemical reactions and also the optimal technologies this processes considering of anisotropy roughness of surface and complicating of contact facts; the disclosure of mechanisms of formation maximum nanolayers on the rough surfaces, which were modeled by random field, with friction and wear and also other contact facts (adhesion, physical and chemical adsorptions and others).

The fundamental problems of research:

1) the research on the base of theory a random field of anisotropy roughness surfaces and disclosure of parameters of description these surfaces;

2) the research on the base of theory an anisotropy field of roughness isotropy surfaces and disclosure of parameters of description these surfaces;

3) the research of parameters of rough surfaces for the search it relation with basic parameters of physic-chemical processes, friction and wear;

4) the getting of mathematical formulas for the description of contact facts;

5) the experimental research of friction and wear solids at absence or presence liquids on the rough surface.

In that time the contact facts on surface of the solids are considered either without considering of roughness of surface (that is, on the ideally even surfaces) or surface is modeled by common patterns which very far from real rough surfaces. In spite of very small micro- and nanosizes of unevens, which are composed the roughness of surface, it is influenced very essentially on various physic-chemical contact facts, namely on: physical and chemical absorptions, adhesion, friction and wear, chemical reactions and others.

I. Review

Review of sources which describe methods, parameters and mathematical and physical models of description of nanometrical and micrometrical roughness of surface of solid states [1].

The mathematical description of anisotropic rough surfaces of solid states has been resulted in [2] using the model of random field. It has been shown that the formulas for isotropic surface follow from the formulas for density probabilities of heights peaks of anisotropic surface model.

It has been shown in [3] that from formulas for average, absolute, main curvatures and correlation of main curvatures in peaks of nano- and microinequalities of anisotropic surface follow formulas for isotropic surface.

The ideal spherical model of isotropic surface has been considered. It has been determined that the ideal spherical model in general has no place in the modeling of nano- and microrough surface by isotropic random field [4, 5].

It has been shown in [6] that from formulas for gradient of anisotropic surface follow formulas for gradient of isotropic surface.

The methods and technique of research of nano- and microrough surfaces modeled by anisotropic and isotropic random field have been considered [7].

The influence of schemes of reinforcing by fibrous carbon materials of polymer composites and schemes contacting of samples of these composites with the surface of metal counterface on the intensity of wear of friction pair and on the changing of microroughness parameters of metal surface have been researched. It has been shown that the topography of metal counterface surface changes in friction carbon plastics with oriented fibers, but the allocation of heights and curvatures of microroughness peaks of friction surface far removed from the Gaussian allocation and close to Rayleigh allocation [8].

The intensity of wear of polymer composite material based on polytetrafluoroethylene and carbon fiber in friction on rough isotropic metal surface without lubrication [9, 10, 11] and in distilled water [9, 12, 13] have been researched.

Tribosurface properties of composite polymer materials in friction on metal counterfaces are determined by parameters of rough surface, size of loading of friction pair, speed of sliding, temperature of surfaces of friction and medium in which is dynamic contact [9-13].

The resistance to wear of composite material – carbon plastic on the base of polytetrafluoroethylene, filled with 20% of carbonized low-module (LM) carbon fiber, obtained from hydrated cellulose fiber (at thermo treatment for temperature 1123 K in CH_4 medium in the presence of fire-proofing compounds $Na_2B_4O_7 \cdot 10H_2O$ and $(NH_4)_2HPO_4$) in friction and wear without lubrication and in distilled water on the tribometer was researched [9-13].

The roughness of surface was estimated at the moments of spectral density (SD): zero order m_0, related to the high-altitude parameter; second order m_2, related to the gradient of surface; fourth order m_4, related to curvature of heights of peaks of isotropic metal surface. The approximated equations of intensity of wear of polymer composite with the moments of spectral density of rough isotropic metal surface have been found using the Brandon method (position of the moments m_0, m_2, m_4 in approximated equations was determined at the coefficients of correlations between I_i and m_j). The results have been analyzed and the minor rows of influence of the moments of spectral density on the intensity of wear of polymer composite on the base of polytetrafluoroethylene and carbon fiber have been established [9-13].

It has been shown that the curvatures in the peaks of initial rough isotropic surface of carbon steel 45 determine formation of the surfaces of friction pair and resistance to wear of polymer composite on the base of polytetrafluoroethylene and carbonized carbon fiber in conditions of friction without lubrication, when intermediate film on contiguous surfaces is formed. For hard and soft steels the high-altitude parameter in greater degree, and then the gradient of surface and the least curvatures in the peaks of initial rough surface of steels determine intensity of wear in both regimes of loading; for soft alloys on the base of copper the gradient of surface in greater degree, then the height of inequalities and less curvature of peaks determine intensity of wear I_1 of polymer composite in regime of the superboundary loadings; in regime of the boundary loadings the curvatures determine intensity of wear I_2 in greater degree than height of inequalities and less the gradient of surface in conditions when formation of intermediate layers on metal surfaces in distilled water is inconvenienced [9-13].

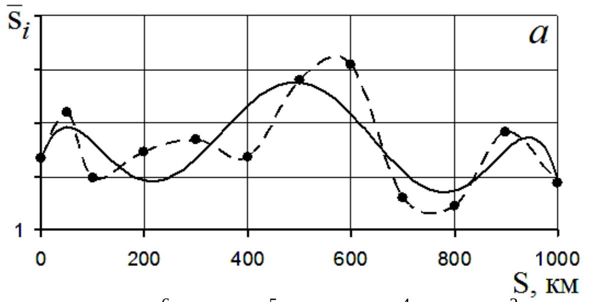
The mathematical expressions for calculation of the specific square of anisotropic rough surface with hard even; specific volume of the contact gap of anisotropic rough surface with hard even; factual contact square of rough anisotropic surface with hard even; coefficient of friction of elastic contact of rough anisotropic surface with even; thermal resistance of elastic-plastic contact of rough anisotropic surface with hard even; adhesion interaction of ellipsoid peak of rough surface with hard even surface considering deformation in the contact zone have been found, based on the description of Gaussian rough surfaces on the base of random field model. From the obtained formulas similar expressions for isotropic model of rough surface have been found. The subjection of values of the specific square surface of counterface from the way of friction and the specific intensity of wear of composite from specific square surface of counterface obtained during friction and wear has been found as a result of research of wear of polymer composite during contact with the steel counterface [14-18].

In Fig. 1 shows a qualitative picture changes specific surface of counterface from steel 45 in friction and wear of polymer composite "flubon-15(20)" on the way friction from 0 to 1000 km [15].

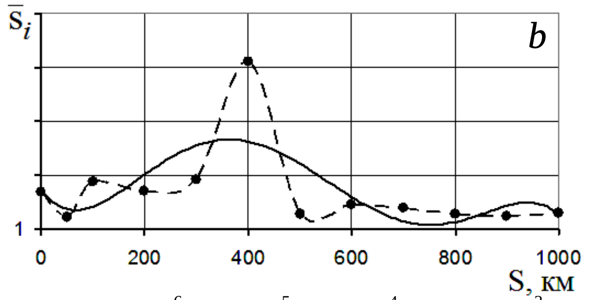
It has been shown and analyzed the phenomenon influence of constant and dynamic loads on the processes of wear, friction and change allocation of heights of peaks and average curvature in the peaks of micro-irregularities surfaces of thermo-lasting polymers, filled with spherical and fibrous dispersed materials, during tests in the compressors without lubrication of high pressure. Leading role in these phenomena there are: geometric form filler of polymer composites, the nature of the gas medium, the pressure of gas and temperature of surface of conjugated pairs of friction [19].

It has been shown that the allocation of heights of peaks and average curvature in the peaks microirregularities surfaces of samples of polymer composites and metal counterfaces depend on the initial moments of the spectral density and the formation on the conjugated metal surfaces of the intermediate films. These allocations change in friction and wear of the friction way from 0 to 1200 km, with the change of allocations is oscillatory in nature, approaching and keeping away from the normal allocation Gauss. Coatings of carbon fibers by copper by zinc technology significantly affects on the processes of formation of films on the surface of metal counterface and changes the allocation of heights of peaks and average curvatures in the peak of microirregularities as counterface well as polymer sample [20, 21].

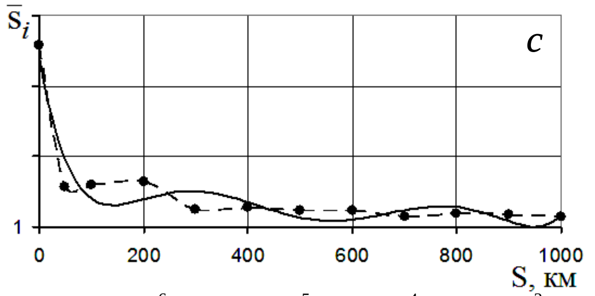
Complex compounds of copper based on benzene and heterocycle ligands were synthesized. By results of tests on four-bullet friction machine in conditions limit loads has been shown that copper complexes with heterocycle ligands dominate copper complexes with benzene ligands by anti-welding properties, herewith bond of copper with oxygen and nitrogen simultaneously



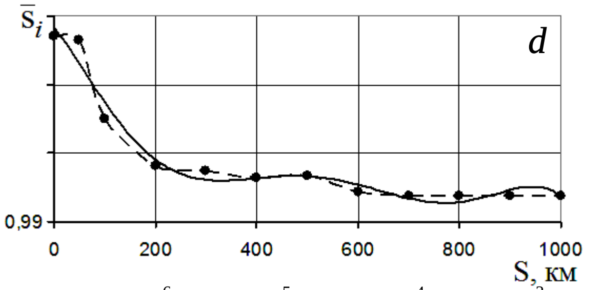
$Y = –1E\text{-}18X^6+4E\text{-}15X^5 – 4E\text{-}12X^4+2E\text{-}09X^3 – 4E\text{-}07X^2+ + 3E\text{-}05X + 1,0013$ ($R^2 = 0,5773$).



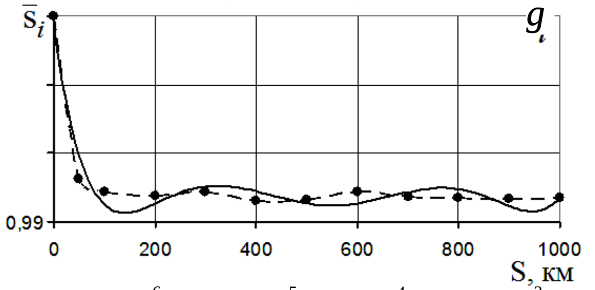
$Y = –2E\text{-}19X^6+5E\text{-}17X^5+7E\text{-}13X^4 – 9E\text{-}10X^3+3E\text{-}07X^2 – – 4E\text{-}05X + 1,0021$ ($R^2 = 0,4344$).



$Y = 4E\text{-}18X^6 – 1E\text{-}14X^5+2E\text{-}11X^4 –1E\text{-}08X^3+3E\text{-}06X^2–$
$–0,0004X + 1,0242$ ($R^2 = 0,9224$).



$Y = –7E\text{-}18X^6 +2E\text{-}14X^5 – 2E\text{-}11X^4 +1E\text{-}08X^3–1E\text{-}06X^2 – – 0,0003X + 1,075$ ($R^2 = 0,9702$).



$Y = 2E\text{-}17X^6 – 7E\text{-}14X^5+8E\text{-}11X^4 – 5E\text{-}08X^3+2E\text{-}05X^2 – – 0.0022X + 1.1048$ ($R^2 = 0.9567$).

FIG. 1. DEPENDENCE OF THE SPECIFIC SURFACE $\bar{s}_i$ OF THE STEEL COUNTERFACE FROM THE WAY FRICTION IN FRICTION AND WEAR OF POLYMER COMPOSITE "FLUBON-15(20)" AT THE INITIAL SURFACE ROUGHNESS OF COUNTERFACE FROM STEEL 45: *A* – RA_0=0,085 MICRONS (EXPERIMENT N 70); *B* – RA_0= 0,22 MICRONS (EXPERIMENT N 72); *C* – RA_0=0,49 MICRONS (EXPERIMENT N 73); *D* – RA_0=0,85 MICRONS (EXPERIMENT N 74); *G* – RA_0=1,42 MICRONS (EXPERIMENT N 75).

much more effective than with each element separately [22].

The changes of surface layers crystal structure of carbon fibres in the course of copper-plating have been investigated. The metallic coating process using modified formaldehyde and zinc technology was realized. It is established, that copper content in copper-copper oxide increases when using two-layer alternately modified formaldehyde and zinc method [23].

The chemical conversions and interaction of flame retardants and oxygen with carbon of surface of carbon fibers on the stage of chemo-mechanical activation technology and friction tests have been researched [24].

The theoretical foundations of physics and chemistry and application technology of single- and double-layer coating based on Cu^0+CuO, Ni^0+P on the surface of carbonated fibers have been reviewed. The results of antifriction tests of polymer composites based on polytetrafluoroethylene and carbon fibers of Ni^0–Cu^0 and Cu^0–Ni^0 coatings have been shown [25].

Soltys L.M. – leading engineer of Department of Inorganic and Physical Chemistry;
Sirenko H.O. – PhD, professor, head of Department of Inorganic and Physical Chemistry.

[1] G.O. Sirenko, L.M. Soltis, Fizika i himija tverdogo tila, 11 (2), 423 (2010).
[2] G.O. Sirenko, M.F. Semenjuk, L.M. Soltis, Fizika i himija tverdogo tila, 11 (3), 768 (2010).
[3] G.O. Sirenko, M.F. Semenjuk, L.M. Soltis, Fizika i himija tverdogo tila, 11 (4), 914 (2010).
[4] M.F. Semenjuk, G.O. Sirenko, L.M. Soltis, Visnik Prikarp. nac. un-tu im. V. Stefanika. Ser. Himija, (IH), 62 (2010).
[5] L.M. Soltis, G.O. Sirenko, Materiali Shostoї Mizhnarodnoї naukovo-praktichnoї konferencії «Rozvitok naukovih doslidzhen' 2010» – m. Poltava, 22-24 listopada 2010 r. InterGrafika, Poltava, 6, ss. 92-93 (2010).
[6] M.F. Semenjuk, G.O. Sirenko, L.M. Soltis, Fizika i himija tverdogo tila, 12 (1), 200 (2011).
[7] G.O. Sirenko, M.F. Semenjuk, L.M. Soltis, Visnik Prikarp. nac. un-tu im. V. Stefanika. Ser. Himija, (H), 123 (2010).
[8] L.M. Soltis, G.O. Sirenko, L.Ja. Midak, Visnik Prikarp. nac. un-tu im. Vasilja Stefanika. Serija Himija, (HI), 95 (2011).

[9] L.M. Soltis, G.O. Sirenko, Fizika i himija tverdogo tila, 12 (2), 508 (2011).
[10] G.O. Sirenko, L.M. Soltis, Visnik Prikarp. nac. un-tu im. V. Stefanika. Ser. Himija, (VII), 104(2009).
[11] G.O. Sirenko, L.M. Soltis, Materiali V Mizhnarodnoї naukovo-tehnichnoї Web-konferencії «Kompozicijni materiali» – m. Kiїv, traven' 2010 r. Kiїv. 102(2010).
[12] G.O. Sirenko, L.M. Soltis. Visnik Prikarp. nac. un-tu im. V. Stefanika. Ser. Himija, (VIII), 99 (2009).
[13] G.O. Sirenko, L.M. Soltis. Materiali Shostoї Mizhnarodnoї naukovo-praktichnoї konferencії «Naukovi doslidzhennja – teorija ta eksperiment 2010» – m. Poltava, 17-19 travnja 2010 r. InterGrafika, Poltava, 5. 81(2010).
[14] M.F. Semenjuk, G.O. Sirenko, L.M. Soltis. Fizika i himija tverdogo tila, 12 (3), 795 (2011).
[15] G.O. Sirenko, L.M. Soltis, M.F. Semenjuk, Visnik Prikarp. un-tu im. V. Stefanika. Ser. Himija, (HII), 133 (2011).
[16] G.O. Sirenko, L.M. Soltis, Materiali S'omoї Mizhnarodnoї naukovo-praktichnoї konferencії «Rozvitok naukovih doslidzhen' 2011». – m. Poltava, 28-30 listopada 2011 r. Poltava: InterGrafika, 8, 35 (2011).
[17] L.M. Soltis, G.O. Sirenko. Materiali V Mizhnarodnoї konferencії «Suchasni problemi fizichnoї himії». – Donec'k, 5-8 veresnja 2011 r. Donec'k: Don. nac. un-t, 216 (2011).
[18] L.M. Soltis, G.O. Sirenko, Avtoreferati dopovidej Vseukr. z mizhnarodn. uchastju konferencії molodih vchenih «Himija, fizika ta tehnologija poverhni», 15-16 travnja 2012 r., Kiїv. – Kiїv: In-t himії poverhni im. O.O. Chujka, 118 (2012).
[19] G.O. Sirenko, V.P. Sviders'kij, L.M. Soltis, I.I. Novikov, V.P. Zaharenko, Fizika i himija tverdogo tila, 12 (4), 1050 (2011).
[20] G.O. Sirenko, L.M. Soltis, M.B. Skladanjuk, Fizika i himija tverdogo tila, 13 (2), 500 (2012).
[21] L.M. Soltis, M.B. Skladanjuk. Tezi dop. H Vseukr. konf. studentiv ta aspirantiv «Suchasni problemi himії». – Kiїv, 19-22 travnja 2009 r. Kiїv, 207 (2009).
[22] G.O. Sirenko, L.M. Soltis, V.I. Kirichenko, L.M. Kirichenko, Visnik Prikarp. nac. un-tu im. Vasilja Stefanika. Serija Himija, (XIV), 38 (2012).
[23] G.O. Sirenko, L.M. Soltis, V.I. Kirichenko, V.P. Sviders'kij, M.B. Skladanjuk, Visnik Prikarp. nac. un-tu im. Vasilja Stefanika. Serija Himija, (XIV), 50 (2012).
[24] G.O. Sirenko, L.M. Soltis, L.Ja. Midak, I.V. Kravec', Visnik Prikarp. nac. un-tu im. Vasilja Stefanika. Serija Himija, (XIV), 149 (2012).
[25] G.O. Sirenko, L.M. Soltis, V.I. Kirichenko, Visnik Prikarp. nac. un-tu im. V. Stefanika. Serija Himija, (XV), 132 (2012).

Л.М. Солтис, Г.О. Сіренко

Вплив нано- та мікрошорсткості поверхні твердих тіл на фізико-хімічні контактні явища (Огляд)

Прикарпатський національний університет імені Василя Стефаника,
вул. Шевченка, 57, м. Івано-Франківськ, 76025, Україна
Тел. (0342) 77.64.15; (096) 813.93.53, e-mail: orijant@gmail.com

Стаття присвячена дослідженню фізико-хімічних явищ на мікрошорстких поверхнях полімерного композиту та металу під час їх динамічного контакту. Проведено огляд літературних джерел інформації, що описують методи, параметри та математичні і фізичні моделі опису нанометричної та мікрометричної шорсткості поверхні твердих тіл.

Ключові слова: полімерний композит, металеве контртіло, карбонові волокна, шорсткість поверхні, моменти спектральної щільності, тертя, інтенсивність зношування, металізація, вибірковий переніс міді.