COMPOSITE MATERIALS AND ADVANCED METHODS OF POLYTETRAFLUOROETHYLENE MODIFICATION

KOMPOZITNÉ MATERIÁLY A POKROČILÉ METÓDY MODIFIKÁCIE POLYTETRAFLUÓRETYLÉNU

Anton Panda - Kristina Berladir - Konstantin Dyadyura

Abstract:

The increasing use as new structural materials, including special purpose currently, are composites based on amorphous-crystalline linear polymers such as polytetrafluoroethylene (PTFE). This material has unique antifriction properties, high chemical inertness, thermal and cold resistance. The advantage of these materials is in the higher values of their mechanical properties compared to amorphous polymers. However, low wear resistance and insufficient mechanical properties preclude its use in unfilled form. For PTFE there is a possibility of effective purposeful regulation of operational characteristics by filling and structural modifying by means of mechanical activation.

Key words:

Polytetrafluoroethylene, Polymer composite materials, Modification, Supramolecular structure, Mechanical Activation, Filling

Introduction – properties of polytetrafluoroethylene

Wide application of polymer composite materials (PCM) based on polytetrafluoroethylene (PTFE) in the nodes of friction and compaction of all kinds of machines and equipment is due to specific features of its molecular structure and supramolecular structure (SMS), which provide for the implementation of unique combination of indices of deformation strength, tribotechnical, anticorrosive, thermo–physical and other operational characteristics [1].

PTFE is one of the amorphous-crystalline polymers with crystallites melting point 600 K and vitrification temperature of the amorphous phase 153 K; it has a high degree of crystallinity; the large number of crystallites is observed even after quenching (rapid cooling starting from melting point) [2]. The material has abnormally low friction coefficient (0,01–0,04), but it is disposed to cold flow which can be lowered by fillers introduction .

Despite the unique characteristics of PTFE, it has a number of properties which limits its use as a tribotechnical material. These include high tensile creep loading that appears under 3 MPa of tensile loading at normal temperatures; high thermal-expansion coefficient at normal temperatures that changes abnormally at temperature in the range of structural phase transitions (temperature range from 280 to 310 K); low thermal conductivity (10-50 times less than in metals); low wear resistance under dry friction conditions especially at high sliding velocity [3].

The heat released in the friction zone due to low thermal conductivity facilitates a significant rise of temperature on the friction surface. As a result the physical and chemical processes that reduce the strength and stiffness of the polymer are intensified and the linear

sizes are greatly increased which can eventually lead to destruction of the friction unit. Thereby it is necessary to use methods of PTFE modification.

2. Types of PTFE modification

Modification of polymers is a directional change of physical-chemical, mechanical or chemical properties of polymers (fig. 1) [4].

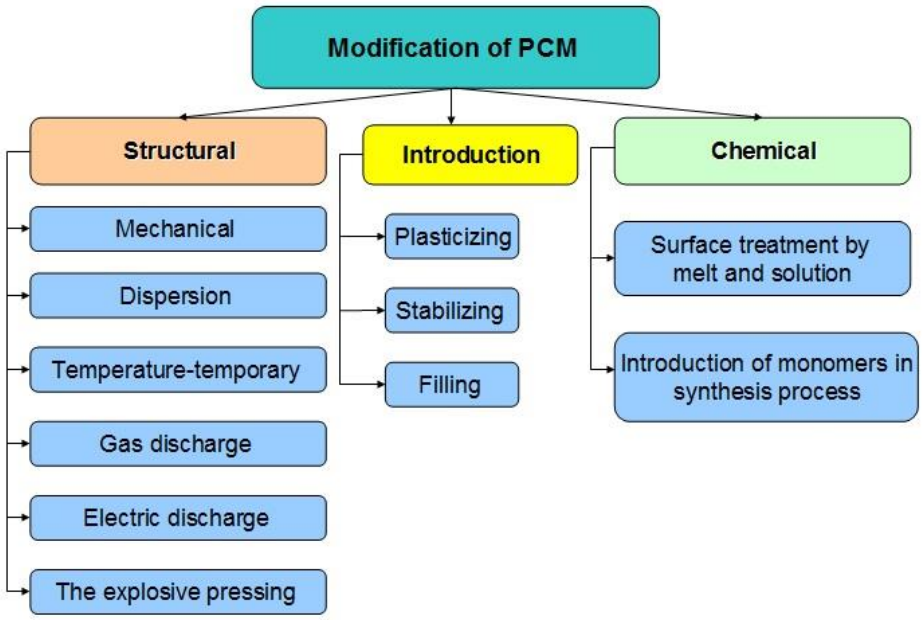

Fig. 1. Scheme of the main methods of modification PCM

1. Structural – modification of physical and mechanical properties without changing the chemical composition of the polymer and its molecular weight – changing SMS of polymer. For example, mechanical activation, shock and wave processing, radiation exposure, using magnetic and electromagnetic fields [5, 6].

2. Introduction to polymer substances that can interact with it, including high-molecular (plasticizing, stabilizing, filling). For example, introduction to PTFE various solid components [7]; matrix modifying by additions of activators of different size, shape and properties [8]; formation of nanopfase matrices with significantly different characteristics [9].

3. Chemical – influence on polymer of chemical or physical agents, is followed by change of the chemical composition of polymer and (or) its molecular weight, and also introduction at a stage of synthesis of a small amount of substance which enters with the main monomer in copolymerization or a sopolikondensation. In particular, the synthesis of polymer matrices of different composition and structure [10]; composition of polymer and oligomer mixture with different levels of interaction [11] etc.

It should be noted that the industrial implementation of these technologies is associated with significant energy, material and labor expenses and requires the managerial study of the price – quality relationship.

3. The current state and problems of creation antifriction PTFE-materials

To obtain an efficient PTFE–composite, the above–mentioned factors need to be considered when choosing the composition of a filler, its dispersity, energy state of the surface layer [12] and technology for the activation of ingredients [13, 14], methods of combining components when obtaining a composite material and technological methods for the formation of PTFE products (patents of Ukraine Nos. 40282, 40959, 40960, 41868, 42870).

The properties of composite materials, in addition to the correct choice of filler, are largely determined by the obtaining technology that determines the nature of interaction at the inter–phase boundary "matrix – filler" and defines the set of properties while forming the material [15].

A positive effect of filling PTFE for improving tribotechnical characteristics is caused by the attenuation of intermolecular bonds in a polymer, formation of the optimum structure of material, involvement of fillers in the process of friction as inhibitors, and increase in workability of the film of friction transfer [16].

Paper [17] demonstrated that the modification of amorphous–crystalline polymers by means of filling leads to changes in the character and morphology of SMS, and this is one of the main reasons for the transformation of properties of a composite.

The structurally active fillers which are distinguished by extremely small particle dimensions are the most interesting in terms of the impact on tribotechnical characteristics of PCM [18]. Their use ensures maximal structuring of polymer matrix at the different levels of structural organization and obtaining materials with unique properties.

Conclusion

Uniqueness of PTFE properties, insufficient study of its physical structure and properties, insufficient informational content of researches of the interphase phenomena and structure-forming processes in case of mechanochemical activation and in the presence of fillers, insufficient study of influence of structure, structure and properties and manufacturing techniques on tribotechnical characteristics of materials on the basis of PTFE do them urgent about objects of further researches.

References

[1] Smith, D.W., Iacono, S.T., Iyer, S.S. (2014). Handbook of fluoropolymer science and technology. Hoboken: Wiley, 646.
[2] Biswas S.K., Vijayan K. (1992). Friction and wear of PTFE - a review. Wear, 158, 193–211. doi:10.1016/0043-1648(92)90039-B.
[3] Khedkar J., Negulescu I., Meletis E. I. (2002). Sliding wear behavior of PTFE composites. Wear, 252, 361–369. doi:10.1016/S0043-1648(01)00859-6.
[4] Мала гірнича енциклопедія, т. 2 / За редакцією В.С. Білецького. – Донецьк: Донбас, 2007. – С. 144.
[5] Mikhailova L., Voropaev V., Gorbatsevich G., Lauryniuk I. (2011). Technology of tribotechnical and sealing composite materials based on polytetrafluoroethylene. Mining mechanical engineering and machine-building, 4, 86–97.
[6] Хатипов С.А. (2009). Фторопласт: закалка радиацией. Химия и жизнь, 8, 4–7.
[7] Буря О.І., Кузнецова О.Ю. (2012). Полімерні композитні матеріали з дисперсними і волокнистими наповнювачами. Композитные материалы, 6 (1), 3–18.

[8] Yan Y., Jia Z., Yang Y. (2011). Preparation and mechanical properties of PTFE/nano-EG composites reinforced with nanoparticles. Procedia Environmental Sciences, 10, 929-935.
[9] Buznik V.M. (2009). New nano-sized and micro-sized objects on the basis of polytetrafluoroethylene. Russian nanotechnologies, 4, 35–41.
[10] Ruiz P., Macanás J., Muñoz M., Muraviev D.N. (2011). Intermatrix synthesis: easy technique permitting preparation of polymer-stabilized nanoparticles with desired composition and structure. Nanoscale Research Letters, 6 (343), 1–6.
[11] Buznik V.M. [et al.] (2013). Structure of polytetrafluoroethylene powders obtained by photochemical polymerization of gaseous monomer. Inorganic Materials: Applied Research, 4, 131–137.
[12] Stanković M., Vencl A., Marinković A. (2013). A review of the tribological properties of PTFE composites filled with glass, graphite, carbon or bronze reinforcement. 13th International Conference on Tribology, Kragujevac, Serbia, 135–140.
[13] Berladir K.V., Budnik O.A., Dyadyura K.A., Sviderskiy V.A., Kravchenko Ya.O. (2016). Physicochemical principles of polymer composite materials technology based on polytetrafluoroethylene. High Temperature Material Processes, 20 (2), 157–184. doi: 10.1615/HighTempMatProc.2016017875.
[14] Budnik O.A., Budnik A.F., Rudenko P.V., Sviderskiy V.A., Berladir K.V. (2015). Influence of mechanical activation polytetrafluoroethylene matrix of tribotechnical composites at its structural and phase transformations and properties. Functional Materials, 22 (4), 499–506. doi: http://dx.doi.org/10.15407/fm22.04.499.
[15] Voropaev V. (2013). Technology of polytetrafluoroethylene-based nanocomposite materials: Structural and morphological aspect. Applied Technologies and Innovations, 9 (2), 59–68. doi: http://dx.doi.org/10.15208/ati.2013.11.
[16] Gujrathi S.M., Dhamande L.S., Patare P.M. (2013). Wear studies on polytetrafluroethylene (PTFE) composites: Taguchi approach. Bonfring International Journal of Industrial Engineering and Management Science, 3 (2), 47–51.
[17] Kirillina Y.V., Lazareva N.N., Sleptsova S.A., Okhlopkova A.A. (2016). Effect of organomodified layered silicates on the properties and structure of polytetrafluoroethylene. Polymer Science Series A, 58 (1), 95–101. doi:10.1134/s0965545x16010065.
[18] Suh J., Bae D. (2016). Mechanical properties of polytetrafluoroethylene composites reinforced with graphene nanoplatelets by solid-state processing. Composites Part B: Engineering, 95, 317–323. doi:10.1016/j.compositesb.2016.03.082.

Contact address

(1.) prof. Ing. Anton Panda, PhD. Technical university in Košice, Faculty of manufacturing technologies with the seat in Prešov, Štúrova 31, 080 01 Prešov, Slovakia
e-mail: anton.panda@tuke.sk
(2.) junior researcher Kristina Berladir. Sumy State University, Faculty of Technical Systems and Energy Efficient Technologies, Rimsky-Korsakov 2, 40007 Sumy, Ukraine
e-mail: kr.berladir@pmtkm.sumdu.edu.ua
(3.) prof. Konstantin Dyadyura, PhD. Sumy State University, Faculty of Technical Systems and Energy Efficient Technologies, Rimsky-Korsakov 2, 40007 Sumy, Ukraine
e-mail: dyadyura@pmtkm.sumdu.edu.ua