Super Strong Durable
Anti-Frictional Thickening Materials

Inside any mechanism there are frictional joints which are the weak points of the mechanism. Anti-frictional and thickening materials are used to alleviate the functioning of moving and fixed joints and make the mechanism`s life of service longer. Recently elaborated super strong-durable polytetrafluorethylene helps to solve the problem of wearing the mechanism out.

Nowadays polymer anti-frictional and thickening materials based on fluoroplastic, polyamide, polyethylene, polycarbonate and polyether are applied for production of joints in engineering, aviation, car and space industry at world and local scale. Each of the above enumerated polymers has certain usage restrictions because of low level durability, high friction coefficient, not high enough temperature of usage, humidity absorbing, chemical vulnerability, viscous, resilient or dielectric properties.

Polytetrafluorethylene (technical name fluoroplastic-4) is the mostly used material in sliding parts. It ensures air tightness of moving and fixed joints. But notwithstanding all advantages, this material has a low level of durability and "creeping' ability. For these peculiarities polytetrafluorethylene is "a negative hero". During more than 50-year-long experience of polytetrafluorethylene usage a lot of modification methods were elaborated. One of them – co-polymerization (adding to polymer chain alien molecular structures) and physical mingling with different essences to reinforce the polymer matrix. Due to that good results were obtained but now it is a bottom line.

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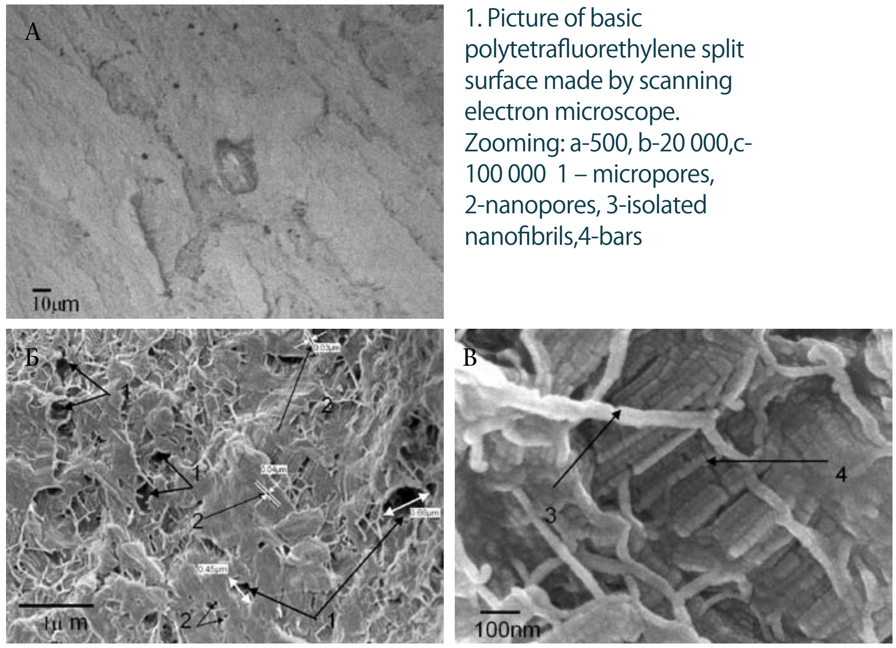
Variants of polytetrafluorethylene enriched by coke, glass fibre, graphite with iron oxide and nanoparticles with different activation methods do not differ much (for instance, for durability within ten and more percent). So far the limit for non-dimentional quantity for friction without lubricating has been $(0.5\text{-}1.0)\times10^{-8}$.

Hard to expect the emergence of new modification methods to remove all polytetrafluorethylene`s drawbacks and preserve its advantages. But recently such methods has been found and exceeded the bounds of expectations. The durability against friction without lube was exceeded fourfold and reached the level of $(0.1\text{-}0.3)\times10^{-9}$. Fluidity and radiation resistance exceeded twofold. It means 10-50 times better result! And the frictional coefficient went even lower but biological and chemical inertia, low surface energy and dielectric peculiarities remain stable as with initial polytetrafluorethylene.

New technology does not need any additional filling or chemical reagents and is based on the permolecular material structure. The main role belongs to the nano-structuring process at the scale of 10-100 nm. This process is initiated by radiation and chemical process on the molecular level.

It seems to be paradoxical because polytetrafluorethylene is vulnerable to radiation influence – it causes C-C connection breaking. Even the smallest portion of radiation reduces its erosion resistance. But it turned out that polytetrafluorethylene is distorted by radiation only under certain temperature, higher than the point of fusion. This peculiarity was taken into account for radiation modification of polytetrafluorethylene.

It was shown that radiation effect induces the permolecular rebuilding process, i.e. reorganization of the nano-structure of the polymer. Fig. 1 and 2 demonstrate us the samples of basic polytetrafluorethylene and modified by radiation. As seen in fig. 1a by low level zooming the external split surface is homogeneous and has no distinguished morphological peculiarities. By high zooming we see non homogeneous structure with porous inclusions (1 b). These inclusions are smoothly spread on



1. Picture of basic polytetrafluorethylene split surface made by scanning electron microscope. Zooming: a-500, b-20 000,c-100 000 1 – micropores, 2-nanopores, 3-isolated nanofibrils,4-bars

the split surface and have notable pore distribution from nano to micron scale. In the pore zone there is the ribbon like structures and isolated nano fibrils (1c). The ribbons consist of fibrils fixed in order. The usual size of the fibril structure is 10 nm.

The radiation modification changes drastically the morphology of the polymer. Under low zooming polycrystalline structures may be seen (2a) with spherical symmetry. The spherulite size varies from 10 to 100 mcm. They consist of many nanofibrils diverging in radial directions from the center (2b,c). We may see here more homogeneous structure, lower porosity at nanoscale (less than 100 nm), and no isolated fibrils.

Thus, radiation influence causes changes in the premolecular structure of the polymer: shifting from ribbon-like to sperulite polycrystalline and nanofibril structures with higher mechanical characteristics.

In the fig. 3,4,5 and in the table 1 we see comparison of the basic polytetrafluorethylene (Ф-4) and its modification (Ф4-PM). The behavior of Ф4-PM under cyclic load differs much from that of Ф-4 (3). The absolute level of deformation is very low and reversible. The list of advantages of Ф4-PM is in fig.4. Modified polymer gets rid of its drawbacks but preserves all the merits. It has lower creeping speed (by 30-50 times), higher radiation resistance (by 102 times) and optical transparence in the visible spectrum range (by 2-3 times). The friction coefficient is lower by 10-20% but dielectrical, chemical and anti-adhesion abilities are the same. Chart 5 brings us to two conclusions:

1 – radiation modification may be applied to composites because it enhances their firmness;

2 – radiation modification of pure Ф-4PM has good characteristics;

The erosion resistance of Ф4-PM with roughness of the counter body Ra=0.15 is 10 000 times more than that of Ф-4 (table 1).

The radiation modification results in shifting to the spherulite structure of crystalline and reduction of porosity. And the process itself is the premolecular and molecular changes.

The molecular mechanism (destruction of polymer chains induced by radiation modification) results in the reduction of the viscosity of polymer and induces the crystallization process near the pores as the germ of spherulites. Neither filling nor co-polymerization give such results.

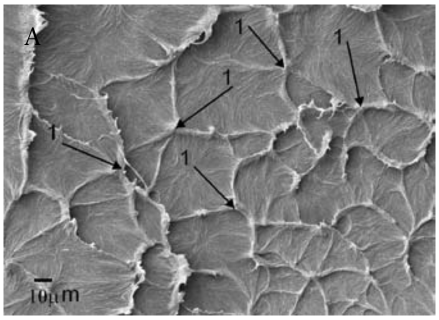
The benefits from this process have not yet been fully understood. But when the new material was used in industry the outcome was rather high: the duration of service life of the parts was 10 times more.

The test period has already gone and the modified polytetrafluorethylene is applied in ball faucets, valves, pumps and hydro cylinders). Due to the high level of its radiation resistance the material was used in air space projects («Electro», «Fobos-Grunt», «Spectr-UF», «Fregat», MTSA) in anti-frictional, thicknening and electrotechnical parts.

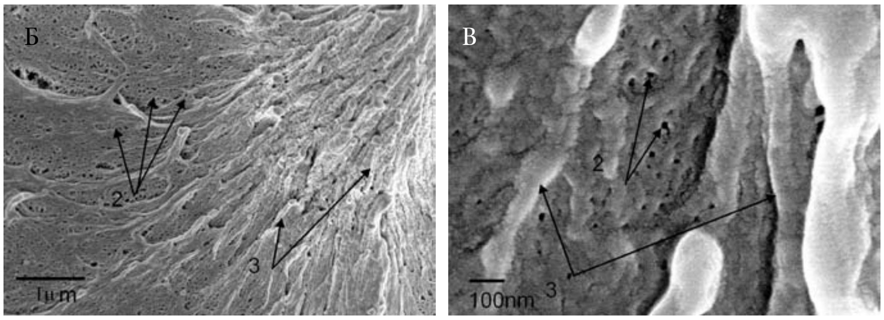
Using of modified polytetrafluorethylene for streamlined antenna cover helps to reach the lowest level of dielectrical permeability and loss tangent. The testing with a lifting vehicle at speed 2.5-3.0 M displays hardness, thermal endurance and erosion resistance of modified polytetrafluorethylene. In comparison with polycarbonate and disulphide of molybdenum fairing streamlined antenna cover helps to improve the technical characteristics of antenna in mm-band: the multiplication factor was 1,5 times higher, the ellipticity coefficient was 10% higher, polar

The Characteristics of Basic Ф-4 and Radiation Modified Fluoroplastic Ф-4Рм

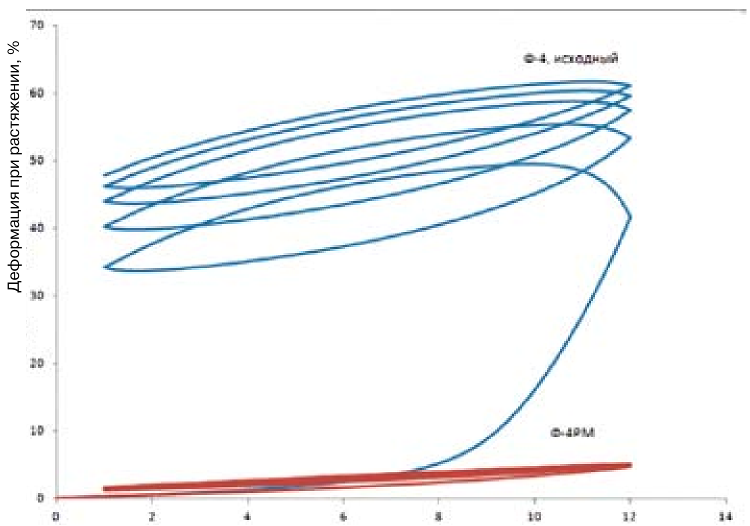
Parameter	Polytetra-fluorethylene	Ф-4PM
Dry friction coefficient in kinematic scheme steel pin disc (Ra=0.15)		
25 kg/cm^2, 1 m/c	0.26-0.27	0.23-0.24
140 kg/cm^2, 1 m/c	Destruction	0.20
Intensity of wearing in kinematic scheme steel pin disc (Ra=0.15) with out lubrication:		
25 kg/cm^2, 1 m/c	1500 mkm/km	0.1-0.2 mkm/km
50 kg/cm^2, 1 m/c	4100 mkm/km	0.3 mkm/km
140 kg/cm^2, 1 m/c	Destruction	1.1 mkm/km



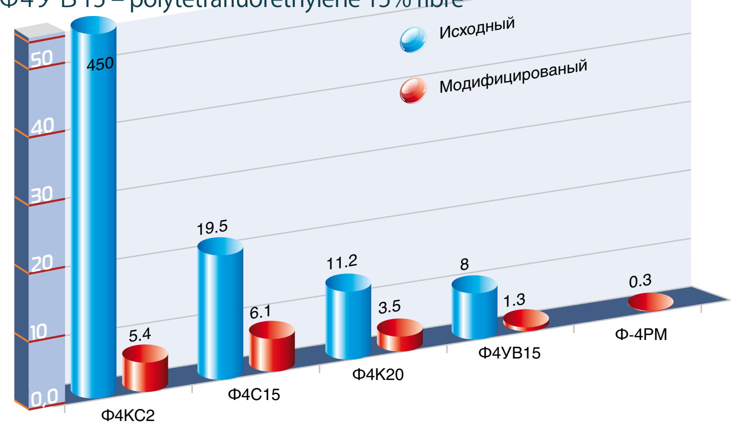
2. The picture of radiation modified polytetrafluorethylene split surface made by a scanning electron microscope.
Zoom: a-500, b-20 000,c-100 000
1-spherulite`s emerging centers
2-nanopores,3-nanofibrils of spherulites.



3. Deformational curve by cyclic stressing: for basic polytetrafluorethylene the deformation is impressing and irreversible; for modified one the deformation is small and reversible;



5. Intensity of wearing of Ф-4 Р М in comparison with the best composites based on basic polytetrafluorethylene and their radiation modifications mkm\km, (5MPa, 1 m\s, steel Ra=0,15)
Ф4 К С 2 – polytetrafluorethylene with 2% cobalt blue
Ф4 С 15 – polytetrafluorethylene with 15% fiberglass
Ф4 К 20 – polytetrafluorethylene 20% coke
Ф4 У В 15 – polytetrafluorethylene 15% fibre



4. Comparison of basic and radiation modified polytetrafluorethylene.

Elastic modulus under stretching	Increases by 1.5-2 times (from 250 to 400-500 MPa)
Elastic modulus under compression	Increases by 1.5-2 times (from 300 to 600-700 MPa)
Compressive strain at 28 MPa for 24 hs	Decreases by 3 times (from 30 to 10%)
Irrevesible part of compressive strain at 28 MPa for 24 hs	Decreases by 10-20 times
Allowed working t^o under loading 1-10 MPa and slip rate (0.5-2 ms)	Increases from 50-100 °C to 200 °C
Creep rate under compression at 25 MPa	Decreases by 60 times
Dielectric characteristics	No change
Radiation resistance	Increases by 100-300 times

pattern minimal width was 4-200 higher, lateral lobe level was 1,5-2 times lower.

There are prospects of applying modified polytetrafluorethylene in reinforcement rods for house heating systems, oil and gas pipelines (in compressors, pumps, faucets, dampers, valves, bolts). To enhance hardness and friction resistance of these joints means to get substantial economic and ecological effect.

Motor building is another important sphere. Composite materials based on polytetrafluorethylene and super molecular polyethylene are used as sliding surface to secure forward-back motion of the backbone sites of car and railway bridges and overpasses. But their characteristics are not as good as those of modified polytetrafluorethylene.

Modified polytetrafluorethylene may also be applied in hydro cylinders of bulldozers, excavators, dump trucks, hydro presses, concrete pumps, mine equipment, hydro manipulators, hydro lifting mechanisms, etc. The list of problems with anti-frictional and thickening materials in hydro cylinders is ample - oil leakage, low functionality, unreliability. The same problems emerge in ship building, power machinery, water equipment, hydro power and atomic power stations.

The research was sponsored by Education and Science Ministry (state contract № 02.523.12.3024).