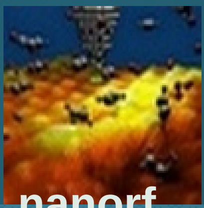
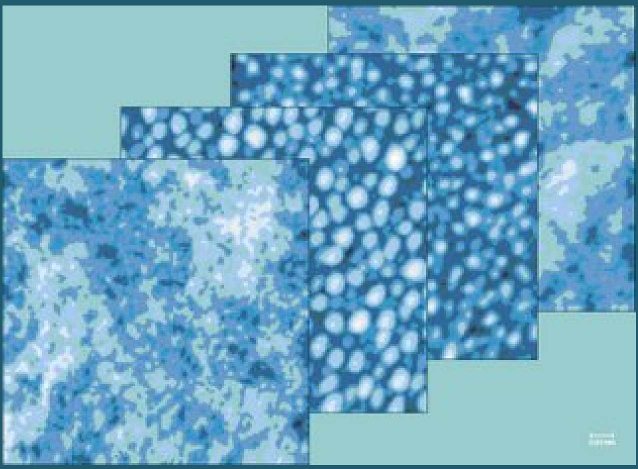


Plexiglass film became smoother



Russian scientists demonstrated precision modification of nanotopography of polymer surface with ultraviolet radiation

Today, the polymer called poly(methyl methacrylate) (PMMA), also commonly known as organic glass or Plexiglass, is widely applied in various fields of science and engineering. In particular, poly(methyl methacrylate) is actively used in nanoelectronics as electron, UV or X-ray sensitive resist; it is often applied in micro- and nanoelectromechanical systems as structural material. Poly(methyl methacrylate) has proved itself to be good in transplantology as nontoxic biocompatible material suitable for fabrication of a number of human artificial organs – intraocular lens, contact lenses, dentures, bone cement and others.

In all the above nanotechnological applications of poly(methyl methacrylate), it is important that one be able to modify the surface in such a way that the parameters of the altered surface correspond precisely to the specific needs of a particular device. One of the polymer parameters having substantial influence upon the working characteristics of the device is surface roughness in nanometer scale.

When using a poly(methyl methacrylate) film as resist, the surface thickness and nanoasperities determine the minimal size of a nanoelement, which can be obtained during a nanolithographic processing. When using poly(methyl methacrylate) as structural material in micro- and nanoelectromechanical systems, the topography of the attrition faces will define the effective force of friction and, therefore, the thermal deformations of the miniature mechanism and energy losses due to the friction. As poly(methyl methacrylate) is applied for microfluidics fabrication, the surface quality of micro- and nanochannels will define the flow regime and flow velocity of the fluids used in the device. In medicine, by changing the surface roughness of a transplantant, it is possible to influence selectively the adsorption of specific proteins, which allows improving biocompatibility of the artificial organ.

In the Institute of Physical Problems named after F. V. Lukin, the State Scientific Center of Russian Federation, Zelenograd, a method was developed and successfully tested which is capable of smoothing asperities of poly(methyl methacrylate) surface in nanometer or subnanometer scales by means of 124 nm wavelength vacuum ultraviolet (VUV). Because of strong absorption of the 200-10 nm wavelength ultraviolet by air, the polymer treatment is carried out in vacuum, which gave the name of “vacuum ultraviolet”.

As the poly(methyl methacrylate) samples are illuminated with the vacuum ultraviolet, the incident photons have enough energy for breaking intermolecular bonds of the polymer. Moreover, under ultraviolet radiation a number of chemical reactions occur which are stimulated by the light quanta (photolysis). Fragments of polymer molecules along with volatile products of the photolysis are continuously evacuated from the working chamber with a vacuum pump. The aggregate of processes evolving from the ultraviolet-polymer interaction will result in smoothing of nanometer scale asperities of the surface topography. One of the main advantages of the described treatment process is that the sample undergoes practically no heating. Furthermore, the modification takes place in just a thin superficial layer of the polymer, leaving the bulk material intact.

According to one of the authors of the method, research scientist Rostislav V. Lapshin from the Solid Nanotechnology Laboratory, the suggested approach permits the surface of the poly (methyl methacrylate) film to be efficiently thinned and smoothed. Until recently, a suitable and easy-to-make test-object was absent from the experimental practice, which would permit reliable registering nanometer scale topography changes during vacuum ultraviolet treatment. While conducting this investigation such test-object was found.

The found test-object represents a poly(methyl methacrylate) film of submicrometer thickness spin-coated on a polished surface of a silicon wafer and then treated in oxygen radio-frequency plasma. During the treatment in the oxygen RF-plasma, the surface of the film undergoes nanostructuring – instead of a smooth surface with the root-mean square roughness of 0.3 nm, some distinct nanograins are formed having the mean lateral size of 66 nm and the mean height of 1.8 nm. The nanotopography of the investigated poly(methyl methacrylate) surfaces was measured with the atomic-force microscope (AFM) Solver™ P4 from NT-MDT Co., Russian Federation by using silicon cantilevers from the Institute of Physical Problems named after F. V. Lukin, Russian Federation.

In the picture, the surface evolution of the poly(methyl methacrylate) film is presented: the original smooth surface obtained by spinning (the nearest one in the figure) -> surface nanostructured in the oxygen RF-plasma -> nanostructured surface after 2 minutes of vacuum ultraviolet irradiation -> nanostructured surface after 10 minutes of vacuum ultraviolet irradiation (the farthest one in the figure). The surface nanostructured after 10 minutes of vacuum ultraviolet irradiation is completely equivalent by its roughness parameters to the smooth original surface obtained by spinning.

Beside the smoothing effect, an interesting phenomenon was discovered by the scientists when analyzing the surface Fourier spectra. The poly(methyl methacrylate) surface nanostructured in the oxygen RF-plasma turned out to be partially ordered. Until recently, the order in positions of structural surface elements was only observed in the diblock copolymers, for example, in polystyrene-poly(methyl methacrylate) (PS-PMMA).

To learn more about the suggested method and the obtained results, see the February issue of the Journal of Surface Investigation for this year, paper “Vacuum ultraviolet smoothing of nanometer-scale asperities of poly(methyl methacrylate) surface”

Tags: modification, nanotopography, plexiglass, polymer surface, ultraviolet radiation