TECHNOLOGY OF TRACK MEMBRANE MANUFACTURE AS A BY-PRODUCT OF SIMULATION OF SPACE DEBRIS INTERACTION WITH SATELLITE'S SURFACE

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ABSTRACT

A beam of microparticles with diameter from 1 to 100μm and velocity up to 12km/s was created in a vacuum chamber by explosive generators. Using a metallic foil or a polymeric film as a target led to making of track membranes. The results of an investigation of the structure and properties of such track membranes from different metals and alloys and polytetraftuoroethylene film are described and analysed. Such metallic foils can be used in space experiments of LDEF or EuReCa type for measuring size of fine dispersed particles and their incident angle and velocity. In addition a capacity of this membrane to work in a chemically aggressive environment, at high temperatures and at high pressure overfall can potentially find an application in different chemical, biological and food industry technologies.

1. INTRODUCTION

According to the majority of space debris models fine dispersed particles with a size of less than 1mm make up 90 to 99% of the full number of particles. It is known also that an interaction of these particles with spacecraft results in halting normal functioning of its various elements (solar batteries, optical surfaces and others).

2. FACILITY

For study of interaction processes of such particles with a surface of a space vehicle an experimental facility was created (fig.1). A basic part of this facility is the vacuum chamber of volume circa 20m^3 and flight base of 6m. The chamber was pumped out by a system of vacuum pumps (1) up to a pressure of 6*10^{-5} mm Hg. To freeze oil/water steam and other components inside

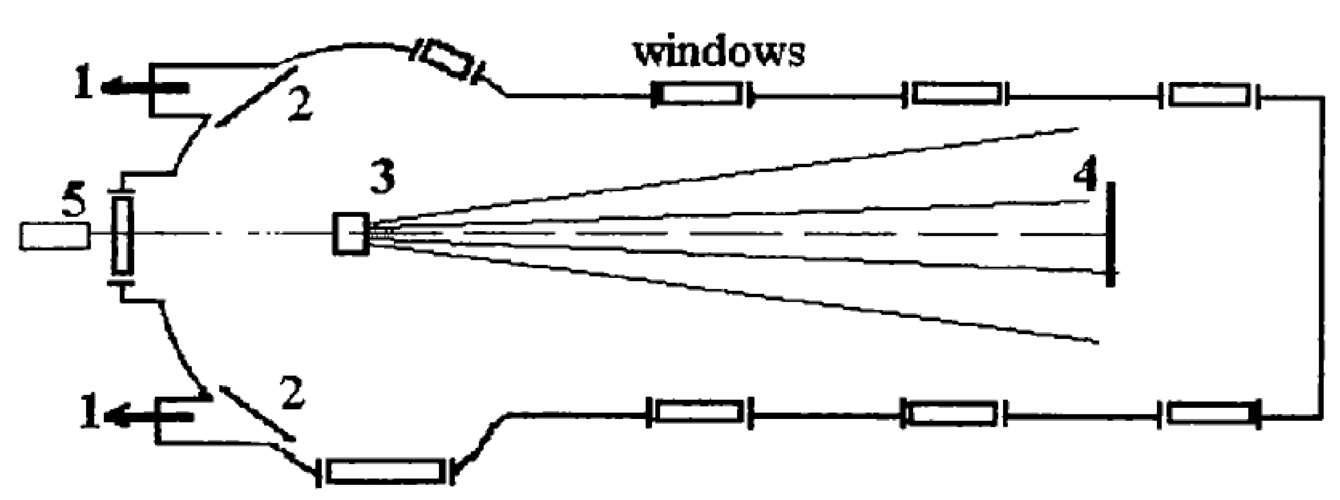

Fig.1. Scheme of experimental facility

the chamber two screens (2), cooled by liquid nitrogen were mounted. In the left part of the chamber a generator (3), insuring an acceleration of a group of model particles to average velocity up to 12km/c, was located. The long cylindrical tube on the right-hand side of the facility is intended for installation of test samples and instruments which measure the parameters of flow and its interaction with the samples (4). Butt-end and cumulative explosive systems were used as generators. A detonation of the explosive generators was carried out with the help of the high-voltage discharge or laser (5). Calibrated powders of various materials (Al, Cu, Cr, W, stainless steel and others) with the diameters from 0.1 up to 500μm were used as model particles. With the purpose of prevention of particles' destruction or sintering in a detonation shock wave, the particles were put into a matrix from a special material. A choice of optimum explosive substance, charge and matrix design allowed the creation of explosive generators which practically did not give rise to collateral condensed products of explosion. These condensed products can be comparable in size to model particles and result in "background" effects on the target surface and these effects are difficult to separate from investigated ones. Various materials (Al, Ti, Ta, W, Ge, Si, stainless steel, glass and quartz of the different sorts and others.), and real elements of solar batteries, heat-shielding covers, mirrors and radiative coolers were used as test samples. The facility was equipped by the necessary diagnostic instruments for a determination of parameters of a particle flow and its interaction with a test sample surface. In particular, one of the techniques of flow density measurement was the use of a foil - mute witness - as a sensing element. This technique suggested an idea to the authors about an opportunity of production of membranes from different materials at the facility. We have named the membranes obtained by this technology as shock track membranes (STM).

3. PROPERTIES OF SHOCK TRACK MEMBRANES

The structures of the STMs from Al, Cu, Ti, Ta, W, stainless steel, and polytetrafluoroethylene film were studied with the help of the electronic microscope

TESLA BS-340 (Ref.1). The thickness of foils and films

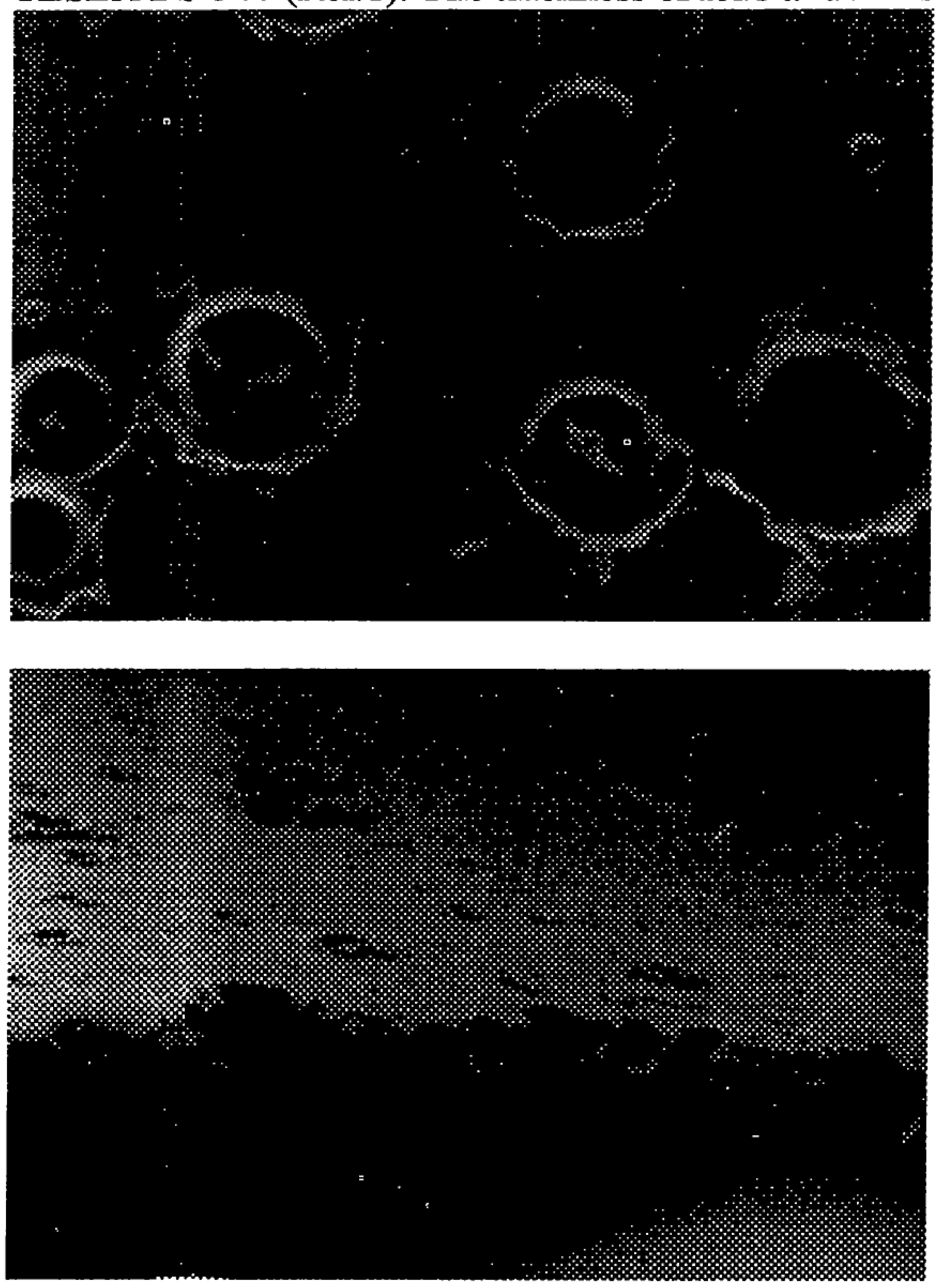

Fig.2. Microphotos stainless steel STM

was from 10 to 100μm. On fig.2 microphotos of a membrane from stainless steel are presented. One can see a typical structure of pores of STM: the inlet is surrounded with a cushion, the thickness and height of which depends on the size of a particle and thickness of an initial foil or film (it should be noted that in case of practical use of such membranes, these microroughnesses can be eliminated by electrobuffing). The diameter of pores is close to the particles' diameter, and their form is close to cylindrical.

The pore diameter distribution functions for several STMs are shown on fig.3. Typically a half width of the distribution function on half of its height makes 20-50% for investigated metal STMs and about 100% for polytetrafluoroethylene STMs. The size of this disorder depends, first of all, on distribution functions of model particles on the sizes and velocities and on properties of an initial foil or film (thickness, uniformity, hardness, etc.). An availability of rather large number of superficial dents for some combinations of experimental conditions is a consequence of these distribution functions also.

The selective properties of STMs were evaluated with the help of filtration of 0.002-0.5% colloidal solutions of calibrated polystirol latex particles with a diameter d=0.5 and 1.0μm, spheres from corund (d=0.5 - 2.0μm)

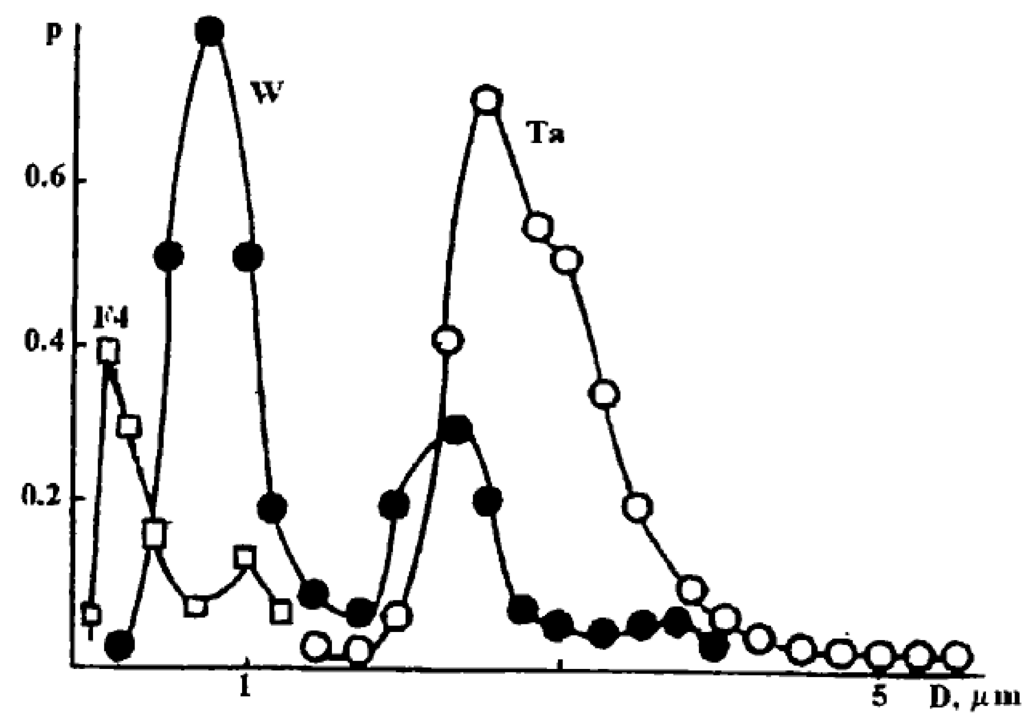

Fig.3. The distribution function of pores' sizes for Ta, W and polytetrafluoroethylene STMs

and porous silica (d=5-50μm). The concentration of microparticles before and after filtration was determined by electron-microscopic examination. On fig.4 relationship between aluminium membrane selectivity and ratio of microparticles diameter to average diameter of pores is presented.

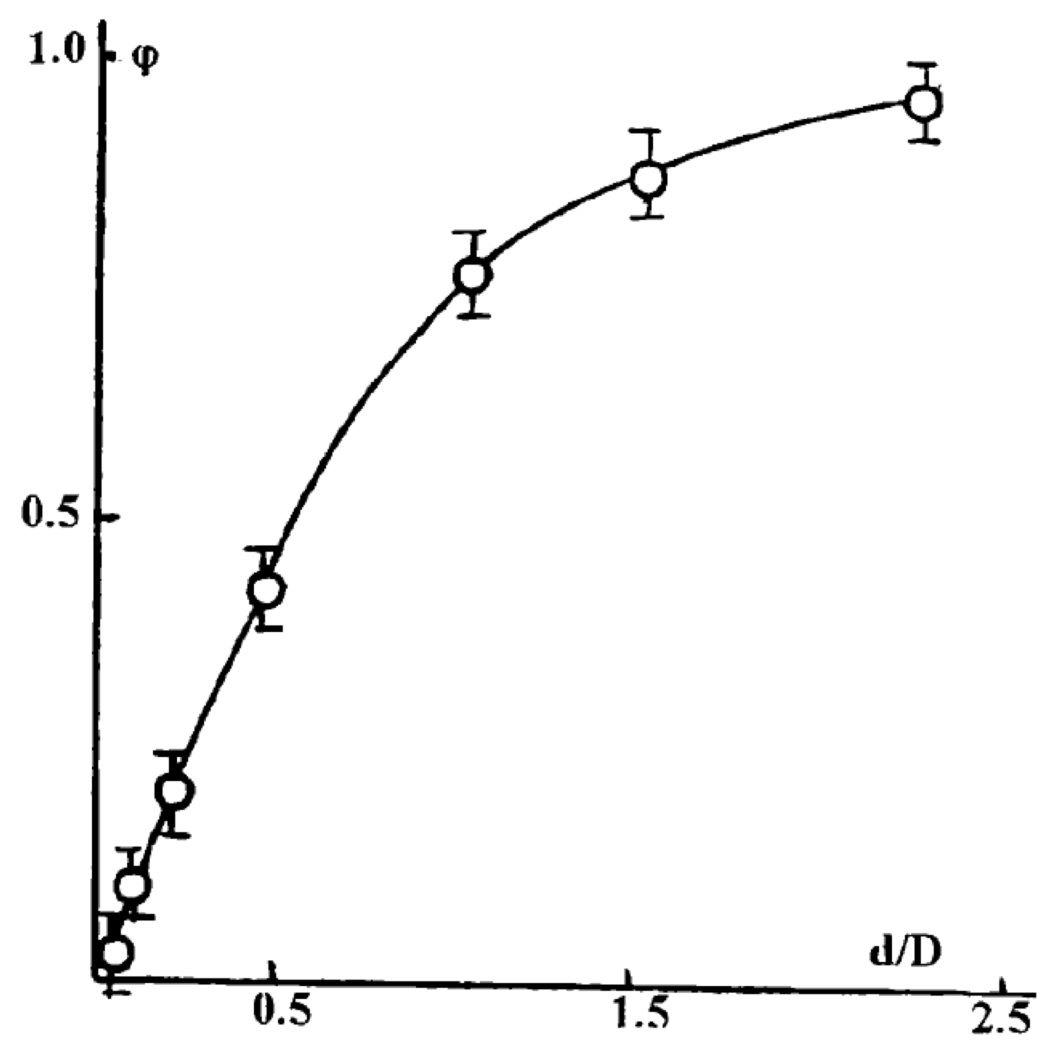

Fig.4. Selectivity of AL STM as a function of ratio the diameter of particles filtrated to average pores' diameter

4. POSSIBLE APPLICATIONS

First of all, in the designed facility it is possible to carry out resource tests of space vehicle elements at particle velocities simulating those of space conditions. Data on interaction of fine dispersed particles of space debris at velocities about 10km/s are new and being systematised (on velocities and materials) they could be used for getting new information from results of such experiments in space as LDEF, EuReCa and future similar experiments.

By attaching the films/foils to a very soft and rather thick substrate, in which the debris particle going through a foil forms a channel, it is possible to determine the size and incident angles of a particle. The length of the channel made can be used to determine the energy of the particle. If the time of impact and orientation of satellite are known, this combined information allows an intelligent assessment of the distribution of debris particles on orbits. It should be noted also that the foil/film test panels are lighter than solid ones and for given mass one can enlarge their surface.

The potential industrial applications of STMs are defined by its special attributes i.e. ability to work at high temperatures, at significant pressure overfall and in chemically agressive environment. Few existing membranes used in industrial applications have the ability to operate effectively in such extreme environments giving the STM a decided advantage over them.

It is essentially important for practical production of STMs to create an automated facility with repeating explosive generator and mobile tape of a foil or film. The productivity of such facility would be many times higher in comparison to experimental one described and by assessments of the authors, makes manufacturing of the STMs economically viable.

5. REFERENCES

1. Evdokimov A. N., Kirillov A. G., Smirnov V .A., Zagorsky D. L., Mchedlishvili B. V. Structural and Selective Properties of New Porous Media -Shock Track Membraines, *Colloidal Journal*, Vol.57, No.6, 912-914, 1995.

Chapter 4

Modelling of Space Debris and Meteoroids