# EROSION ACTION OF THE SPT JET ONTO SOLAR BATTERIES OF METEOR-PRIRODA SPACECRAFT

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*The results of laboratory experiment concerning the SPT jet action onto of Meteor-Priroda performances (the SC was launched in 1987) are represented in the paper. The SB fragment containing 8 groups of 16 elements in every one was investigated. The action was done with the help of SPT thruster in vacuum chamber with oil free pumps. The thruster operated under 300 V, 2.2 A. In this case the current density on the panel was ~0.05 mA/cm2. The duration of action was 40 hours. As a result of such action the power of the solar battery was decreased sufficiently (on 25%). The reason of power reduction was the following fact: on the surface of protected glasses the micro relief in the form of inclusions and grooves are formed. The results of the experiment can explain data obtained under real conditions.*

## Introduction

Nowadays in order to solve the tasks of spacecraft (SC) correction and stabilization electro-rocket thrusters are used more often. First of all it is due to the fact that ERT has high specific performances and so propulsion system mass can be reduced and payload – increased. But at the same time ERT jet, which is the dense flow of high-energy ions, can acts negatively on to different elements and systems of the SC, including solar batteries (SB).

Therefore in 1978 the stationary plasma thruster IOL-2 was tested onboard the SC Meteor-Priroda. During this test the unique space experiment was carried out. During this experiment the thruster was operating continuously for 300 hours and its jet hit to the SC SB. During this experiment is was found out that electric power of the radiated segment of the SB dropped on 35% [1] (ion flow from the ERT had a density – 0.025 mA/cm$^2$; ion energy – 100eV). So one can see that jet action onto the SB panels can be great and such influence should be taken into account under SC design.

Unfortunately nowadays there is not single opinion about mechanism of ERT jet action onto the SB. Jet ions bombarding the SB surface can cause different physical phenomenons spoiling SB energetic performances. Such phenomenons can be the following ones: sputtering of a protecting quartz glass cover, antireflecting coatings, destruction of a commutative elements, overheating of a photo emission transducers, SB surfaces contamination by sputtered products from the SC structure or the thruster.

In this paper it is represented the results of laboratory experiment simulating real conditions of Meteor-Priroda SB operation. Such simulation permits to clarify mechanism of the ERT jet action onto the SB.

## Experimental procedure

The main idea of the experiment is: to radiate a segment of the SB by plasma jet for a long time (40 hours). Structure and parameters of the tested segment was completely the same as Meteor-Priroda SB had. The segment consists of 8 groups; each group contains 16 solar elements. The elements are connected parallel – in serious 4×4. Solar element sizes – 2×2 cm; group size – 8.8×9.2. The SPT-70 was used as a source of ions. The thruster operated under discharge potential 300V; discharge current - 2.2 A; propellant – Xe. Thruster and SB segment disposition is represented in the fig. 1. In this case ion current density on the SB surface was ~ 0.05 A/cm$^2$; ion average energy – 100…150 eV. The experiment was carried out in the vacuum chamber with oil-free pumps under pressure $10^{-4}$ torr.

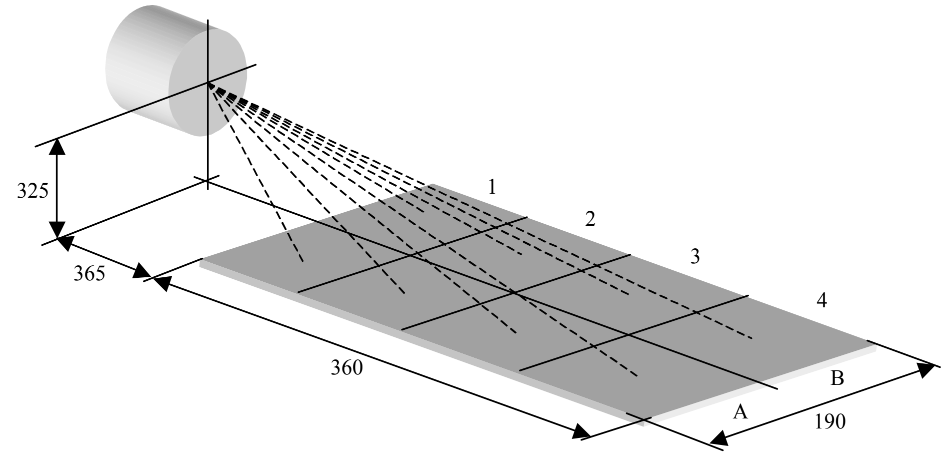



*Figure 1: Thruster and SB segment disposition*

During the experiment the short-circuit current for every group of element were recorded. The measurements were done before and after action. As a source of light the lamp is used. The exposition was 100 W/m$^2$ and was controlled with photometer.
Protecting glass (from two characteristic points of the SB) was examined by microscope and spectroscope methods after action.

**Results and discussion**

In the diagram fig.2 one can see short-circuit current losses for every group after action.

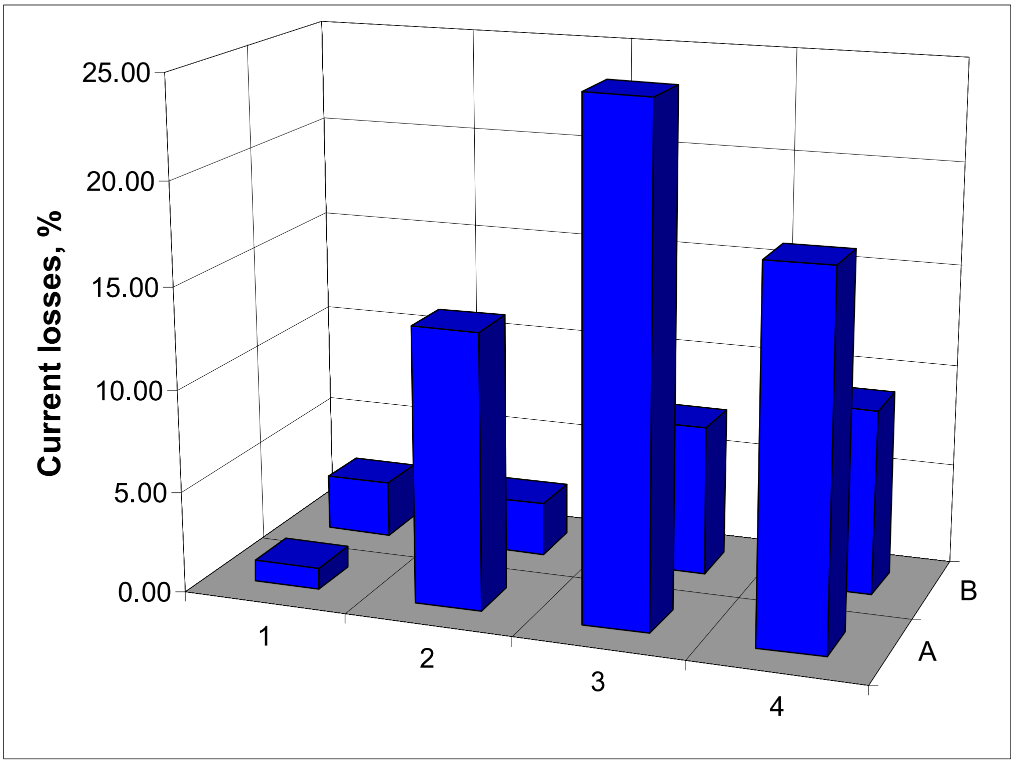
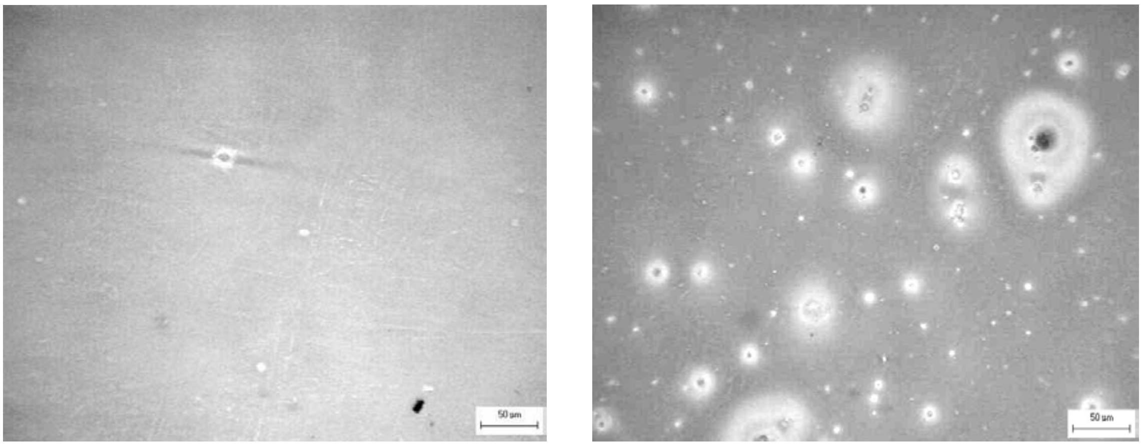



*Figure 2: Short-circuit current losses for every group after action*

Sufficient current losses for the group $A_3$ are due to the fact that on the glass surface the cloudy (non-transparent) coating was formed (one can see it visually). Some patch, formed after action, was found out on the glass surface with the help of microscope (fig. 3).



(a) (б)

*Figure 3: Patch on the glass surface (group $A_3$): a) the glass surface before jet action; b) after jet action.*

Glass spectral transparency weakness was happened in the whole range of wavelength. In the area of short wavelength one can see great absorption (fig. 4).

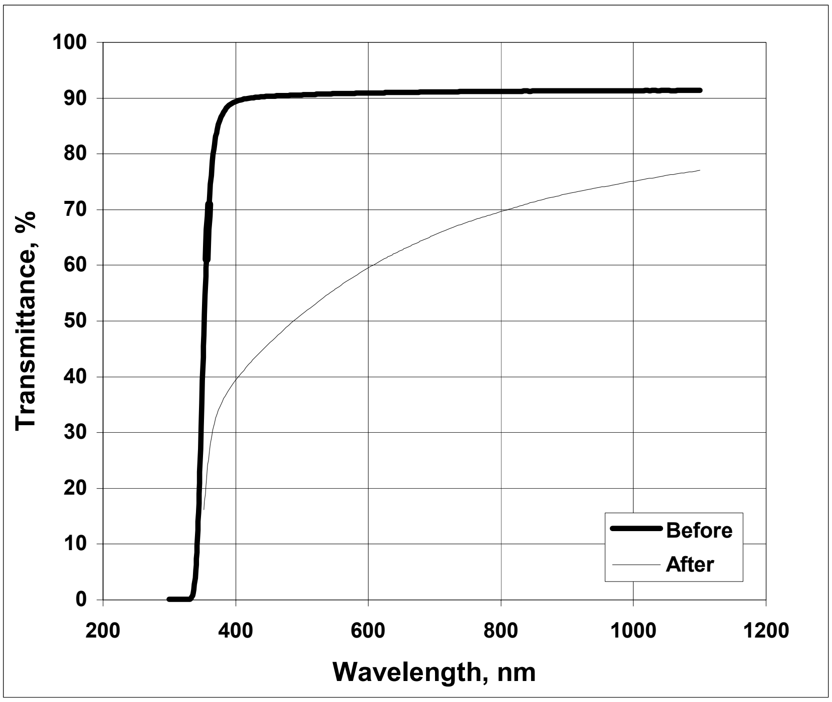



*Figure 4: Glass spectral transparency change for the group $A_3$*

May be that glass cloudy was happened due to the fact that sputtered products from vacuum chamber structure were deposited onto the glass surface (only the line A) was spoiled. For the line B transparency losses was less in two times. At the same time cloudy effect was not on all elements of the group, and cloudy area itself had legibly boundary. So it is possible to assume that cloudy effect is the result of joint influence of plasma jet and flows of deposition and it has threshold character.

In the group $B_2$ and $B_3$ the changes are qualitatively differ. There is no patch, but there are long scratches directed along the line of ion flow action. The length of the scratches is closed to the length of the solar elements. Cross size is a share of microns. Besides scratches on the glass surface a few craters with size 20 – 30 microns were found out (fig. 5). Transparency losses for these glasses are sufficiently less even absorption is also taken place (fig. 6).

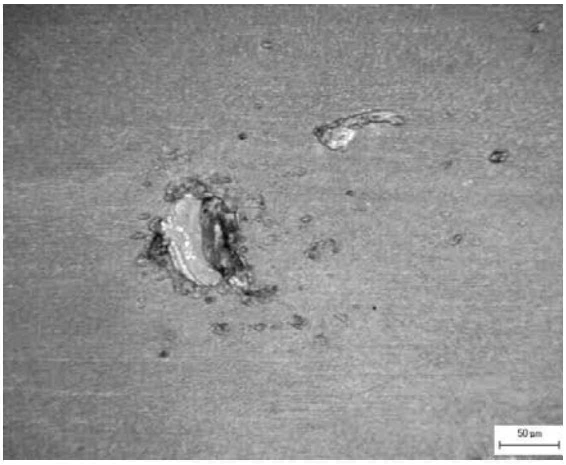



*Fig.5 Scratches and craters on the solar elements surface for the group $B_3$*

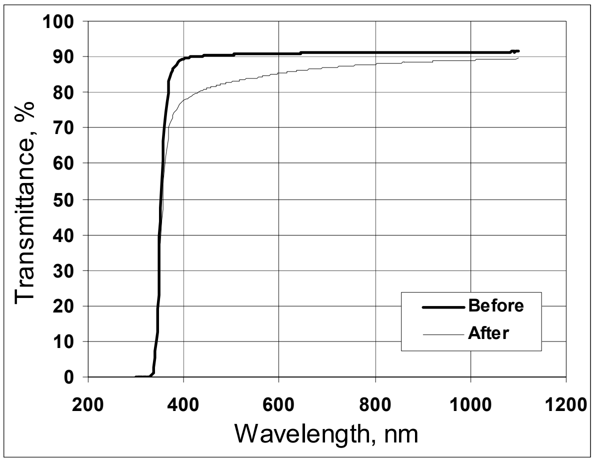



*Fig.6 Glass spectral transparency change for the group $B_3$*

Scratches appearing can be explained by the following way: technical non-uniformity in the glass is displayed. It is necessary to point out that erosion depth was 3 – 5 μm under mentioned parameters of the flow. So micro-relief development with typical size ~ 1 μm can be assumed as possible. Light flow weakness by the scratches depends insufficiently on wavelength and according to fig. 6 is about 2% (λ=1000 nm). Large craters appearing obviously can be explained also by technology reasons. Under jet action technological patch and un-uniformity become contrast and develop into large craters.

## Conclusions

So, it is possible to point out several mechanisms of the ERT jet action onto the SB surface. Firstly, surface micro-relief formation due to non-uniform etching of the glass. Secondly, glass cloudy by the account of joint action of the jet and sputtered product flows. In the first case transparency losses are units of percents and cased by light scattering by appeared non-uniforms. In the second case – can reach dozens of percents and caused by light absorption by formed surfaced structures. Cloudy formation in the case if background particle flows are presented, can have threshold character and depend greatly on ion energy and incidental angle.

Experimental results show that if the ERT jet acts onto the SB panel under some conditions, sufficient degradation of the SB performances can happened. May be that great power losses occurred onboard the SC Meteor-Priroda can be explained by joint action of the jet and sputtered product flows from the SC structure to which the jet hit. In particular, it can be antennas, placed on the SB panels, body structures or current-conduct elements of neighbor groups. But for reasons clarifying, it is necessary to carry out an additional experiment.

## References

1. Sheremet'evsky N.N., Khodnenko V.P The main results of the ERT with the SPT (IOL-2) space test onboard the SC Meteor-Priroda. All-Russian conference about plasma accelerators and ion injectors, Moscow, 1978, pp.317 – 321 (in Russian).