Radiation Resistance Tests of Solar Cells for Space Applications

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Abstract: ***The radiation resistance of space technology components is gaining importance nowadays. This trend is related to the development of new approaches to the construction of small satellites, the so-called CubeSat, whose creation is often caused by already renowned and space-based companies, but on the contrary, scientific research organizations or consortia of smaller private companies, universities, and schools. The increasing demand for satellite durability, stability, and lifetime, as well as the lowest purchase price, emphasizes the use of readily available but also proven durable components within a range of expected functional conditions. Research CentreŘež, Ltd, tests components for resistance to gamma and neutron radiation. And since the tests themselves often bring many surprises to scientists themselves, this article brings a small tasting of new solar cell endurance results for space applications under the influence of gamma and neutron radiation.***

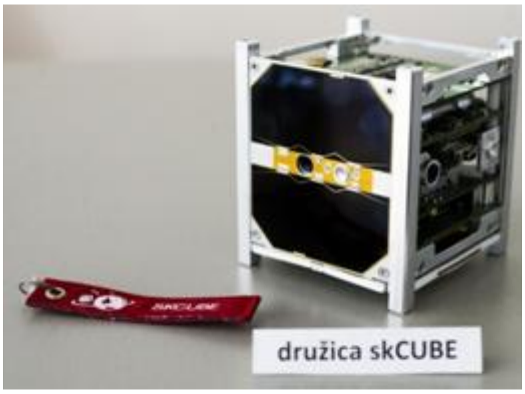
Keywords: Radiation resistance, CubeSat, neutron irradiation, solar cell, I-V characteristic, space application

1. Introduction

The project of solar cells radiation testing dedicated to space applications was started in 2018 and the subject of study was radiation endurance by escalated doses of gamma radiation. The results were unexpectedly surprising in favor of the robustness of the samples, and in 2019, a follow-up project focused on another part of cosmic rays, this time neutrons. The aim was to determine whether and to what extent the cells are resistant to this type of radiation and how the degradation of the material is manifest in their electrical properties.

1.1 Samples and Technical Equipment

For this purpose, two types of solar cells were included in the study. The first was the 3G30A manufactured by AZUR SPACE Solar Power GmbH (1). The second is SMX TASC-02X25 from SPECTROLAB, Inc. (2), belonging to the holding company Boeing Corp. The reason for the selection was the previous consideration of both types for installation on the first Slovak satellite skCUBE (Fig. 1) by RMC, Ltd., which provided for this satellite solar power, battery charging and power supply. RMC, s.r.o. (3) is a partner of the Research CentreŘež, Ltd. (CVŘ) (4) in both projects focused on radiation resistance of solar cells. AZUR SPACE was then selected as the solar energy source for skCUBE, and CubeSat was launched into Earth's orbit from the Shriharikota (or Satish Dhawan Space Center) in India on June 23, 2017 (Fig. 2) .



Obr. 1: Solar cells installed at skCUBE (6)

Obr. 2: Satish Dhawan Space Centre (7)

1.2 Gamma radiation and its influence on solar cells

In the first project, the main topic was the effect of gamma radiation on both types of solar cells. 6 pcs of AZUR SPACE photovoltaic cells and 36 pcs SPECTROLAB were ready for testing. For testing purposes, the capacities of the Gamma irradiation facilitywere used. It is a newly reconstructed irradiation facility, which has a unique technology called experimental box. It is a cylindrical double-casingstainless-steel box, thanks to which its construction can achieve a considerable range of environmental conditions in its internal volume. The box can be heated up to + 400 °C or cooled to cryogenic temperatures up to - 196 °C, which corresponds to the temperature of liquid nitrogen flow into the double-casing space of the box. It is also possible to achieve a high level of vacuum inside because of installed turbomolecular pump.

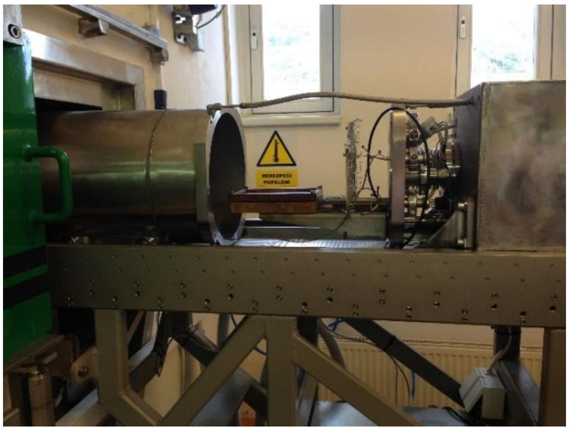
1.3 Neutron radiation and solar cells

In the second project, neutron radiation and its impact on the electrical properties of photovoltaic cells were tested. The project was basically a follow-up research and for this reason the same samples were used. The samples were reduced to 3 pcs AZUR SPACE and 3 pcs SPECTROLAB over time to obtain a maximum irradiated dose of 12 Gy. The reason for reducing the number of samples was the limitation in the space around the neutron source, where radiation can be considered as homogeneous and very long irradiation times versus considerable scientific and research involvement of the irradiation facility in other projects. The irradiation took place in the Laboratory of Neutron Generators of CVŘ, where the source of 4 MeV neutrons was the Cf^{252}. The irradiation facility itself is a unique technology. The radionuclide source in the form of a pellet is "injected" by compressed air in the transport tube from the area of the shielding box by remote control into the irradiation room.

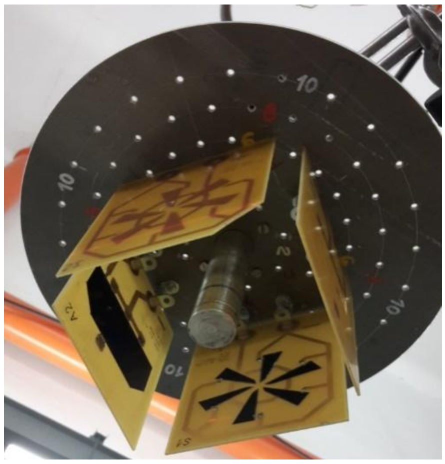
2. Tests of samples

In the case of a gamma irradiation testing, a data from Swiss CubeSat's temperature sensors have been obtained and it was decided about irradiation during two temperatures: + 35 °C and - 35 °C. These two extremes correspond to heating / cooling the outer cask of a polar orbit when the CubeSat is exposed to sunlight and when it is hidden by the Earth's shadow. To reach the indicated temperatures, the samples were divided into two equally numerous sets and placed in an experimental box (Fig. 3).One set was irradiated at + 35 °C and the other at - 35 °C. Samples were irradiated to single cumulative doses of 0.5, 1, 2, 10 and 30 kGy. After each dose irradiation, the samples were transported to the laboratory of RMC, s.r.o., which not only provided the solar cell samples remaining after skCUBE construction, but also developed a special lighting chamber. It is intended for measuring of electrical properties of tested solar cells. Voltampere (I-V) characteristics and performance data of the individual solar cells were the result of data acquisition from the lighting chamber.

Neutron radiation testing then proceeded in a similar way as in the case of gamma irradiation, but this time at room temperature. A support structure for solar cells was prepared around the end capsule where the pellet with the Cf^{252} source is injected (Fig. 4). This task was to keep the samples at a enough distance while maintaining sufficient neutron flux homogeneity. The cumulated doses were then 0.1, 0.3, 1 and 12 Gy. In the case of neutron radiation, it was necessary to proceed at lower doses because there were no known studies of the effect of 4 MeV neutrons on the material of the tested types of photovoltaic cells. Caution was therefore appropriate. As in the first project, the samples were evaluated for electrical properties in the lighting chamber after each exposure to a determined dose.



Obr. 3: Samples before irradiation in Gamma irradiation facility



Obr. 4: Samples before irradiation in the Laboratory of Neutron Generators

3. Gamma and neutron laboratory results

The aim of both projects was to evaluate the effect of gamma and neutron radiation, i.e. two components of cosmic radiation, on the electrical parameters of photovoltaic cells intended for use in space. Evaluation of the measured results and their comparison in the non-irradiated state and irradiation to the maximum dose that was selected for the individual radiation components was performed. Based on them, it was determined whether and to what extent the selected types of solar cells degraded their properties.

The results of the solar cells irradiationby gamma radiation were surprising. Not only that the temperature effect was not prove at + 35 ° C and - 35 ° C range and CubeSat can cycle temperatures within this range without affecting the electrical properties of its solar cells, but the data from the exposure chamber itself came in favor of considerable radiation resistance. In Graph. 1 and Graph. 2 shows the I-V characteristics of AZUR SPACE and SPECTROLAB solar cells after accumulated doses of gamma radiation. By comparing the states between the non-irradiated state (0 kGy) and the irradiation to the maximum dose (30 kGy), the

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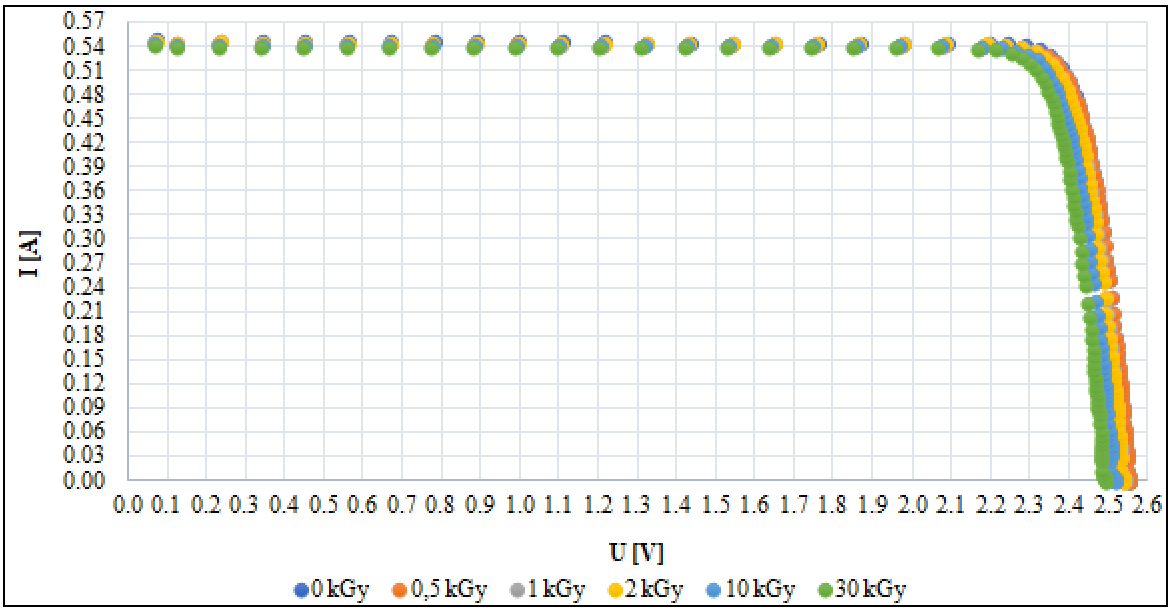
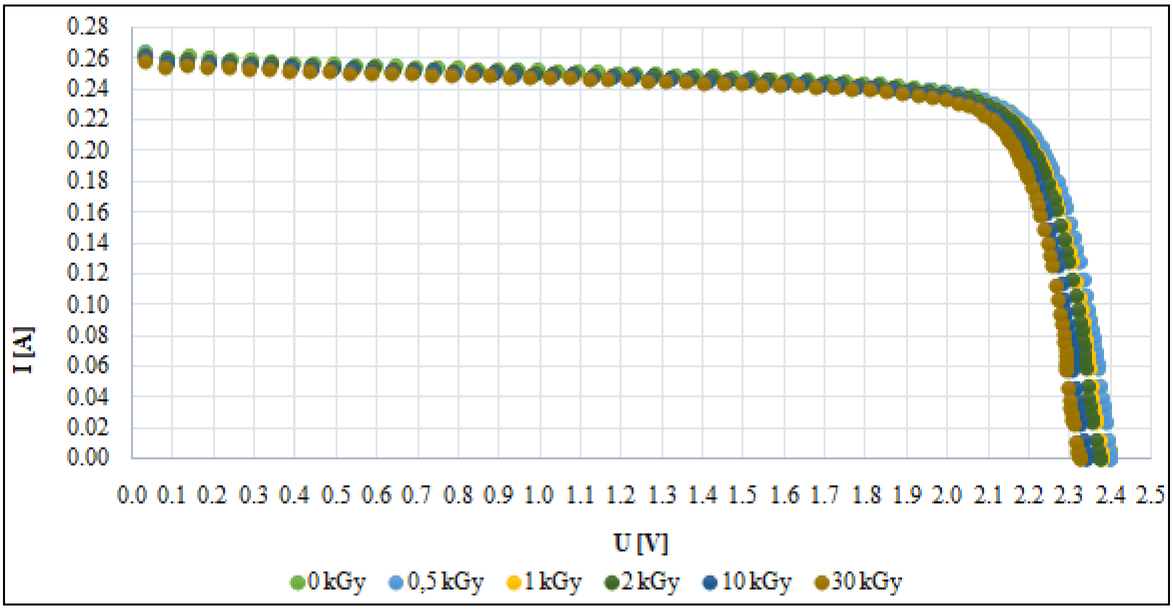
selected electrical parameters can be evaluated, i.e.: no-load voltage drop of 2.3% for AZUR SPACE samples and 2.5% for SPECTROLAB. Furthermore, the short-circuit current dropped by 1.3% for AZUR SPACE and 2.7% for SPECTROLAB. And an important parameter is the decrease in maximum power, which decreased from 1.247 W to 1.201 W and thus decreased by about 3.7% in the case of AZUR SPACE and SPECTROLAB cells from the original value of 0.489 W decreased to 0.471 W and thus decreased by 3.7%.

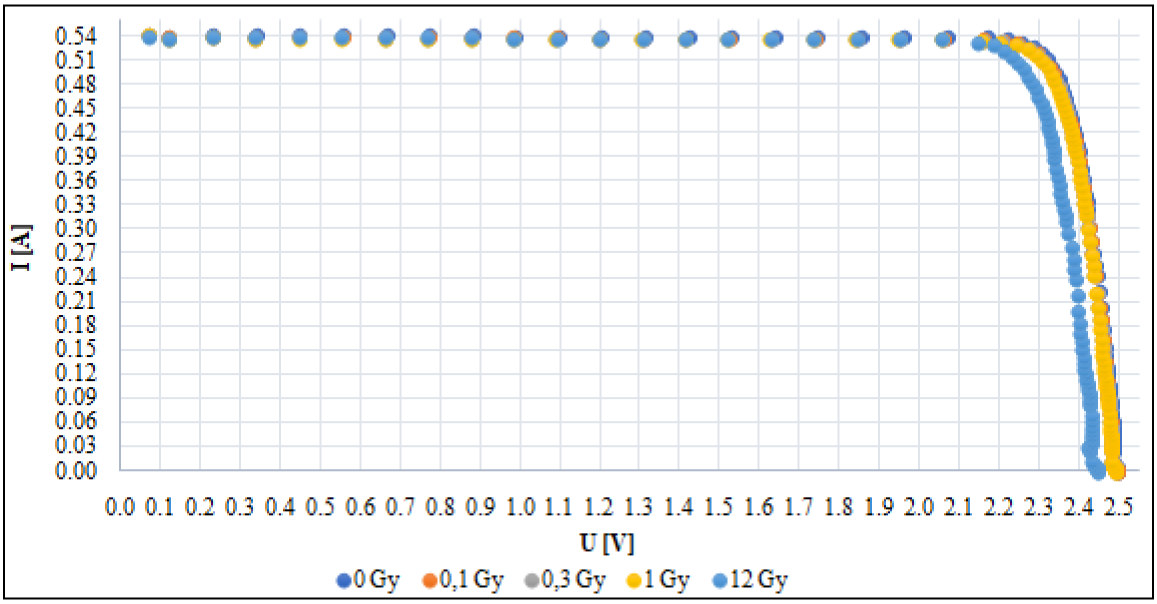
Based on the measured data after irradiation of solar cells with neutron radiation, the graphs can be plotted: Graph. 3 and Graph. 4 I-V characteristics of tested solar cells. By compare the results of the non-irradiated state (0 Gy) and irradiation to the maximum dose (12 Gy), it is possible to determine the changes in the monitored electrical properties. The open-circuit voltage drop is 2.1% for AZUR SPACE samples and 2.5% for SPECTROLAB. Furthermore, the short-circuit current dropped by 0.5% for AZUR SPACE and increased by 0.9% for SPECTROLAB. The AZUR SPACE maximum power dropped from 1.204 W to 1.156 W, thus decreasing by about 3.9%, and from SPECTROLAB cells, it dropped from 0.471 W to 0.449 W, thus decreased by 4.6%.



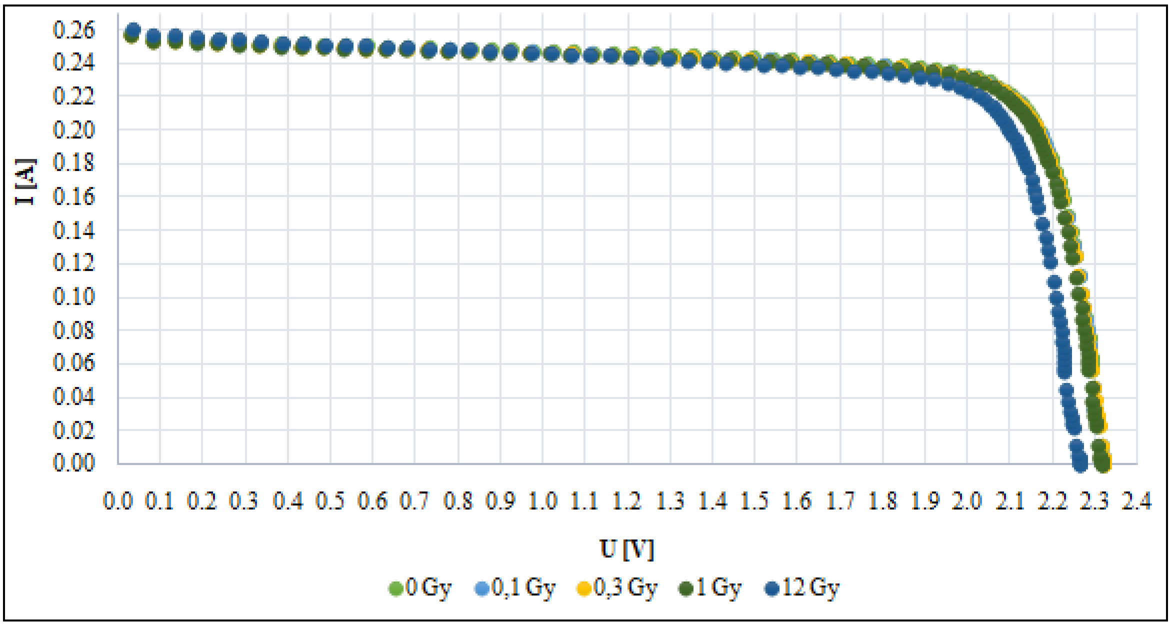
Graph 1: I-V characteristics of solar cells Azur Space samples - gamma irradiation.



Graph 2: I-V characteristics of solar cells Spectrolab samples - gamma irradiation.



Graph 3: I-V Characteristics of solar cells Azur Space samples - neutron irradiation



Graph 3: I-V characteristics of solar cells Spectrolab samples - neutron irradiation

By comparing the measured data, it can be stated that the solar cells of the tested types show considerable radiation resistance and robustness in the range and conditions of the performed irradiation. Radiation testing appears to be an increasingly important discipline in the space industry. With the rapid development of opportunities for participation in various space projects, which are primarily aimed at supporting universities and small and medium-sized companies and where often not certified but commercially available components are used, such tests are applied in predicting durability and, in particular, expected lifetime, whether individual parts of the satellite, but also the whole system. For example, solar cells are among the basic functional elements of every CubeSat. At the same time, these tests will provide answers to scientific questions not only in the field of material sciences, but also valuable information for manufacturers and designers of artificial Earth satellites.

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