Solar Cells for Space Applications - Gamma Radiation Resistance Testing for Polar Orbit CubeSats

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Abstract: ***This paper summarizes the results of electric properties measurement of degradation of solar cells for space applications due to gamma radiation. Two types of solar cells from companies AZUR SPACE Solar Power GmbH and SPECTROLAB, Inc. were tested. The solar cells samples were exposed to the different doses of ^{60}Co gamma radiation source under +30/-30 °C temperatures placed in a special experimental box. The gamma radiation doses were increased as follows: 0, 0.5, 1, 2, 10 and 30 kGy. The I-V characteristics, open circuit voltage, maximum electric power, etc. were studied after every irradiation in the illumination-measurement chamber.Two primary aims of this study are as follows: 1. to investigate the changes in electrical properties under various gamma radiation doses and 2. toascertain the temperature effect of low and higher temperatures to the proper function of the solar cells.In cooperation of Research Center Rez Ltd. (Department of Diagnostics and Qualification) with the Slovak company RMC, s.r.o., the unique results of solar cell degradation were obtained in the conditions of space application, i.e.combination of gamma radiation and elevated/low temperatures simulatingspace environment conditions.***

Keywords: Solar cells, gamma radiation, experimental box, I-V characteristic, maximum electric power

1. Introduction

So So far, solar cells have been one of the cheapest, most reliable and inexhaustible energy sources in the Earth's orbit. These are very important components for proper function of the most of the electrical devices onboard CubeSats. However, in a space environment, such facilities are exposed to the conditions which are not very suitable conditions for their operation. . Radiation in the form of cosmic radiation, alternating low and high temperatures, depending on orientation towards the sun, etc. have a significant impact on the operation and functionality of satellites. Because of the facts mentioned above, it is very important to determine the electrical changes caused by radiation. An objective of this study was to investigate the determinations of solar cells degradation under one component of cosmic radiation - gamma radiation. This study, therefore, was set out to assess the effect of +30 °C and -30 °C temperatures to degradation of electrical properties. Data for this study were collected using irradiation in the gamma irradiation facility and measuring the I-V characteristics in the illumination chamber (Fig. 2). The findings should make an important contribution to the field of improvement of life prediction and equipment failure capability. This study is unable to encompass the entire range of cosmic radiation and it is focused only on a single component: gamma radiation. A full discussion of other parts of cosmic radiation lies beyond the scope of this study. In the vicinity of Prague, in the Research Center Rez Ltd., a newly equipped Gama Irradiation Facility was recently established. A special test sample irradiation box (Fig. 1), in which cryogenic temperatures (-196 °C) can be reached by cooling with liquid nitrogen, is a unique to this facility. High temperatures (up to +400 °C) can also be achieved thanks to the heating cassette. In addition, a high vacuum condition can be prepared by using a turbomolecular pump. The source of gamma radiation is 60Co emitter of 200TBq. Moreover, the possibility of irradiation at different dose rates, which can be corrected by suitably selected irradiation geometry, is an advantage. The gamma irradiation facility is primarily used for radiation aging testing of equipment and materials for nuclear power plants where it is important to demonstrate the endurance and robustness of the material. Due to the characteristics and parameters of the technology, its use is also suitable for simulation of space conditions. Cooperation with the Slovak company RMC s.r.o. (1), which has developed and produced a power supply system for the first Slovak satellite skCUBE(Fig. 5) (solar power source, battery charging, and power supply)has been established. Consequently to the development of skCUBE and solar cells, which were still available after the production of the source, the project intent was to set with the aim of experimental verification of the radiation resistance of the cells with a focus on changing their electrical properties.

Figure 1: Experimental irradiation box with heating cassette/sample holder.

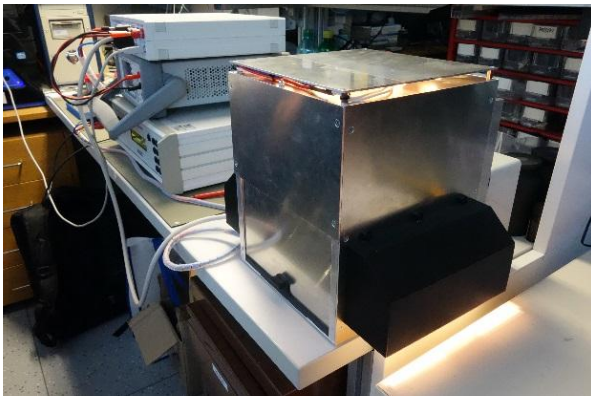


Figure 2: The illumination chamber for measurement I-V characteristics.

2. Methods

The tested samples were two sets of solar cells used in the space industry. Six pieces of 3G30A photovoltaic cells from the German company AZUR SPACE Solar Power GmbH were tested in the first set. The second set featured 36 pieces of SMX TASC-02x25 photovoltaic cells from SPECTROLAB, Inc. Both companies are leading producers of photovoltaic cells for space applications: AZUR SPACE has been a leading manufacturer of high-quality components with about 1.5 million solar cells in space for over 50 years (3). Holding Boeing Corp.'s SPECTROLAB has become the supplier of solar cells for Apollo (1969), Mars Rover Space (2004), Juno to Jupiter Orbit (2016) and, of course, the International Space Station (ISS). (4).

Technical details of the solar cells are as follows: Material AZUR SPACE solar cells: InGaP / GaAs / Ge with Ge substrate - triple junction. Cell thickness 280 µm. SPECTROLAB solar cell material: GaInP2 / GaAs / Ge - triple junction. Cell thickness 190 µm. The individual solar cells were mounted on the printed circuit boards, allowing easy handling of such fragile material (Fig. 3, Fig. 4).

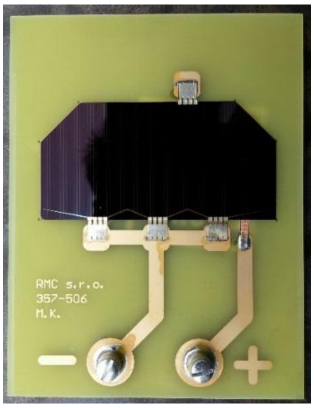


Figure 3: Tested sample from Azur Space company

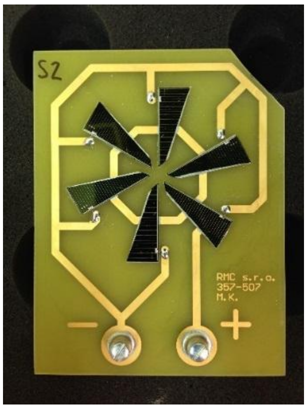


Figure 4: Tested sample from Spectrolab company

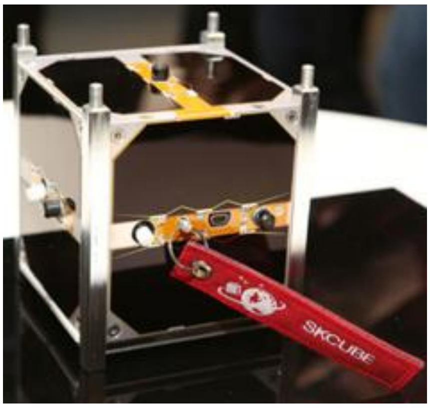


Figure 5: Solar cells on skCUBE CubeSat(5).

The company RMC s.r.o. has developed the illumination chamber and measuring system to measure I-V characteristics of the solar cells. In order to determine the temperature conditions of irradiation, it was a great benefit to obtain real data from the Swiss CubeSat (provided from internal RMC s.r.o. sources) and literature search provided an overview of the radiation load[1]. Furthermore, both sets of samples were divided into two groups with the following conditions for gamma degradation research as follows:

Set No. 1: 3 pieces of the AZUR SPACE solar cells + 18 pieces of the Spectrolab solar cells
Irradiation conditions: dose rate: 0.16 kGy/h, temperature inside the experimental box: -30 °C

Set No. 2: 3 pieces of the AZUR SPACE solar cells + 18 pieces of the Spectrolab solar cells
Irradiation conditions: dose rate: 0.16 kGy / h, temperature inside experimental box: +30 °C.

The escalation of irradiation doses in the Gamma Irradiation Facility were selected as follows: 0, 0.5, 1, 2, 10 and 30 kGy. Each irradiation (Fig. 6) was followed by measurement of the I-V characteristics of the solar cells in the illumination chamber (Fig. 7).

[1]All resources from which information was drawn are listed in the References section (sources (5), (6), (7), (8), (9), (10), (11), (12), (13), (14)).

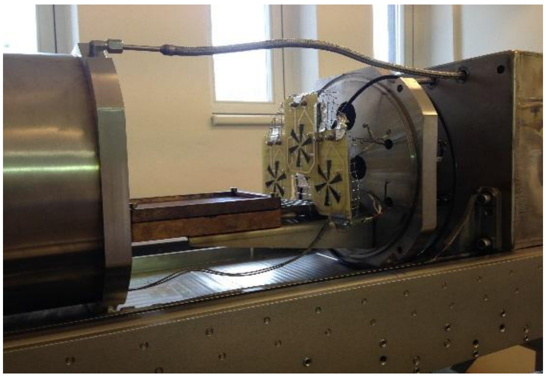


Figure 6: Samples on the irradiation geometry before closure of the experimental box and irradiation

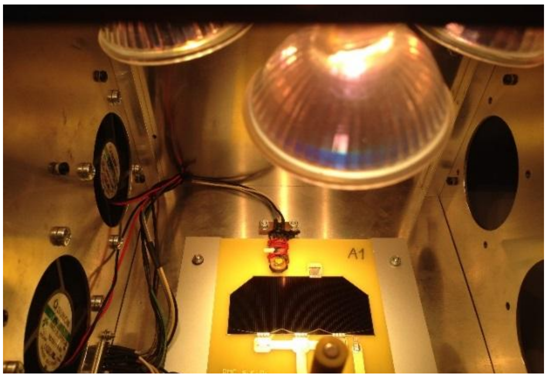


Figure 7: A look into the exposure chamber where I-V characteristics were measured

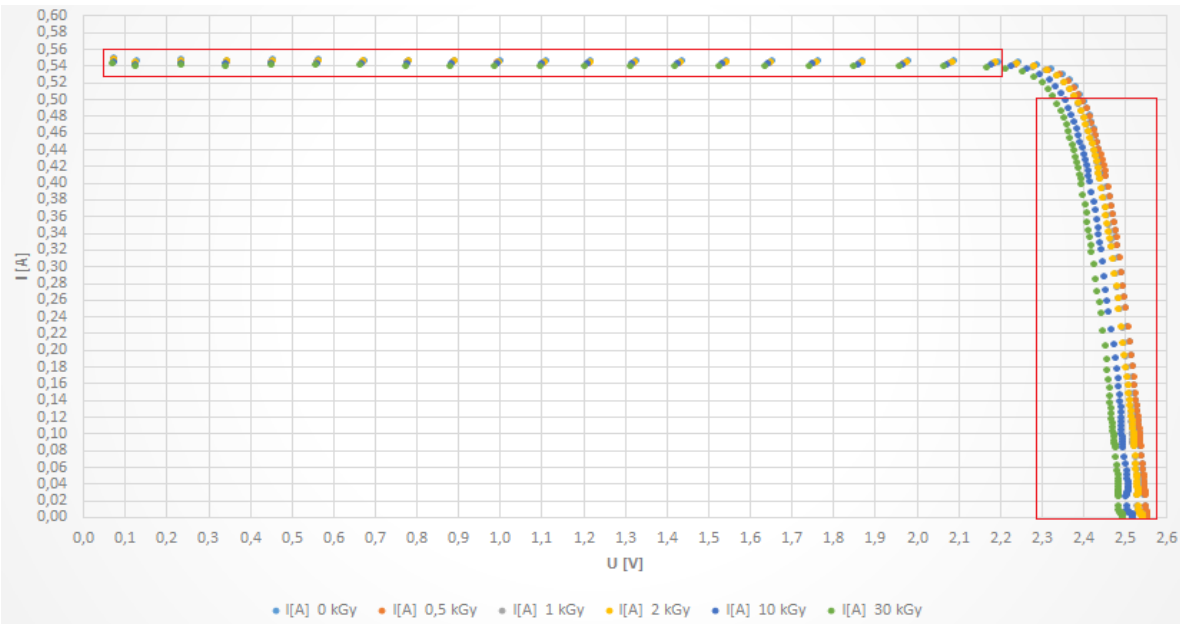
3. Results

The first finding was that the temperature effect was not demonstrated on the degradation of solar cells in both groups. This is an interesting unexpected result. Thus, the tested solar cells can rotate cyclically to the facing and reverse sides to the Sun, and this phenomenon has a negligible effect on the lifetime of the solar cells. The single most striking observation to emerge from the data comparison was the fact that the results from the radiation load were in favor of considerable radiation resistance. Most electronics and electrical components are very sensitive to radiation. Some components are made with increased radiation resistance.

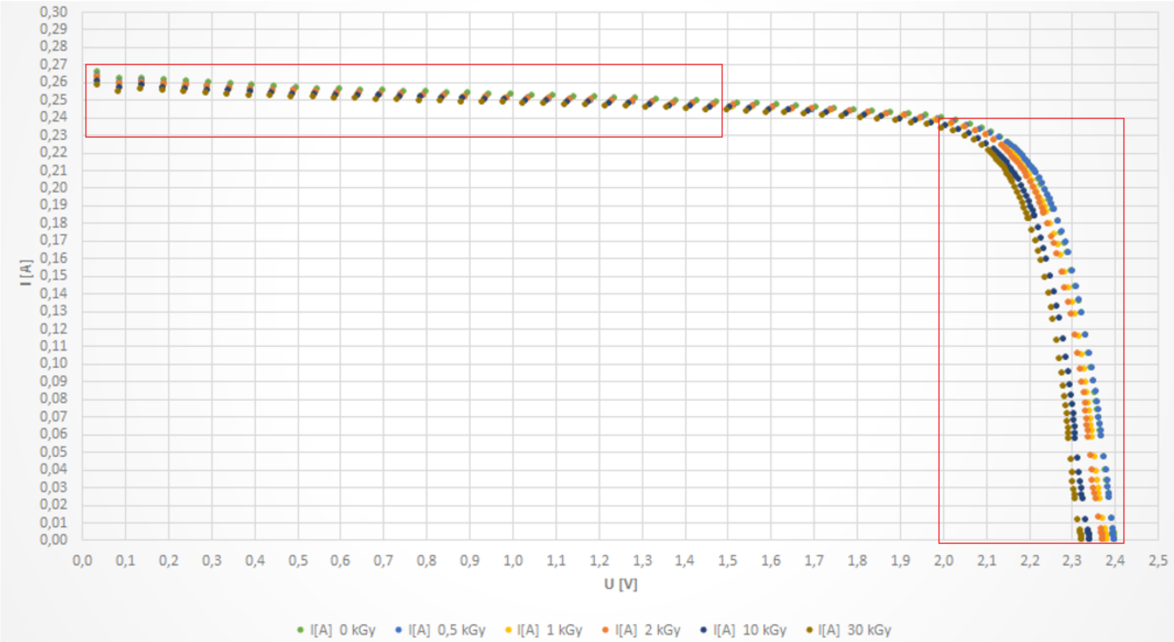
Based on the evaluation of the results I-V characteristics (Graph 1, Graph 2) before and after irradiation, the voltage drop can be determined due to gamma radiation degradation in comparison to the non-irradiated state and irradiated state to a maximum dose of 30 kGy.This decrease is only about 2.5 % in the case of solar cells from the Azur Space in the range of 0.10-0.50 A and about 4.8% in the case of Spectrolab solar cells in the range of 0.00-0.24 A.

Regarding the current drop before and after irradiation to 30 kGy, the results were as follows: for theAzur Space solar cells, the current drop was 1.3% in the range of 0.07-2.20 V and 2.7 % for the Spectrolab solar cells in the voltage range 0.04-1.48 V.

Finally, the maximum power of the Azur Space solar cells has dropped from 1,247 W to 1,201 W.Thus, dropping by about 3.7% of the maximum power in the non-irradiated state to 30 kGy, while the Spectrolab has decreased from 0.489 W to 0.471 W.This represents a decrease of about 3.7% of the maximum power in the non-irradiated state versus irradiation at 30 kGy. For a clearer representation, the resulting values of no-load voltage (U_{oc}) and maximum solar cell power (P_{max}) for non-irradiated samples and irradiated at 30 kGy are given in Table 1.



Graph 1: I-V characteristics of Azur Space solar cells after accumulated gamma radiation doses.



Graph 2: I-V characteristics of Spectrolab solar cells after accumulated gamma radiation doses

Table 1: Overview of U_{oc} and P_{max} for 0 kGy and 30 kGy

Azur Space				Spectrolab			
Non-irradiated		Irradiated to 30 kGy		Non-irradiated		Irradiated to 30 kGy	
U_{oc} [V]	P_{max} [W]	U_{oc} [V]	P_{max} [W]	U_{oc} [V]	P_{max} [W]	U_{oc} [V]	P_{max} [W]
2,5544	1,247	2,4963	1,201	2,4002	0,489	2,3233	0,471

4. Conclusion

Surprisingly, no differences in the electrical properties were found during irradiation at +30 ° C or -30 ° C. The solar cells are proved to be robust against these temperatures.

The most interesting finding based on the experimental results was that in the case of one type of the cosmic ray radiation - gamma radiation, both types of solar cells are very resistant and there is no significant changes in electrical properties were notedup to a cumulative dose of 30 kGy at a dose rate of 0.16 kGy/h.

In general, it was shownthat the temperatures +30/-30 °C do not affect the electrical properties of solar cells.At the same time, a slight effect of gamma radiation on the electrical properties of the escalated doses: 0, 0.5, 1, 2, 10 and 30 kGy, was observed. These findings suggest that both types of solar cells - 3G30A from the Azur Space Solar Power GmbH and SMX TASC-02x25 from the SPECTROLAB, Inc. - are robust within the range of test conditions outlined in this study.

5. Acknowledgement

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