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PERFORMANCE OF HUGHES GaAs CONCENTRATOR CELLS UNDER 1-MeV ELECTRON IRRADIATION

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Several Hughes gallium arsenide (GaAs) concentrator cells were exposed to 1-MeV electrons at fluences up to 1×10^{15} electrons/cm^2. Performance data were taken after several fluences, at two temperatures (25 and 80 °C), and at concentration levels from 1 to ~150x AM0. Data at 1 sun and 25 °C were taken with an X-25 xenon-lamp solar simulator. Data at concentration were taken using a pulsed solar simulator with the assumption of a linear relationship between short-circuit current and irradiance. The cells are 5 by 5 mm with a 4-mm-diameter illuminated area.

INTRODUCTION

The use of concentrating optics for space photovoltaic power generation has been under consideration for some time. The potential advantages of concentrators include higher cell efficiency, better radiation resistance, and lower cost. One possible optical design out of several is the miniature Cassegrainian concept developed by TRW (ref. 1). This design involves small GaAs cells operating at a concentration level of 100 to 130x AM0. The cells are 5 by 5 mm with a 4-mm-diameter illuminated area which leaves about half the cell area covered with outer bus-bar.

One of the unanswered questions involving concentrator cells is their performance degradation at concentrated light levels after electron irradiation. As part of an ongoing concentrator-cell program at NASA Lewis, several Hughes concentrator GaAs cells were irradiated with 1-MeV electrons. The data presented here are intended to be a first look at the performance of concentrator cells after electron bombardment.

EXPERIMENTAL DESCRIPTION

Five Hughes GaAs small-area concentrator cells were individually mounted in separate cell holders. The holders consist of a small bottom metal base and a washerlike metal top with a beveled hole slightly larger than the illuminated area of the cell. These two pieces supply both a permanent support for the cell and an area for the four-wire electrical attachment. The cells remained in their holders throughout all electron irradiations and performance measurements. There were no cover glasses attached to the cells nor was there any shielding by optical elements during the irradiations.

Electron irradiations using 1-MeV electrons were performed at the NASA Lewis dynamitron and at the Naval Research Laboratory Van de Graff generator. (The electron irradiation facilities at NRL were made available through the cooperation of Richard Statler and Robert Farr.) The cells were irradiated to a total fluence of

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1×10^{15} electrons/cm^2, with performance measurements made at several intermediate fluence levels. The performance measurements consisted of the following:

(1) I-V data at 25 °C and 1 AM0 using an X-25 xenon solar simulator and a reference cell

(2) I-V data at 25 °C at several concentrations up to 100 times AM0 and above using a pulsed xenon solar simulator and the linear assumption between irradiance and short-circuit current

(3) Short-circuit current data at one fixed concentration at both 25 and 80 °C in order to set the current scale at the elevated temperature

(4) I-V data at 80 °C at several concentrations as in step (2)

During I-V measurements the cells in their holders are mounted to a temperature-controlled block. The concentration level on the cell is varied by a combination of changing the distance from the light source and using and not using a fresnel lens. Since the duration of the light pulse from the flash simulator is just 2 msec, there is no heating effect from the concentrated light. The elapsed time at 80 °C was about 90 min for each cell. Several repeat measurements were made at 1 sun and 25 °C after the elevated temperature measurements in order to determine if any annealing had taken place.

RESULTS AND DISCUSSIONS

The data presented in the tables and figures are the average of the five cells which were carried throughout the electron irradiations. Table I shows the initial I-V parameters before irradiation. One cell was somewhat lower in current and efficiency than the others and therefore lowered the averages. Two cells had an efficiency of 19 percent at 100x AM0 and 80 °C.

Figure 1 is a plot of cell efficiency versus concentration level for the unirradiated case and two irradiated cases for data taken at 25 °C. One common factor among the three curves is that they get flatter with increasing electron fluence. This indicates that there is more power loss due to electron irradiation at concentrated levels than at 1 sun. This can be seen more clearly in figure 2, which shows the ratio of maximum power P_{max} after irradiation to the initial value as a function of electron fluence for both AM0 and 100x at 25 °C.

Table II shows the ratios of short-circuit current I_{sc}, open-circuit voltage V_{oc}, fill factor, and P_{max} after irradiation to the unirradiated values for several fluence levels at 25 °C and at 1 and 100x AM0. At 1 sun the power degrades to 78.9 percent of the unirradiated value while it drops to 74.1 percent at 100x AM0. Both the voltage and fill-factor changes contribute to the greater power loss after irradiation at concentration. Note that the fill factor increases by 3 percent at 1 sun after irradiation while it decreases by 1.6 percent at 100x AM0. The ratios for short-circuit current are the same for both solar irradiation levels due to the linear current-irradiance assumption.

There is somewhat more V_{oc} degradation at 100x AM0 than at 1 sun (0.91 versus 0.925). This indicates that even though the unirradiated V_{oc} is larger at 100x AM0 than at 1 sun, it is still taking a larger percentage drop after irradiation. This can be seen more clearly in table III, which lists the differences in V_{OC} between 100x AMO and 1 sun measured after different fluence levels. The initial V_{OC} difference of 180 mV drops to about 150 mV after irradiation to 1×10^{14} electrons/cm^2 and then remains fairly constant for the final two electron fluences.

The decrease in the V_{OC} difference indicates that the cell is becoming more diffusion current dominated and less space-charge recombination current dominated, as the electron fluence increases. A difference of about 120 mV (60 mV/decade for 2 decades) would be expected for a cell with an n value of 1. At present, we have no good explanation for the change in V_{OC} differences.

Figure 3 shows the degradation in P_{max} at 100x AMO for both 25 and 80 °C. The curves are nearly identical indicating that the effects on cell performance due to electron irradiation are essentially the same at the two temperatures.

Performance data were also taken at 25 °C after the 60 to 90 min spent at 80 °C for measurement purposes in order to determine if there were any annealing effects. In all cases, there was no annealing due to the time spent at 80 °C.

CONCLUDING REMARKS

Five small Hughes GaAs concentrator cells were irradiated with 1-MeV electrons to a total fluence of 1×10^{15} electrons/cm^2. After several different intermediate fluences, performance measurements were made at both 25 and 80 °C at different irradiance levels. The major conclusions are as follows:

1. The drop in P_{max} after irradiation was larger at 100x AMO than at 1 sun.

2. There was no significant difference in the degradation of cell performance when measured at 25 or 80 °C.

3. There was no annealing due to about 90 min spent at 80 °C for measurements.

REFERENCE

1. Patterson, Robert E.: Preliminary Concept of a 100-Kilowatt Miniaturized Cassegrainian Concentrator Solar Array. Space Photovoltaic Research and Technology 1983, NASA CP-2314, Oct. 1983, pp. 157-162.

TABLE I. - I-V PARAMETERS FOR UNIRRADIATED CELLS

Concentration	1	100
Temperature, °C	25	80
Short-circuit current, I_{sc}, mA	3.46	365.5
Open-circuit current, V_{oc}, V	0.947	1.041
Fill	0.755	0.815
Efficiency, percent	14.5	18.3

TABLE II. - RATIOS OF IRRADIATED TO INITIAL VALUES FOR SEVERAL FLUENCES

Irradiation, electrons/cm^2	Short-circuit current, I_{sc}	Open-circuit current, V_{oc}	Fill	Maximum power, P_{max}
1 sun				
1×10^{13}	0.982	0.990	1.010	0.982
3×10^{13}	.965	.980	1.007	.954
1×10^{14}	.925	.964	1.019	.908
3×10^{14}	.893	.947	1.024	.866
1×10^{15}	.828	.925	1.030	.789
100x AMO				
1×10^{13}	0.982	0.978	0.997	0.957
3×10^{13}	.965	.962	.994	.924
1×10^{14}	.925	.941	.992	.863
3×10^{14}	.893	.932	.988	.822
1×10^{15}	.828	.910	.984	.741

TABLE III. - DIFFERENCES IN CURRENT V_{OC} BETWEEN 100x AM0 AND 1 SUN AT 25 °C

Electron irradiation, electrons/cm^2	V_{oc} difference, mV
Unirradiated	180
1×10^{13}	165
3×10^{13}	157
1×10^{14}	149
3×10^{14}	152
1×10^{15}	150

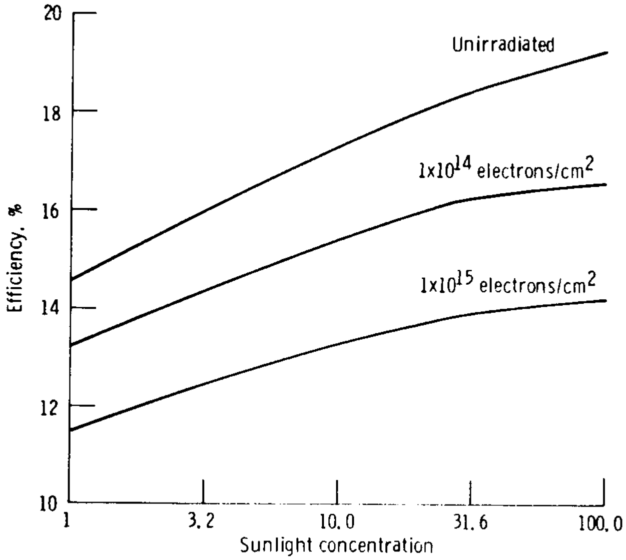

Figure 1. - Cell efficiency versus sunlight concentration for different electron fluences.

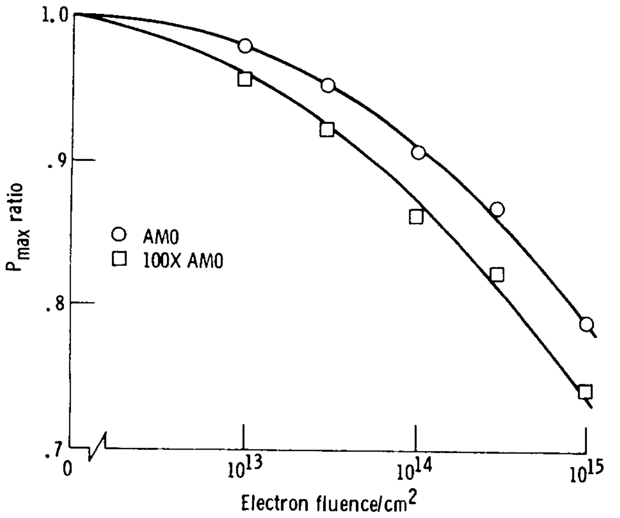

Figure 2. - P_{max} ratio versus electron fluence for 1 sun and 100X AM0 at 25 °C.

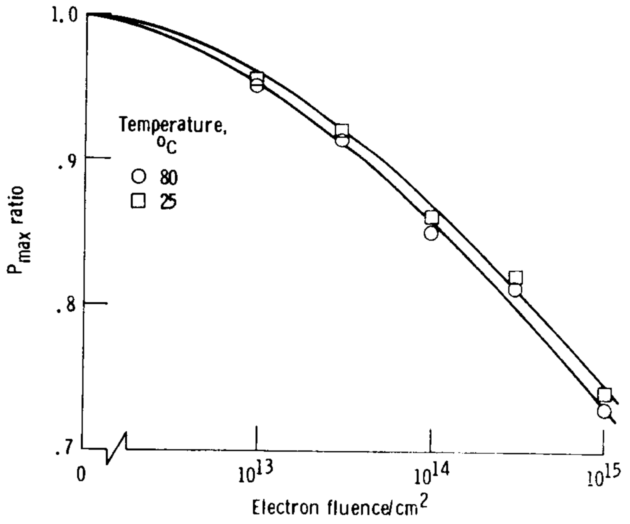

Figure 3. - P_{max} ratio versus electron fluence for 100X AM0 at 25 and 80 °C.