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Effects of Electron and Proton Irradiations on n/p and p/n GaAs Cells Grown by MOCVD

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CELLS GROWN BY MOCVD  (NASA)  8 p  Avail:
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EFFECTS OF ELECTRON AND PROTON IRRADIATIONS ON n/p and p/n GaAs CELLS GROWN BY MOCVD

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SUMMARY

State of the art n/p and p/n heteroface GaAs cells, processed by metal organic chemical vapor deposition, were irradiated by 1 MeV electrons and 37 MeV protons and their performance determined as a function of fluence. It was found that the p/n cells were more radiation resistant than the n/p cells. The increased loss in the n/p cells was attributed to increases in series resistance and losses in the p-region resulting from the irradiation. The greater loss in fill factor observed for the n/p cells introduces the possibility that the presently observed superiority of the p/n cells may not be an intrinsic property of this configuration in GaAs.

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INTRODUCTION

At present, the n/p configuration is exclusively preferred for silicon cells used in space. This follows from a demonstrated superior radiation resistance when compared to the p/n configuration (ref. 1). However, the increased radiation resistance of one configuration over the other has yet to be determined for GaAs solar cells. In a modest beginning toward establishing a preference it was determined that GaAs n/p homojunction cells were more radiation resistant than p/n heteroface cells under 10 MeV proton irradiations (ref. 2). In this latter case, a comparison was made between cells fabricated by two different methods (CVD and LPE) with the further complication that only the heteroface cell had an AlGaAs passivating front surface layer. In the present case, we compare the radiation resistance, under both proton and electron irradiations, of n/p and p/n GaAs heteroface cells fabricated by metal organic chemical vapor deposition (MOCVD), both configurations having a passivating AlGaAs front surface layer.

EXPERIMENTAL

Cell dimensions, geometries and dopant type and concentrations are shown in figure 1. All cells were fabricated by Varian using MOCVD (ref. 3). Additional processing details are contained in reference 3. Irradiations by 37 MeV protons was carried out in the NASA Lewis Research Center cyclotron while irradiation by 1 MeV electrons was performed using the U.S. Naval Research Laboratories Van de Graaf accellerator. Air mass zero performance measurements were obtained in the Lewis X-25 xenon arc, air mass zero, solar simulator using a flight calibrated GaAs standard cell as reference. Pre-irradiation performance parameters are shown in table I. All measurements are based on total rather than active areas.

RESULTS

Normalized efficiencies for both proton and electron irradiations are shown in figures 2 and 3. The data shown are mean values for the present cells. From the figures it is seen that, in terms of normalized efficiencies, the present p/n GaAs cells are more radiation resistant under the present irradiations. Normalized mean values of the remaining cell parameters, at high fluences, are shown in table II. Considering the proton irradiations it is seen that, for both cell types, the degradation in V_{OC} is greater than that observed for I_{SC}. However, under electron irradiation, I_{SC} of the n/p cell degrades more than V_{OC} while the opposite is true for the p/n cells.

DISCUSSION

The thinner emitter of the present n/p cells could be expected to result in increased radiation resistance for these cells. This would seem to follow from previous results on LPE grown heteroface GaAs p/n cells where radiation resitance was observed to increase with decreased emitter thickness (ref. 4). However, despite the decreased emitter thickness, the present n/p GaAs cells exhibit significantly decreased radiation resistance. To examine this behavior in greater detail, we first consider the I-V curves of the present cells both before and after electron irradiation (figs. 4 and 5). From figure 5, relatively small changes in both shunt and series resistance are indicated for the p/n configuration as a result of the irradiation (ref. 5). On the other hand, for the n/p cells, the I-V curves indicate a relatively large increase in series resistance as a result of irradation (ref. 5). Hence increased series resistance is a contributing factor to the decreased current, fill factor and efficiency observed for the n/p cells under the present electron irradiations. Noting, in table II(a) the relatively large loss in I_{SC} for the n/p cells, we consider the normalized spectral response at high electron fluence (fig. 6). Here the position of the junction is approximated by the optical path length $1/\alpha(\lambda)$ where $\alpha(\lambda)$ is the absorption coefficient at wavelength λ. It is seen from the figure that, for the n/p cell, most of the loss in I_{SC} occurs in the p region while for the p/n cell considerable portions of the loss occur in both the p and n regions of the cell. In view of the n/p cells relatively thin emitter, the dominance of the cell's p region in contributing to current loss is not surprising. The surprising factor is, despite our past experience with n/p homojunction cells (ref. 2), the relatively larger loss in efficiency exhibited by the present n/p cells. The higher p dopant concentration in the present n/p cells, when compared to the homojunction cells, may be a factor in contributing to increased defect production and thus increased loss under irradiation. Although this was found to be the case in boron doped silicon (ref. 6), we are unable to find comparable data for p type GaAs.

Considering proton irradiations, in general it is noted that the greatest damage occurs at the end of the proton path (ref. 7). However, at 37 MeV, the proton path extends well beyond the range of the present cell thickness. Hence, the principal difference between the present proton and electron irradiations lies in the increased defect production and cell degradation occuring at lower proton as compared to electron fluences. Aside from this, one would expect that effects, similar to those observed under electron irradiation would be encountered in both configurations as a result of the present proton irradiations. In accordance with this observation, it is found that the effects of the present proton irradiations on the I-V and spectral response curves are similar to those observed under electron irradiaton. Hence increased series resistance and a relatively greater loss in fill factor are significant factors in the greater degradation of the n/p cells observed under proton irradiation.

The dependence of fill factor on cell processing leads one to suspect that, contrary to the present results, p/n GaAs cells are not intrinsically more radiation resistant than n/p GaAs cells. This point of view is supported by our previous results on n/p homojunction cells (ref. 2).

The increased degradation in V_{OC}, when compared to I_{SC}, for most of the present cells is consistent with our previous results on similar high efficiency p/n GaAs cells (ref. 8). In this latter case, the degradation in V_{OC} was attributed to increases in the diffusion component of dark current (ref. 8). In the present case, it is found that the diffusion component of the dark current increases significantly less for the electron irradiated n/p cells than that observed for the remaining cells. Hence, the degradation in V_{OC} observed for the electron irradiated n/p cells is relatively lower and less than that observed for I_{SC}.

CONCLUSION

The high p dopant concentration in the present n/p cell may be a factor in contributing to the relatively decreased radiation resistance. However, this has yet to be confirmed by independent experiment. Thus, it would be desirable to determine defect production rates as a function of dopant concentration in a manner similar to the DLTS experiments on boron doped silicon (ref. 6). On the other hand, the increased series resistance and greater loss in fill factor experienced by the n/p cells suggest that cell processing may be a significant factor in the presently observed radiation effects. This suggests that the presently observed superiority of the p/n cells may not be an intrinsic property of this configuation in GaAs. Thus, it would be advantageous to determine damage coefficients for both p and n type GaAs over a wide range of dopant concentrations (ref. 9).

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TABLE I. - PRE-IRRADIATION PERFORMANCE PARAMETERS[a]

(a) Before electron irradiation

Cell	Efficiency, percent	V_{oc}, V	J_{sc}, ma/cm^2	FF, percent
n/p	19.8	1.034	30.6	86
	18.8	1.018	30.9	82
p/n	19.8	1.044	32.1	81.1
	19.6	1.041	31.8	81.2

(b) Before proton irradiation

Cell	Efficiency, percent	V_{oc}, V	J_{sc}, ma/cm^2	FF, percent
n/p	17.2	1.009	30.4	76.9
	19.7	1.042	31.7	81.8
p/n	18.4	1.022	29.9	82.6
	18.6	1.017	30	83.6

[a] Air mass zero-total area.

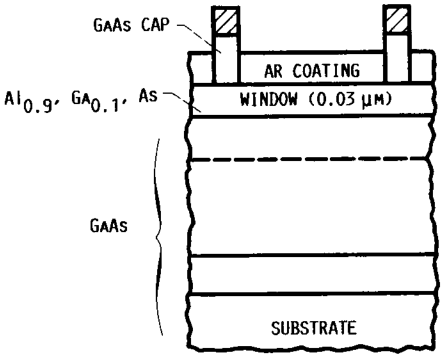
TABLE II. - NORMALIZED CELL PARAMETERS AT HIGH FLUENCE

(a) 1 MeV electron fluence = 3x10^{15}/cm^2

Cell	$\frac{\eta_\phi}{\eta_o}$	$\frac{V_{oc\phi}}{V_{oco}}$	$\frac{J_{sc\phi}}{J_{sco}}$	$\frac{FF_\phi}{FF_o}$
n/p	0.52	0.83	0.73	0.85
p/n	.66	.81	.9	.93

(b) 37 MeV proton fluence = 4.2x10^{13}/cm^2

Cell	$\frac{\eta_\phi}{\eta_o}$	$\frac{V_{oc\phi}}{V_{oco}}$	$\frac{J_{sc\phi}}{J_{sco}}$	$\frac{FF_\phi}{FF_o}$
n/p	0.43	0.7	0.76	0.8
p/n	.54	.76	.8	.89



FABRICATION METHOD - MOCVD

n/p CELL			
TYPE	THICK-NESS, μM	DOPANT	
		ATOM	CONCEN-TRATION, CM^{-3}
n	0.2	SE	$1.5x10^{18}$
p	3	ZN	$7x10^{17}$
p	.5	ZN	$8x10^{18}$

p/n CELL			
TYPE	THICK-NESS, μM	DOPANT	
		ATOM	CONCEN-TRATION, CM^{-3}
p	0.5	MG	$1.5x10^{18}$
n	3	SE	$7x10^{17}$
n	.5	SE	$8x10^{18}$

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FIGURE 1. - GAAs CELL CONFIGURATIONS.

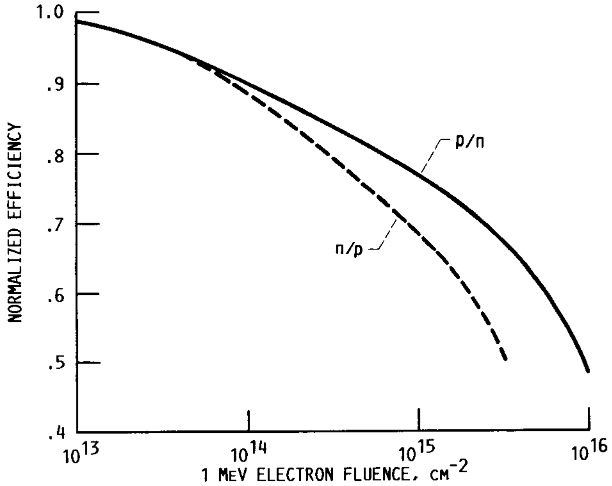

FIGURE 2. - NORMALIZED EFFICIENCIES OF GAAs CELLS AFTER ELECTRON IRRADIATION.

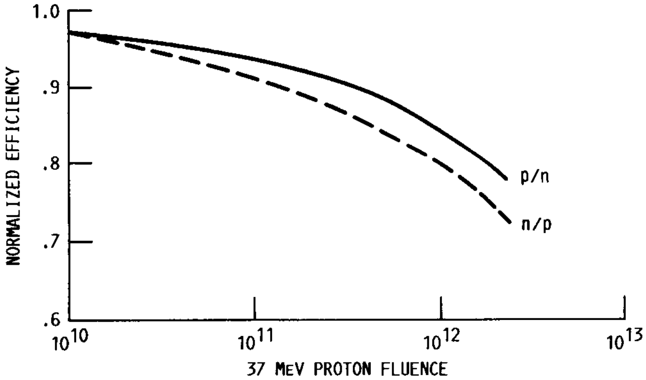

FIGURE 3. - NORMALIZED EFFICIENCIES OF GAAs CELLS AFTER PROTON IRRADIATION.

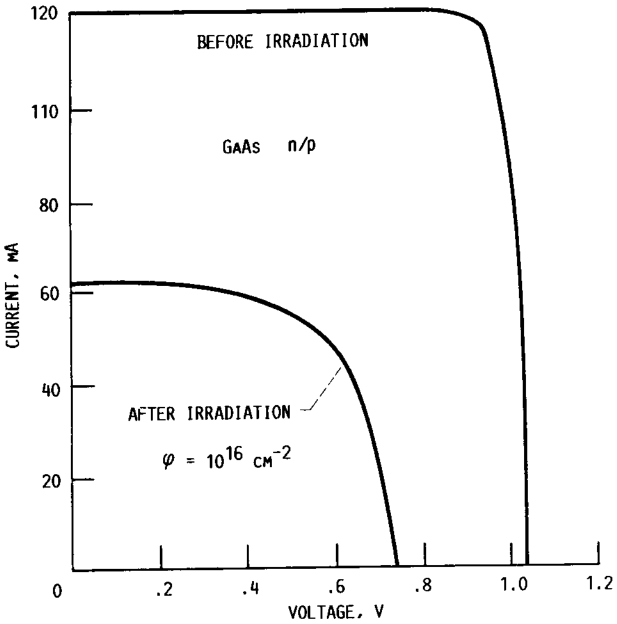

FIGURE 4. - I-V CURVES OF n/p CELLS BEFORE AND AFTER 1 MEV ELECTRON IRRADIATION.

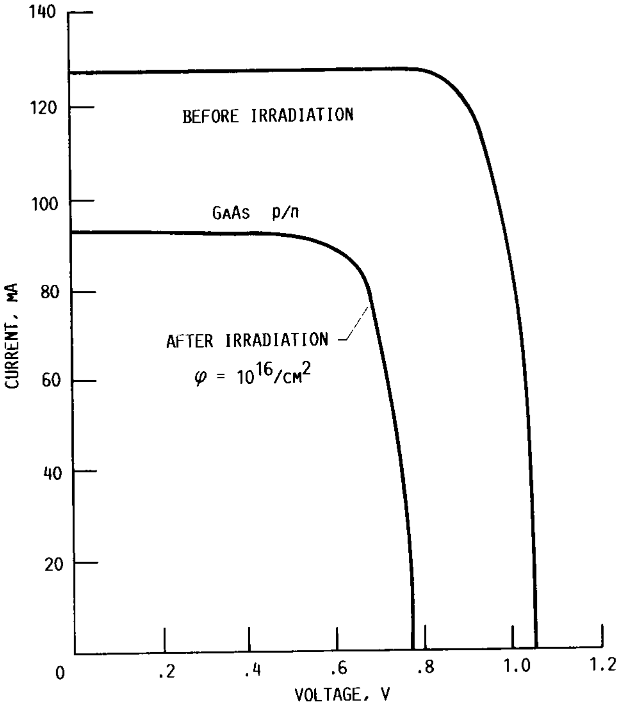

FIGURE 5. - I-V CURVES OF p/n CELLS BEFORE AND AFTER 1 MEV ELECTRON IRRADIATION.

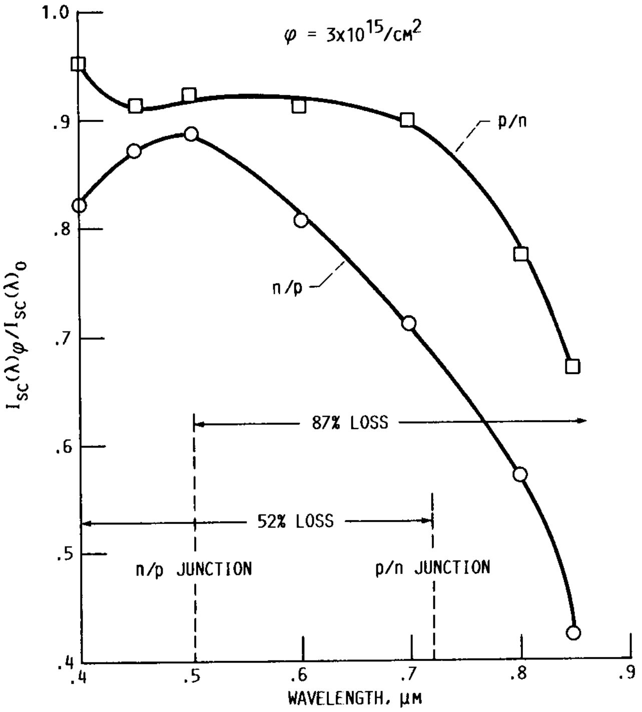

FIGURE 6. - NORMALIZED SPECTRAL RESPONSE OF GAAS CELLS AFTER 1 MEV ELECTRON IRRADIATION.

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16. Abstract

State of the art n/p and p/n heteroface GaAs cells, processed by metal organic chemical vapor deposition, were irradiated by 1 MeV electrons and 37 MeV proton and their performance determined as a function of fluence. It was found that the p/n cells were more radiation resistant than the n/p cells. The increased loss in the n/p cells was attributed to increases in series resistance and losses in the p-region resulting from the irradiation. The greater loss in fill factor observed for the n/p cells introduces the possibility that the presently observed superiority of the p/n cells may not be an intrinsic property of this configuration in GaAs.

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