IN 33
40647

NASA Technical Memorandum 106819

Performance of $Ga_{0.47}In_{0.53}As$ Cells Over a Range of Proton Energies

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(NASA-TM-106819) PERFORMANCE OF Ga0.47In0.53As CELLS OVER A RANGE OF PROTON ENERGIES (NASA. Lewis Research Center) 6 p

N95-22112

Unclas

G3/33 0040647

Prepared for the
First World Conference on Photovoltaic Energy Conversion
cosponsored by IEEE, PVSEC-Japan, and PSEC-Europe
Waikoloa, Hawaii, December 5–9, 1994

National Aeronautics and
Space Administration

PERFORMANCE OF $Ga_{0.47}In_{0.53}As$ CELLS OVER A RANGE OF PROTON ENERGIES

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ABSTRACT

$Ga_{0.47}In_{0.53}As$ solar cells were processed by OMVPE and their characteristics determined at proton energies of 0.2, 0.5, and 3 MeV. Emphasis was on characteristics applicable to use of this cell as the low bandgap member of a monolithic, two terminal high efficiency InP/GaInAs cell. It was found that the radiation induced degradation in efficiency, I_{sc}, V_{oc} and diffusion length increased with decreasing proton energy. When efficiency degradations were compared with InP it was observed that the present cells showed considerably more degradation over the entire energy range. Similar to InP, R_c, the carrier removal rate, decreased with increasing proton energy. However, numerical values for R_c differed from those observed with InP. The difference is attributed to differing defect behavior between the two cell types. It was concluded that particular attention should be paid to the effects of low energy protons especially when the particle's track ends in one cell of the multibandgap device.

INTRODUCTION

Because of their inherently low efficiencies, single junction GaInAs cells are poor candidates for use in space. On the other hand, when combined with InP in a monolithic, three terminal solar cell, $InP/Ga_{0.47}In_{0.53}As$ has demonstrated a terrestrial efficiency of 31.8% under 50X concentration [1]. In addition, Air Mass Zero one sun efficiencies of 20.1% have been achieved for a monolithic, two terminal tandem configuration [2]. If this cell is to be used in space, it is necessary to know its behavior, and that of the component cells under a variety of irradiation conditions. Considering the component cells, there exists for InP a considerable amount of data for both electron and proton irradiations [3]. Recently, both the $InP/Ga_{0.47}In_{0.53}As$ and $Ga_{0.47}In_{0.53}As$ cells have been irradiated by 1 MeV electrons and their characteristics determined over a range of fluences [4]. However, the necessity for current matching in the two terminal case, and the tendency of protons to cause maximum damage at the end of their track, make it essential that performance be determined over a range of proton energies. In the present case we have irradiated $Ga_{0.47}In_{0.53}As$ cells at proton energies of 3, 0.5 and 0.2 MeV. These are the first reported results concerning the behavior of these cells under proton irradiations. Our objective lies in determining and interpreting the behavior of these cells under a wide range of proton energies the results to serve as the beginning of a data base for use in cell design.

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EXPERIMENTAL RESULTS

The cells, processed by OMVPE, were produced in the Photovoltaic Branch at NASA Lewis. Cell details, with proton ranges calculated using the TRIM (Transport of Ions in Matter) program, are shown in fig.1 The best cell had an efficiency of 9.5%, the average efficiency for six cells being (9.2+0.3)%. In comparison, the best reported efficiency for this cell was 11.2% [5]. Although these latter cells were produced at Lewis, the present cells were produced at the beginning of the fabrication program and are thus of lower efficiency. The cells were irradiated at proton energies of 0.2, 0.5 and 3 MeV using proton accelerators at the University of Michigan. Normalized efficiencies after irradiation, shown in fig.2, are consistent with the proton ranges and the fact that most of the damage occurs at the end of the proton's track. The degradation in V_{oc} and I_{sc} follow the same trend as the efficiencies with degradation increasing as energy decreases. When compared to previous proton irradiations of $n^{+}p$ InP cells [6], the present cells show higher degradation at all three proton energies over most of the fluence range. This is illustrated for one proton energy in table I. The collection efficiencies shown in fig.3 indicate that there is considerable degradation in the cell's emitter. In fact, our calculations show that, at 0.2 MeV the short circuit current loss in the emitter is 43% of the total current while at 3 MeV, 27% of the current loss occurs in the emitter. The fact that degradation in the emitter increases with decreasing proton energy is consistent with the dependence of proton range on energy.

Carrier removal rates for the present cells, shown in table II, show a relatively small increase with decreasing energy. This differs somewhat from removal rates we have observed for InP, where more than an order of magnitude change in carrier removal rate occurs when going from 3 to 0.2 MeV. Since carrier removal depends on the type of defect created by the irradiation [7], it is not surprising that the removal rates behave differently for the two cell types.

DISCUSSION AND CONCLUSIONS

Although current matching is critical in two terminal tandem cells, we were not able, at this time, to obtain short circuit current data for representative n+p InP cells at these proton energies. However, since I_{sc} degradation follows the same tendency as efficiency, the observed differences in normalized efficiencies in table I tend to indicate that current matching could be a problem at these proton energies. A more pertinent comparison would be with InP cells processed by OMVPE. However, in general, the present results tend to indicate that the problem of cell matching would be most serious at low proton energies. This is especially the case where the proton's track ends in one cell of the tandem pair resulting in differential degradation between the two cell types. Hence, it is concluded that for $InP/Ga_{0.47}In_{0.53}As$ and any other monolithic two terminal tandem cell arrangement, it is essential to determine and understand tandem and individual cell behavior under proton irradiation, especially at low energies. For the three terminal case, current matching is not as severe a problem. However, in assessing the overall performance of this device, it is further concluded that one still needs to determine and understand individual cell behavior over a range of proton energies.

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Table I: Normalized Efficiencies of n^+p InP and n^+p $Ga_{0.47}In_{0.53}As$
E_p = 0.5 MeV

Fluence (cm^{-2})	*10^{11}*	*10^{12}*	*10^{13}*
InP	*0.88*	*0.64*	*0*
$Ga_{0.47}In_{0.53}As$	*0.72*	*0.39*	*0.06*

Table II: Carrier Removal Rates - $Ga_{0.47}$ $In_{0.53}$ As

Proton Energy (MeV)	*0.2*	*0.5*	*3*
Carrier Removal Rate (cm^{-1})	*6.4×10^4*	*2.3×10^4*	*1.1×10^4*

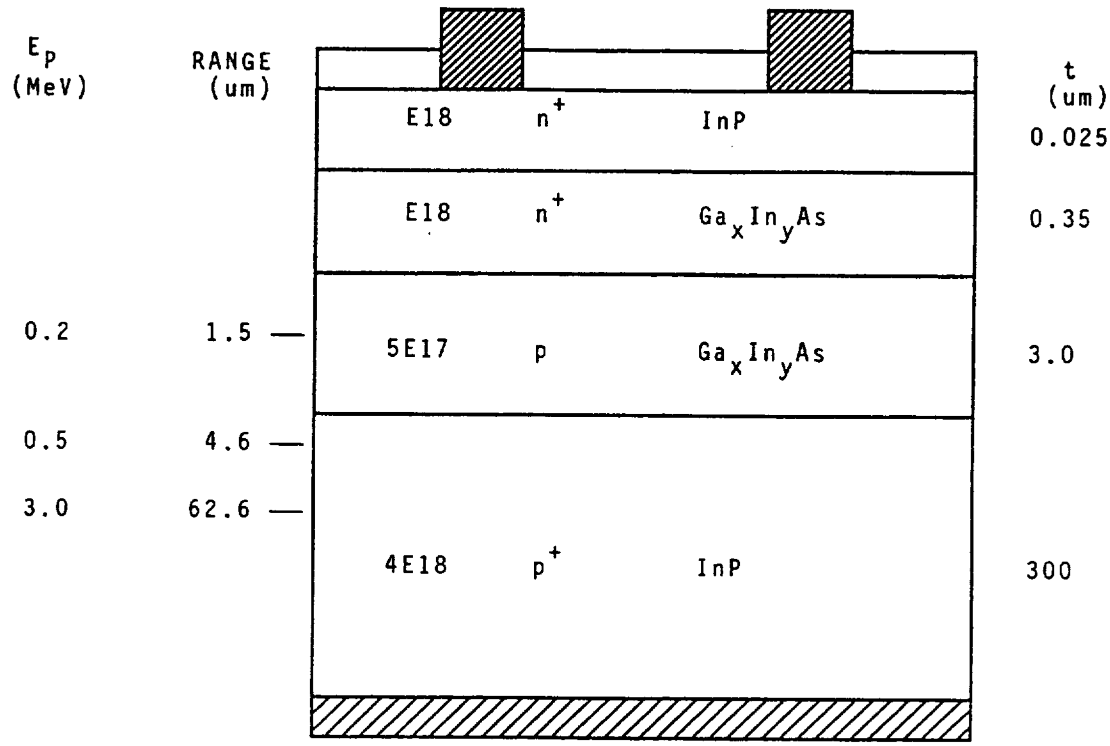

Figure 1. CELL DETAILS; x=0.47, y=0.53

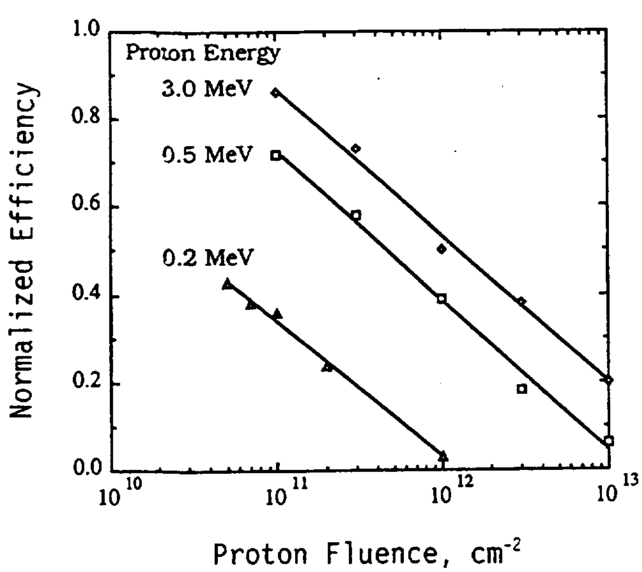

Figure 2. NORMALIZED EFFICIENCIES AT THREE PROTON ENERGIES

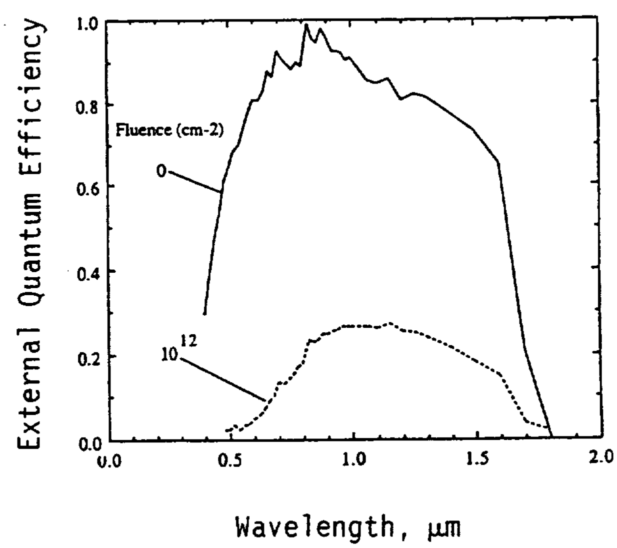

Figure 3. EXTERNAL COLLECTION EFFICIENCY, E_p = 0.2 MeV

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
January 1995

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Performance of $Ga_{0.47}In_{0.53}As$ Cells Over a Range of Proton Energies

5. FUNDING NUMBERS
WU–233–02–0A

6. AUTHOR(S)
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National Aeronautics and Space Administration
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8. PERFORMING ORGANIZATION REPORT NUMBER
E–9359

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, D.C. 20546–0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA TM–106819

11. SUPPLEMENTARY NOTES
Prepared for the First World Conference on Photovoltaic Energy Conversion cosponsored by IEEE, PVSEC-Japan, and PSEC-Europe, Waikoloa, Hawaii, December 5–9, 1994. I. Weinberg and D.M. Wilt, NASA Lewis Research Center; R.K. Jain, University of Toledo, Toledo, Ohio 43606, and NASA Resident Research Associate at Lewis Research Center; C. Vargas-Aburto, Kent State University, School of Technology, Kent, Ohio 44242; D.A. Scheiman, NYMA, Inc., Engineering Services Division, Brook Park, Ohio 44142 (work funded by NASA Contract NAS3–27186). Responsible person, D.M. Wilt, organization code 5410, (216) 433–6293.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category 33

This publication is available from the NASA Center for Aerospace Information, (301) 621–0390.

12b. DISTRIBUTION CODE

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14. SUBJECT TERMS
Gallium indium arsenide solar cells; Proton radiation

15. NUMBER OF PAGES
6

16. PRICE CODE
A02

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102