NASA Technical Memorandum 102103

Indium Phosphide Solar Cell Research in the United States—Comparison With Nonphotovoltaic Sources

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Prepared for the
European Space Power Conference
sponsored by the European Space Agency
Madrid, Spain, October 2–6, 1989

NASA

(NASA-TM-102103) INDIUM PHOSPHIDE SOLAR CELL RESEARCH IN THE US: COMPARISON WITH NONPHOTOVOLTAIC SOURCES (NASA. Lewis Research Center) 13 p CSCL 10A
N89-27868
Unclas
G3/31 0225956

INDIUM PHOSPHIDE SOLAR CELL RESEARCH IN THE UNITED STATES - COMPARISON WITH NONPHOTOVOLTAIC SOURCES

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E-4869

SUMMARY

Highlights of the InP solar cell research program are presented. Homojunction cells with AMO efficiencies approaching 19 percent were demonstrated while 17 percent has been achieved for ITO/InP cells. The superior radiation resistance of these latter two cell configurations over both Si and GaAs have been demonstrated. InP cells on board the LIPS III satellite show no degradation after more than a year in orbit. Computer modelling calculations have been directed toward radiation damage predictions and the specification of concentrator cell parameters. Computed array specific powers, for a specific orbit, are used to compare the performance of an InP solar cell array to solar dynamic and nuclear systems.

INTRODUCTION

Though still in an early developmental stage, indium phosphide solar cells are prime candidates for use in the space radiation environment. This is apparent from their greatly increased radiation resistance when compared to gallium arsenide and silicon (refs. 1 and 2). It has also been shown that radiation damage in InP can be reduced by exposure to light at room temperature (ref. 3). In addition, air mass zero efficiencies of over 21 percent are predicted by computer modelling calculations (ref. 4). These results have served as motivation for the NASA Lewis Research Center to initiate and continue a program of InP solar cell research directed toward their use in space. This research effort has, involved, beside NASA Lewis and the Naval Research Laboratory, efforts at several universities and industrial laboratories in the United States. At the same time, a continuing major effort is underway in Japan. Additional ongoing research in the United Kingdom has been focused mainly on the development of ITO/InP solar cells. The current paper summarizes highlights in the U.S. program. Results emanating from other countries are included where appropriate.

BACKGROUND

Considering silicon solar cells, a long period of R&D directed toward their use in space, was followed by an intensive program directed toward their use in the terrestrial environment. Exactly the opposite has occurred for InP. Prior to 1984, published research on InP solar cells was concerned with terrestrial applications. Much of the early work considered multicomponent structures such as ITO/InP, Cds/InP (refs. 5 and 7) and simplified structures such as MIS Schottky barrier cells (ref. 8). Reports of the first reasonably good monolithic cell appeared in 1980 (ref. 9). A summary of some early results is shown in table I for measurements reported at other than air mass zero.

The first reported radiation damage data on InP appeared in 1984 when Yamaguchi and his coworkers in Japan reported on the comparative radiation resistance of InP, GaAs and Si under 1 MeV electron irradiation (ref. 2). This was followed, in the United States by the observed superior radiation resistance of InP over GaAs and Si under 10 Mev proton irradiation (ref. 1). It can be noted from table I, that a wide disparity of reporting methodology existed in the terrestrial effort. Measurements in this early program were reported at air masses varying between 1 and 2 and, in some cases, in terms of active, rather than total cell area. Since it is standard practice in the space solar cell community to report total area efficiencies at air mass zero, we shall adhere to this procedure in the remainder of this paper.

CELL PERFORMANCE

Progress in achieving high efficiency, dating from 1984, is shown in figure 1. The first cells were prepared by a closed tube diffusion process (refs. 2 and 11). The highest efficiency (18.8 percent) was achieved by a combination of both OMCVD and ion-implantation (ref. 12). The geometry and dopant concentration of this cell are shown in figure 2. In addition to the aforementioned process, cells in the U.S. have been processed by open tube diffusion and LPE (refs. 13 and 15). All of the cells depicted in figure 1 were small with areas varying between 0.25 and 0.31 cm^2. These sizes represent economic limitations imposed by the high InP wafer cost. Larger area (2 and 4 cm^2) cells have been produced in Japan using a closed tube diffusion process (ref. 16). These latter cells have been produced in relatively large quantities and are intended to power a small piggy back lunar orbiter on board the Japanese MUSES A satellite, scheduled for launch in 1990 (ref. 17). The highest efficiency achieved for these large area cells is 16.6 percent. This represents the best efficiency achieved using a diffusion process (ref. 16). In addition to monolithic InP, cells processed by sputtering n-indium tin oxide onto p-type InP (ITO/InP) are of interest because they represent a simpler, relatively inexpensive processing alternative. The best ITO/InP cells, processed at SERI by DC magnetron sputtering, have achieved AMO efficiencies of 17 percent (ref. 18). Parameters of the best cells produced by different techniques are shown in table II. Of the various processes listed, OMCVD is the most flexible and has produced the best, albeit small area, cells.

EFFECTS OF RADIATION

Experimental Data

Both n/p homojunction and ITO/InP cells are included in small experimental modules, presently in space, on board the LIPS III satellite (refs. 19 and 20). The homojunction cell module was supplied by NASA Lewis. The ITO/InP module contains cells processed by Newcastle Upon Tyne Polytechnic and is under the aegis of RAE Harnwell. The status of the NASA Lewis module will be discussed at this conference (ref. 20). In summation, after more than a year in orbit, no degradation was observed in the homojunction cells. On the other hand, we have no information on the ITO/InP module. Since the latter cells represent a simplified processing alternative, and reasonable high efficiencies have been achieved, it is necessary to determine their comparative performance in a laboratory environment. Hence, we have irradiated ITO/InP cells, obtained from

SERI, with 10 MeV protons and compared their performance to n/p InP and GaAs homojunction cells including large area n/p cells similar to those on board the MUSES A satellite. Preirradiation parameters for these cells are shown in table III while figure 3 shows normalized efficiency as a function of fluence. It is seen that the ITO/InP cells exhibit radiation resistance, under 10 MeV proton irradiations, which is comparable to that of the InP homojunction cells. It is noted that the larger InP cell outperforms the remaining cells at low fluences but falls off at the higher fluences. With regard to the behavior at high fluence; it is noted that the junction depth of the larger InP cell lies between 0.2 and 0.3 μm (ref. 16) while the junction depth of the smaller area cell is well under 0.1 μm (ref. 13). Dependence of radiation resistance on junction depth has previously been noted for GaAs where a decrease in junction depth accompanied increased radiation resistance (ref. 21). In the absence of similar data for InP, it is speculated that the fall off at high fluence may be due to the cell's relatively deep junction depth. On the other hand, the increased radiation resistance, observed at lower fluence, may be due to improved substrate quality. Additional research is required to assess the validity of these speculations.

Modelling of Radiation Damage

Comparison of InP and GaAs cells, under laboratory conditions, have employed cells with widely differing BOL characteristics. For example; the n/p GaAs cell of figure 3 has a base dopant concentration which is an order of magnitude greater than that of the InP cells. Previous comparisons under 1 MeV electron irradiations, shown in figure 4, have used p/n GaAs cells with an AlGaAs window and compared them to n/p InP cells with no window and with widely differing base dopant concentrations (ref. 22). In order to compare these cells on an equal basis, a calculation was performed using a previously published computer model (ref. 23). Parameters used in the comparison are shown in table IV. The model predicts an AMO efficiency of 20.4 percent for InP and 21.5 percent for GaAs. However by reducing the emitter width to 300 Å, grid shadowing to 4 percent and use of an optimized 2 layer AR coating, the optimum efficiency is 21.5 percent for InP and 22.5 percent for GaAs.

Because of carrier removal effects, lifetime rather than diffusion length damage coefficients were employed using, $1/\tau = 1/\tau_0 + K\tau\,\phi$, where K_τ is the lifetime damage coefficient. The plot used to obtain K_τ for InP is shown in figure 5, a similar plot being used for GaAs. From these data, it was found that, for a p-base concentration of $5\times10^{16}/cm^3$, $K_\tau = 1.3\times10^{-6}$ and 3.1×10^{-5} cm^2/sec for InP and GaAs respectively. The calculated performance for these cells under 1 MeV electron irradiation, is shown in figure 6 where it is seen that the InP cell outperforms the GaAs cell.

Estimated Performance in Space

A comparison of the estimated performance, of PV arrays and nuclear and solar dynamic systems, in a 30° circular orbit, is shown in figure 7. Array specific powers were obtained for a distribution of altitudes with a 5 yr stay at each altitude. The calculations were performed using silicon 1 MeV electron equivalent data (ref. 24). This is admittedly a rough approximation for GaAs and InP. However, it is felt that the use of silicon data tends to overestimate the degradation of the III-V solar cells. Specific powers were calculated using published data for the JPL/TRW Advanced Photovoltaic Solar Array (APSA) (ref. 25). The 5.3 kW wing developed under the APSA program achieves a BOL specific power of approximately 132 W/kg using 2.2 mil, 13.5 percent silicon solar cells, a 2 mil cover glass and a 10 percent weight add-on for contingencies. Our calculations were performed using the same cell thickness with the substitution of a 10 mil cover glass. The BOL efficiencies used, at 28 °C for the flat plate cells, were 18, 19 and 15 percent for InP, GaAs and Si respectively. These values were felt to be reasonably close to the values achievable in production. An additional specific power was calculated for InP in a Fresnel lens concentrator array at 100 °C and 100X assuming a BOL efficiency of 22 percent at this concentration and temperature (refs. 26 and 29). The considerable effect of battery storage was included by assuming 100 W-Hr/kg for the battery and a nominal eclipse period of 1/2 hr. The battery specific energy used appears achievable using sodium-sulphur batteries. Specific powers for the nuclear (SP-100) and solar dynamic systems were obtained from previously published data, assuming no degradation while in orbit (ref. 27). It was also assumed, based on annealing data, that the InP concentrator cells would not degrade at 100X and 100°C (refs. 3 and 28). The results indicate that the InP flat plate and concentrator solar cell arrays could outperform the solar dynamic system and that the concentrator system performs as well as the nuclear system. These results are tentative, pending the acquisition of 1 MeV electron damage equivalents for InP and GaAs and confirmation of the assumed annealing behavior of the Inp concentrator cells. It is also noted that the APSA array is an advanced system whose ultimate goal is to achieve a specific power of 300 W/kg (ref. 25).

PREDICTED BEHAVIOR UNDER CONCENTRATION

The high cost of InP wafers makes concentrators, with their greatly decreased cell size, an attractive alternative. Since InP concentrator cells are not readily available, we used the model of reference 23 to compute the expected performance of these cells under varying concentration and temperature. The calculations were performed using cell geometries suitable for the cassegranian and SLATS concentrators. The geometry of a circular cell for the Cassegranian concentrator and a rectangular cell for the SLATS concentrator are shown in figures 8 and 9. Cell parameters are shown in table V. Some calculated results are shown in figures 10 and 11. At 80° and 100X, the circular cell efficiency is 21.1 percent while the rectangular cell efficiency, at 80 °C and 20X, is 20.6 percent. It is noted that a more comprehensive computer model is under development, using a multilayer AR coating and is expected to add at least 1 percent to these efficiencies. Furthermore, the addition of a prismatic cell cover is expected to also add efficiencies between 1 and 2 percent (ref. 26).

CONCLUSION

Although progress in developing InP cells for use in space has been satisfactory, several avenues of research merit increased attention. Additional effort needs to be directed toward producing large area high efficiency devices. Since cells 8 cm^2 in area are commonplace for both Si and GaAs, this size is a desirable goal for InP. However a more significant contribution lies in reducing cell cost. At present the wafer accounts for over 90 percent of the cell cost. One effort, now underway, aims toward the processing of solar cells using a few microns of InP epitaxially deposited on cheaper substrates such as Si. In this case one needs to overcome problems caused by lattice misfit and thermal expansion differences. Additional research is directed toward the use of techniques such as the CLEFT process. This latter method incorporates the use of reuseable substrates. In addition to the preceding there exists a need for high efficiency concentrator cells. In our opinion, successful completion of these efforts is required in order to realize the full potential of InP solar cells for use in space.

REFERENCES

1. Weinberg, I.; Swartz, C.K.; and Hart, R.E.: Potential for Use of InP Solar Cells in the Space Radiation Environment. Eighteenth IEEE Photovoltaic Specialists Conference - 1985, IEEE, 1985, pp. 1722-1724.

2. Yamaguchi, M., et al.: Electron Irradiation Damage in Radiation-Resistant InP Solar Cells. Jpn. J. Appl. Phys., vol. 23, no. 3, Mar. 1984, pp. 302-307.

3. Ando, K.; and Yamaguchi, M.: Radiation Resistance of InP Solar Cells Under Light Illumination. Appl. Phys. Lett., vol. 47, no. 8, Oct. 15, 1985, pp. 846-848.

4. Goradia, C.; Geier, J.V.; and Weinberg, I.: Theory of the InP Shallow Homojunction Solar Cell. Solar Cells, vol. 25, no. 3, 1988, pp. 235-253.

5. Sree Harsha, K.S., et al.: n-Indium Tin Oxide/p-Indium Phosphide Solar Cells. Appl. Phys. Lett., vol. 30, no. 12, June 15, 1977, pp. 645-646.

6. Bachmann, K.J., et al.: Solar Cell Characteristics and Interfacial Chemistry of Indium-Tin-Oxide/Indium Phosphide and Indium-Tin-Oxide/Gallium Arsenide Junctions. J. Appl. Phys., vol. 50, no. 5, May 1979, pp. 3441-3446.

7. Bettini, M.; Bachmann, K.J.; and Shay, J.L.: CdS/InP and CdS/GaAs Heterojunctions by Chemical Vapor Deposition of CdS. J. Appl. Phys., vol. 49, no. 2, Feb. 1978, pp. 865-870.

8. Kamimura, K.; Suzuki, T.; and Kunioka, A.: Metal-Insulator Semiconductor Schottky-Barrier Solar Cells Fabricated on InP. Appl. Phys. Lett., vol. 38, no. 4, Feb. 15, 1981, pp. 259-261.

9. Turner, G.W.; Fan, J.C.C.; and Hsieh, J.J.: High-Efficiency InP Homojunction Solar Cells. Appl. Phys. Lett., vol. 37, no. 4, Aug. 15, 1980, pp. 400-402.

10. Coutts, T.J.; and Naseem, S.: High Efficiency Indium Tin Oxide/Indium Phosphide Solar Cells. Appl. Phys. Lett., vol. 46, no. 2, Jan. 15, 1985, pp. 164-166.

11. Yamamoto, A.; Yamaguchi, M.; and Uemura, C.: High Conversion Efficiency and High Radiation Resistant InP Homojunction Solar Cells. Appl. Phys. Lett., vol. 44, no. 6, Mar. 15, 1984, pp. 611-613.

12. Keavney, C.J.; and Spitzer, M.B.: Indium Phosphide Solar Cells Made by Ion Implantation. Appl. Phys. Lett., vol. 52, no. 17, Apr. 25, 1988, pp. 1439-1440.

13. Parat, K.K., et al.: Solar Cells in Bulk InP, Made by an Open Tube Diffusion Process. Solid State Electron., vol. 30, no. 3, 1987, pp. 283-287.

14. Choi, K.Y.; and Shen, C.C.: p/n InP Homojunction Solar Cells With a Modified Contacting Scheme by Liquid Phase Epitaxy. J. Appl. Phys., vol. 63, no. 4, Feb. 15, 1988, pp. 1198-1202.

15. Weinberg, I., et al.: Comparative Radiation-Resistance, Temperature-Dependence and Performance of Diffused Junction Indium-Phosphide Solar Cells. Solar Cells, vol. 22, no. 2, 1987, pp. 113-124.

16. Okasaki, H., et al.: Production of Indium Phosphide Solar Cells for Space Power Generation. Twentieth IEEE Photovoltaic Specialists Conference - 1988, vol. 2, IEEE, 1988, pp. 886-892.

17. Nagatomo, M.: Private Communication. Institute of Space and Astronautical Science, Tokyo, Japan, 1988.

18. Coutts, T.J., et al.: Proceedings of the 4th International Science and Engineering Conference, Sydney, Australia, Feb. 14-17, 1988, to be published.

19. Brinker, D.J.; Hart, R.E.; and Weinberg, I.: InP Homojunction Solar Cell Performance on the LIPS III Flight Experiment. Twentieth IEEE Photovoltaic Specialists Conference - 1988, vol. 2, IEEE, 1988, pp. 819-823.

20. Brinker, D.J.: On-Orbit Results of the LIPS III/InP Homojunction Solar Cell Experiment. NASA TM-102131, 1989, (Also This Conference).

21. Loo, R.; Kamath, G.S.; and Knechtli, R.C.: Radiation Damage in GaAs Solar Cells. Fourteenth IEEE Photovoltaic Specialists Conference - 1980, IEEE, 1980, pp. 1090-1097.

22. Weinberg, I., et al.: Radiation and Temperature Effects in Gallium Arsenide, Indium Phosphide, and Silicon Solar Cells. Nineteenth IEEE Photovoltaic Specialists Conference - 1986, IEEE, 1986, pp. 548-557.

23. Goradia, C.; Geier, J.V.; and Weinberg, I.: Experimental and Theoretical Comparison of 1 MeV Electron-Induced Radiation Damage in InP and GaAs Space Solar Cells. Technical Digest, 3rd International Photovoltaic Science and Engineering Conference, Japan Society of Applied Physics, pp. 207-210, 1987.

24. Tada, H.Y., et al.: Solar Cell Radiation Handbook, 3rd Edition, JPL-PUB-82-69, NASA CR-169662, 1982.

25. Kurland, R.M.; and Stella, P.: Advanced Photovoltaic Solar Array Development. Space Photovoltaic Research and Technology - 1988, NASA CP-3030, 1988, pp. 128-144.

26. O'Neill, M.J.; and Piszczir, M.F.: An Advanced Space Photovoltaic Concentrator Array Using Fresnel Lenses, Gallium Arsenide Cells, and Prismatic Cell Covers. Twentieth IEEE Photovoltaic Specialists Conference - 1988, vol. 2, IEEE, 1988, pp. 1007-1012.

27. Brandhorst, H.W., Jr.; Juhasz, A.J.; and Jones, B.I.: Alternative Power Generation Concepts for Space. Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space, W.R. Burke, ed., ESA-SP-267, European Space Agency, 1986, pp. 13-19.

28. Yamaguchi, M., et al.: Injection-Enhanced Annealing of InP Solar-Cell Radiation Damage. J. Appl. Phys., vol. 58, no. 1, July 1, 1985, pp. 568-574.

29. Goradia, C., et al.: Predicted Performance of Near-Optimally Designed Indium Phosphide Space Solar Cells at High Intensities and Temperatures. Twentieth IEEE Photovoltaic Specialists Conference - 1988, vol. 1, IEEE, 1988, pp. 695-701.

TABLE I. - InP CELL PARAMETERS MEASURED AT OTHER THAN AIR MASS ZERO

Cell type	Source	Air mass	Efficiency,[a] percent	V_{oc}, mV	J_{sc},[a] mA/cm^2	FF, percent
n/p homojunction	Ibaraki ECL	1.5	[b]18.6	833	27.7	81
ITO/InP (n/p)	Ref. 10	1	15.8	768	26.9	76.7
		1.5	[b]16.2			
n-CdS/p-InP	Ref. 7	2	[c]15	780	18.7	73.5
$n^+/p/p^+$	Ref. 9	1	15	780	26.5	71.5
MIS	Ref. 8	2	14.5	739	17.8	79

[a]Efficiencies and short circuit currents based on total cell area except when otherwise noted.
[b]Light intensity - 100 mW/cm^2.
[c]Based on active area.

TABLE II. - AIR MASS ZERO PARAMETERS OF BEST InP CELLS

Cell type	Growth method	Area, cm^2	Efficiency, percent	J_{sc}, mA/cm^2	V_{oc}, mV	FF, percent	Reference
n^+pp^+	OMCVD and ion-implant	0.25	18.8	35.7	873	82.9	12
n^+p	Closed tube diffusion	4	16.6	33.7	828	81.6	16
ITO/InP	DC magnetron sputtering	0.72	17	28	813	83	18

TABLE III. - PREIRRADIATION AMO PARAMETERS OF CELLS IN FIGURE 3

Cell type	Area, cm^2	Efficiency, percent	J_{sc}, mA/cm^2	V_{oc}, mV	FF, percent
n/p InP	2	16.4	32.9	825	83
n/p InP	0.25	13.6	27.6	826	81.8
ITO/InP	0.717	13.2	32.6	761	78
n/p GaAS	4	16.6	29	960	81.8

TABLE IV. - PREIRRADIATION CELL PARAMETERS USED IN THEORETICAL COMPARISON OF InP AND GaAs

	InP	GaAs
Junction area, cm^2	1.00	1.00
Total illuminated area, cm^2	0.94	0.94
Grid coverage, percent	6.00	6.00
Specific contact resistance, Ω-cm^2	1.0×10^{-3}	1.0×10^{-3}
Front surface recombination velocity, cm/sec	1.0×10^{5}	3.0×10^{5}
n^+ emitter width, Å	400	400
n^+ emitter doping, cm^{-3}	6.0×10^{17}	6.0×10^{17}
p base width, μm	1.50	1.50
p base doping, cm^{-3}	5.0×10^{16}	5.0×10^{16}
p^+ BSF/buffer layer width, μm	250	250
p^+ BSF/buffer layer doping, cm^{-3}	5.0×10^{18}	5.0×10^{18}

TABLE V. - GEOMETRICAL AND MATERIAL PARAMETERS OF NEAR-OPTIMUM CELL DESIGN

[The following parameters are identical for both rectangular and circular cells.]

Emitter	
Width, W_E, μm (Å)	0.04 (400)
Doping, W_{dE}, cm^{-3}	2×10^{18}
Effective lifetime, τ_pE, ns	1.26
Diffusion length, L_{pE}, μm	0.42
Base	
Width, W_B, μm	1.5
Doping, N_{2b}, cm^{-3}	5×10^{16}
Effective lifetime, τ_n, ns	17.8
Diffusion length, L_nÅ, μm	12.75
BSF region	
Width, W_{BSF}, μm	250
Doping, W_2, BSF, cm^{-3}	5×10^{18}
Effective lifetime, τ_n, BSF, ns	0.18
Diffusion length, L_n, BSF, μm	1.06

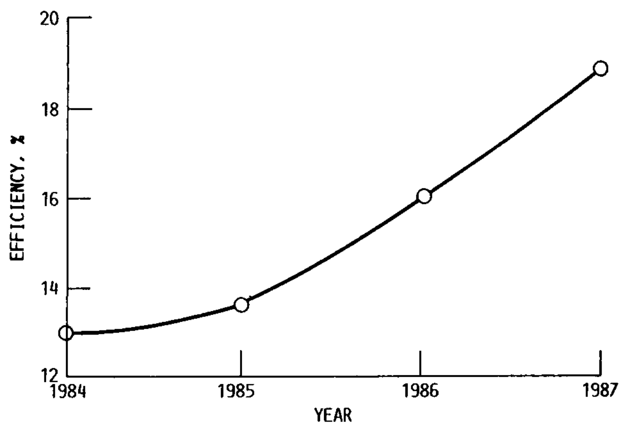

FIGURE 1. - InP - PROGRESS IN ACHIEVING HIGH-EFFICIENCY.

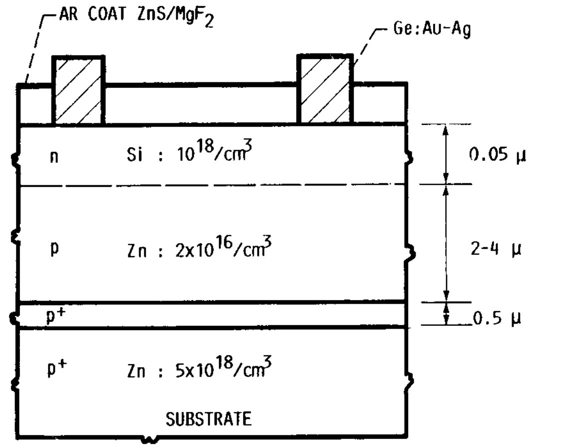

FIGURE 2. - N^+PP^+ InP CELL STRUCTURE - OMCVD.

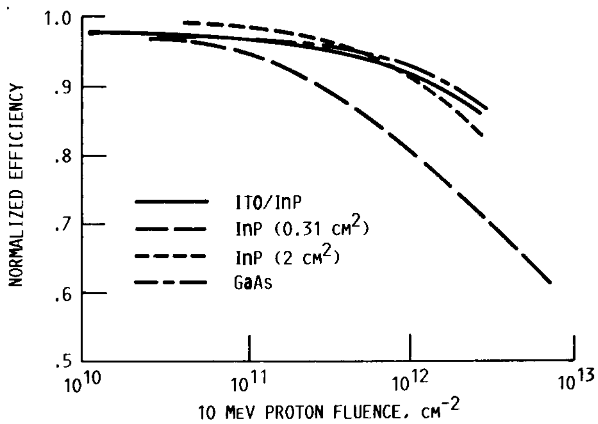

FIGURE 3. - NORMALIZED EFFICIENCY VERSUS PROTON FLUENCE, ITO/InP, n/p InP, AND n/p GaAs.

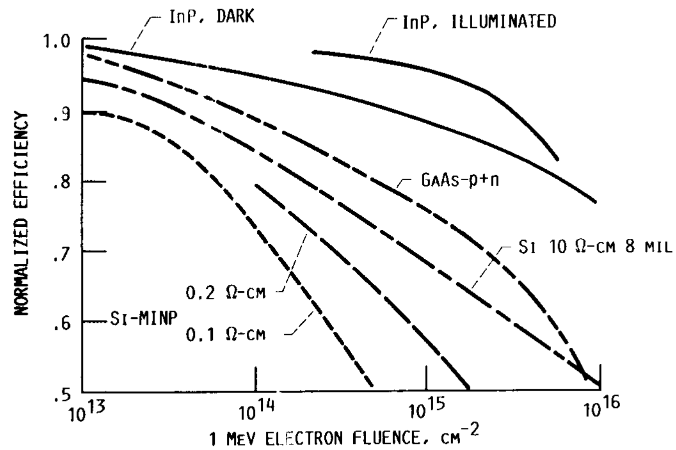

FIGURE 4. - NORMALIZED EFFICIENCIES OF InP, GaAs AND Si AFTER 1 MeV ELECTRON IRRADIATION.

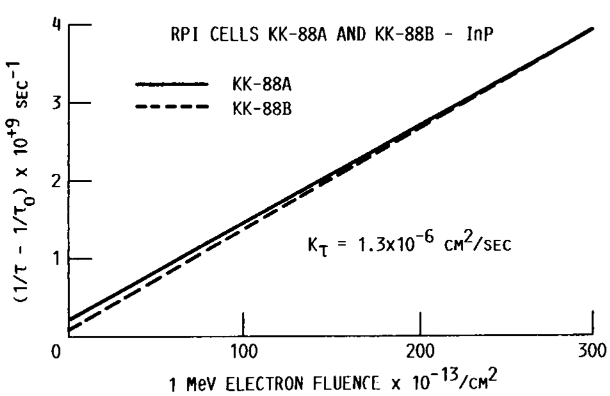

FIGURE 5. - GRAPHICAL PLOTS USED TO OBTAIN LIFETIME DAMAGE COEFFICIENTS FOR InP.

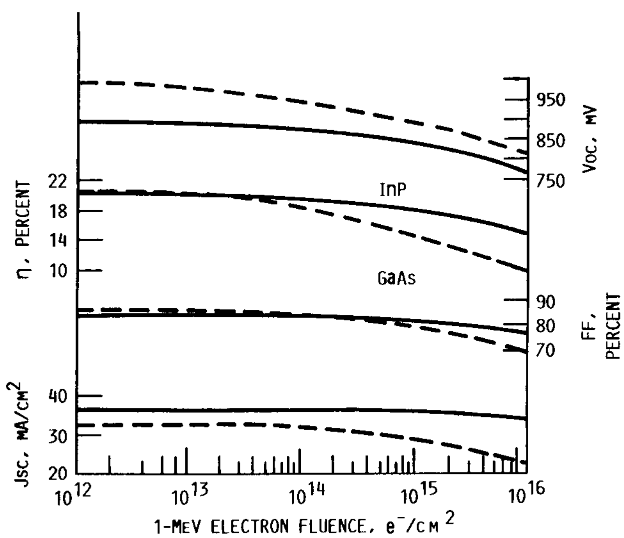

FIGURE 6. - PERFORMANCE PARAMETERS VERSUS 1 MeV e^- FLUENCE: THEORETICAL VARIATION FOR InP AND GaAs.

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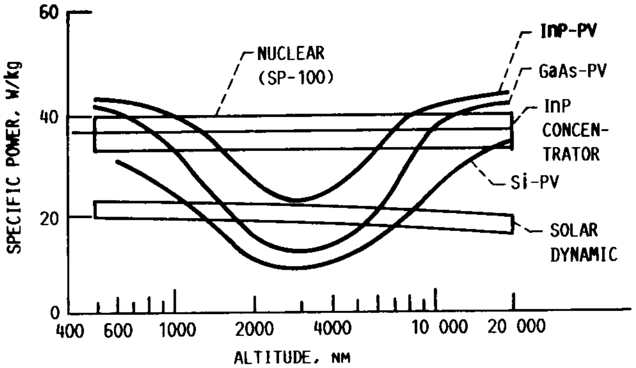

FIGURE 7. - SPECIFIC POWER AFTER 5 YEARS IN ORBIT.

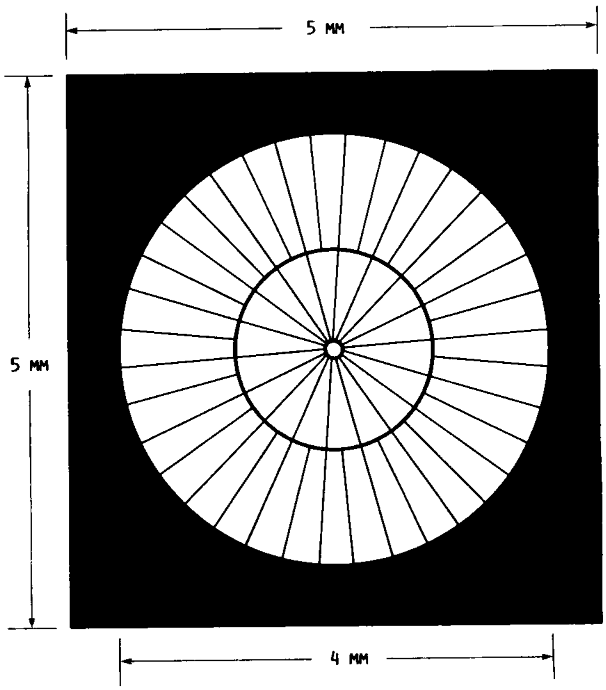

FIGURE 8. - CIRCULAR CELL FOR CASSEGRAINIAN CONCENTRATOR 100 AMO, 80 °C.

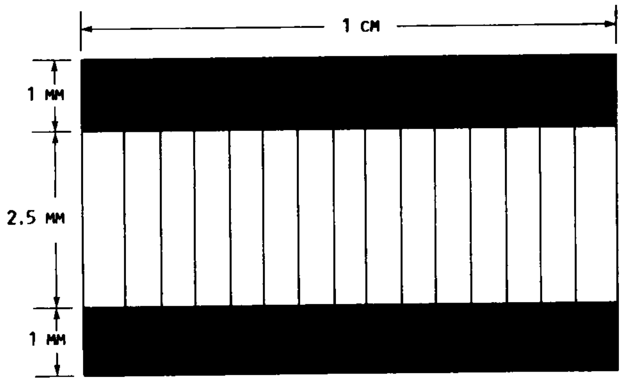

FIGURE 9. - RECTANGULAR CELL FOR SLATS CONCENTRATOR 20 AMO, 80 °C.

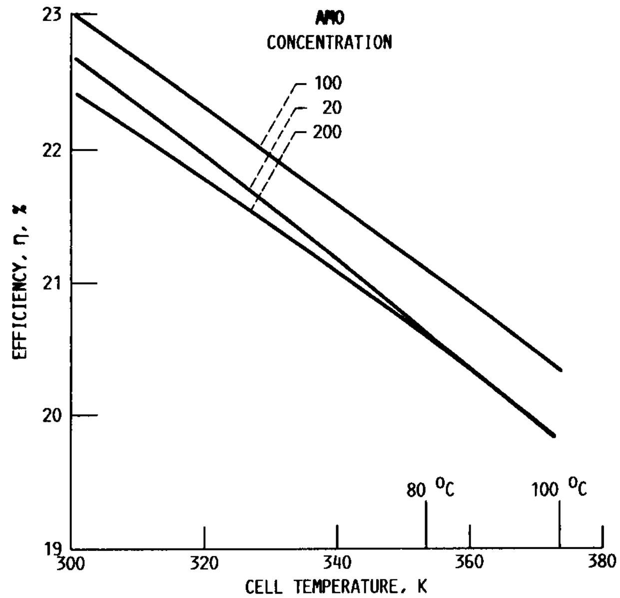

FIGURE 10. - EFFICIENCY VERSUS TEMPERATURE AT VARIOUS AMO CONCENTRATIONS - CIRCULAR CELLS.

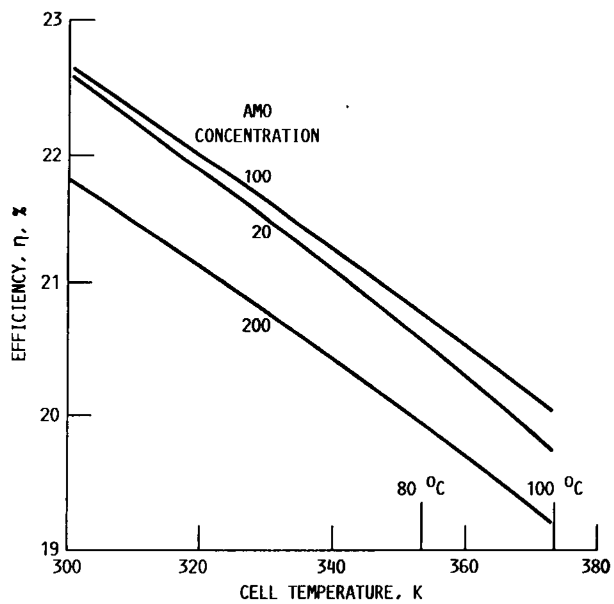

FIGURE 11. - EFFICIENCY VERSUS TEMPERATURE AT VARIOUS AMO CONCENTRATIONS - RECTANGULAR CELLS.

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-102103		

4. Title and Subtitle
Indium Phosphide Solar Cell Research in the United States—Comparison With Nonphotovoltaic Sources

5. Report Date

6. Performing Organization Code

7. Author(s)
I. Weinberg, C.K. Swartz, and R.E. Hart, Jr.

8. Performing Organization Report No.
E-4869

10. Work Unit No.
506-41-11

9. Performing Organization Name and Address
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135-3191

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, D.C. 20546-0001

13. Type of Report and Period Covered
Technical Memorandum

14. Sponsoring Agency Code

15. Supplementary Notes
Prepared for the European Space Power Conference sponsored by the European Space Agency, Madrid, Spain, October 2-6, 1989.

16. Abstract
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17. Key Words (Suggested by Author(s))
Solar cells
Indium phosphide
Radiation damage

18. Distribution Statement
Unclassified – Unlimited
Subject Category 31

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No of pages	22. Price*
Unclassified	Unclassified	12	A03

*For sale by the National Technical Information Service, Springfield, Virginia 22161