GaAs WORKSHOP REPORT

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The following report was the result of the workshop on GaAs solar cells held at NASA Lewis October 17, 1980, at the end of the Fourth High Efficiency and Radiation Damage Solar Cell Meeting. The members of the workshop were

Peter Borden	Varian
Dennis Flood	NASA Lewis
Sanyiv Kamath	Hughes Research Labs (Chairman)
John Lear	Martin Marietta
Ken Masloski	AFAPL
K. L. Wang	JPL
Gil Walker	NASA Langly

It was a productive workshop with active participation from all the members, and the following is a brief summary of the major conclusions reached about the status and future directions of work on GaAs solar cells.

The group felt very strongly that the advantages offered by the GaAs cells have been demonstrated in laboratory experiments and that it was time to fly the cells. The important next steps are to convey the information to the wider technical community, especially to the project offices that control the space satellite programs in the Air Force, Navy, NASA, and ESA. The group felt that a pilot line production of the cells to make the cells available to the missions in the near future could best be based on the present LPE technology and that this should be done as expeditiously as possible.

The findings of the workshop were divided into six main categories.

I. GaAs: Advantages and Disadvantages
II. The Substrate Problem
III. Cell Fabrication
IV. Future Trends
V. Cost
VI. Conclusions

I. GaAs: Advantages and Disadvantages

Advantages

1. 20 Percent higher η than silicon (BOL).
2. High temperature capability.[1]
3. High resistance to radiation damage vis-a-vis silicon. (We note that the 4-1/2 year old GaAs cell with deep junction flying in the NTS II package compares with the best silicon cell on the NTS II.)

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[1]Note that by improving the solder and the glue for cover glass, GaAs solar cells can be made suitable for operation at 500° C or higher.

4. The possibility of continuous annealing of GaAs cells looks very exciting and real.

Items 2, 3 and 4 above combine to produce EOL η close to beginning of life, increasing the advantage over silicon for all space missions. Special advantage for missions such as near sun or high radiation environment are specially noteworthy.

5. Thin film capability because of the short (<5 μm) absorption length for solar radiation and the short minority carrier diffusion length (~10 μm). John Fan (Lincoln Labs) has demonstrated that a "peeled film" with less than 10 μm thickness is capable of yielding 18 percent AMO efficiency. This compares with the 15 percent AMO, 50-μm cell in Si.

Disadvantages

1. Weight: The thinner cells eliminate this problem. However, the technology for thin cells still needs to be perfected. If the project office realizes the eventual advantages, the cost of development can be demonstrated to be fully justified by the reduction of system cost. The reduction in cover glass weight and packaging may be an additional possible advantage for GaAs.
2. Cost of material: GaAs now costs about \$3/cm^2 more than does silicon. However, since the solar cell is an area (and therefore volume) intensive device, the increase in volume of cell demand will bring down the cost of material (see LED cost history, for example). In the long term we feel the GaAs cells will only cost <\$1/cm^2 extra for practical space cells. This is not an important consideration for any practical space system during the next 10 years or more. Furthermore, the cell cost may be more than offset by gain in efficiency (especially EOL) that the GaAs cells offer.
3. Mechanical reliability, especially in flight testing, needs to be established. This would be true for any new technology. Continuous annealing, which seems possible to minimize radiation damage, may lead to the elimination of the cover glass and thus reduce cell package weight even further.

II. The Substrate Problem

The committee considered the substrate problem. The present solution of growing a buffer layer to permit the use of the commercial GaAs available is admittedly costly. However, since the development of new techniques, such as solution regrowth (IBM), efficient epitaxial batch processing techniques (LPE, MOCVD) are reducing the additional fabrication cost. We feel strongly that radical improvements in the quality of substrates should not be financed by solar cell development, especially in view of the severe shortage of research funds in this area.

Additionally, the committee felt that other device requirements, especially in the microwave area, should be used as the prime driver for substrate development in GaAs. This is especially true since the present thinking is that substrates such as Si can possibly be used as substrates for the GaAs solar cell. When we consider further that new technology, such as the Varian cells developed for DOE and the Lincoln Lab thin film cells (John Fan) made by the peeled film technology, are all aimed at elminating the extensive use of substrates altogether, we have to question the wisdom of using our limited research funds to finance GaAs bulk growth development. This argument gains further weight when we consider that the capability for diagnostics in GaAs to determine the degree of improvement is itself extremely limited.

The argument for improvement in silicon technology is more convincing since silicon needs to be at least 2 mils thick, and the development rides piggyback on the considerable existing technology. We discussed the Westinghouse ribbon growth in GaAs. While this is an attractive alternative, the cheap cell argument is so much stronger for the terrestrial applications; we felt they should be induced to at least share as the prime driver in this new development.

III. Cell Fabrication

The major conclusions were

1. LPE cells exist and should be flown as rapidly as possible to increase acceptance of the cell.
2. OMCVD is an attractive technique among all CVD techniques and should be considered the heat alternative to LPE. Long term advantages for both GaAs as well as for multijunction cells is an important consideration.
3. Ion implantation, laser annealing, and other processing tools should be used only when their development is sufficiently extensive on the basis of other needs.
4. MBE needs development that cannot be financed by solar cells alone. Piggyback effort may be justified if funds warrant it.
5. The n-on-p vs p-on-n question needs to be answered for the cell structure to see if there is any clear advantage for either. The topics to be considered are efficiency and radiation damage. The high temperature contacts may make homojunction cells impossible due to the shallow n layer. Questions: Is the n-on-p cell going to suffer in the blue response? Can you effectively contact it with suitable metals without the anodic oxide as a protection?

IV. Future Trends

Efficiency improvement

- Goal: 20 Percent AMO feasibility in 1981.
- Increase reproducible cell efficiency on pilot line to 18 percent AMO by 1982.

- Develop packaging (contacts, glass cover adhesive) to permit cell use at 400° C.
- With some typical missions in mind, develop panels that will deliver EOL efficiency close to BOL. Can a concentrator system be used to increased advantage for GaAs?
- Persuade JPL to include in the next handbook on radiation damage an expanded chapter on GaAs.
- Evaluate MOCVD.
- Evaluate thin cell capability for GaAs (2 mils and less); Peeled film, graphoepitaxy to be considered. The possibility of thin cells is not in question since the photocathodes developed by Varian have demonstrated the feasibility of using 10-μm material. Lincoln Lab's peeled film cell also proves the point very effectively. In the short run, is the polishing technique used by Varian effectiveμ It should at least be tried. Again, the terrestrial program on solar cells could be a partner in the development of a thin film cell.
- Ribbon growth. Evaluate economics of development (discussed previously in the substrates section).

V. Cost

The cost of the cell should be carefully evaluated with the cost of technology development, cell qualifications, and the cell production volumes in mind. The choice of specific missions as targets will greatly facilitate this exercise. Progressive cost reduction with increasing volume is possible on this approach. The various project officers could greatly facilitate the development by close coordination of the varying needs. NASA, DOD, and ESA are suggested as the prime agencies that could help identify realistic needs for the missions in 1983 and beyond.

VI. Conclusions

GaAs technology has arrived and has significant contributions to space power during the next decade. We have the prime responsibility as the technical community to make the relevant information available to the various mission project offices. Identify special areas such as near Sun missions, high radiation belts, orbit raising missions, concentrator cells, etc., where the special advantages offered by GaAs give it a definite edge to offset higher present cost. We feel that this procedure will result in the systematic development of the GaAs cell at a minimum of total cost with substantial benefit to the total space power program in the 1980s.