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Flexibility in Space Solar Cell Production

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Summary

This paper describes the wide range of cells that must be available from present-day production lines for space solar cells.

Introduction

After over thirty years of space-cell use, there is very little standardization in solar cell design. It is not generally recognized what a wide range of designs that must remain available on cell production lines. This paper surveys this range of designs.

Cell Design Variations

There are obvious variations, namely whether the cells are made from Silicon or GaAs. There are also differences in size. Concentrator cells are specifically designed for particular collectors, and range from 0.5 cm square to 2×6 cm (or sometimes even larger). Mostly for space use, the range is from 0.5 cm square to 1.5 cm square.

For flat plate cells, the sizes used nowadays extend from 2×2 cm to 8×8 cm. Even for discrete sizes (say 2×4 cm), there are several minor variations dictated by the user's preference in matching cell size to the planned array layout. This means that "2×4" cells often include 6 to 8 different variations; in some cases, this also complicates the efficiency claims for "nominal" size cells. The specified contacts also cover a wide range. The external contacts may be Ag, sometimes soldered either completely or in designated areas. The front contact stack for Si is usually TiPdAg although CrAnAg has been used. The back contact stack is usually TiPdAg but often a highly reflective layer (Al) is used to enhance IR reflectance and reduce solar absorptance - so called BSR cells. These cells are combined with a back surface of high reflectance.

The grid design varies widely from planar to concentrator cells, and also within each category. The back contact may be gridded, either to reduce bowing in thin cells or to allow most of the unabsorbed IR radiation to pass through the cell, again reducing solar absorptance - so called BST cells. For this latter cell, usually an AR coating is applied to the back surface to enhance IR transmission.

The contact configuration most used is called "top/bottom," but both wraparound and wrapthrough contact configurations are gaining popularity.

Internally, Si cells may use a range of resistivities (1 to 14 ohm-cm). In some cases, especially for thinner cells, a back surface field is used,and this must also be formed to retain any BSR or BST features.

Finally the specified cell thickness can vary widely. Mostly for larger cells, 8-10 mils is adequate. However, for weight reduction and increased radiation resistance, Si is often thinned to the range of 2 to 6 mils. GaAs (and Ge) are both over twice as dense as Si. Therefore, for weight reduction, the starting substrate is often thinned. Because Ge is stronger than GaAs but allows good MOCVD growth of active GaAs layers, large area GaAs cells are usually grown on thin Ge substrates.

Critical Manufacturing Areas

Although there are many combinations possible with the above described variations, it is important that the basic cell properties are maintained. These properties include

- maximum efficiency, for the resistivity range used. This often involves trade-off between EOL and BOL efficiency, and may be dictated by the orbit selected;
- reasonably high radiation resistance;
- good contact strength and good ruggedness under temperature cycling;
- good performance when exposed to the short wavelength UV in space;
- good performance in the environmental stress tests specified;
- controlled solar absorptance;
- good mechanical strength, perhaps combined with redundant contact placement.

The critical manufacturing steps with most influence on the final cell properties are

- ingot growth and polishing (ingot size must be compatible with good yield of final cell size). The surface finish helps control the solar absorptance;
- contact deposition, usually by evaporation. The surface cleanliness controls the contact adhesion. Photoresist technology is usually used to produce fine grid patterns;
- AR coatings are deposited usually by evaporation;
- sintering treatments are used to enhance contact or coating adhesion;
- the in-process handling and fixturing must often be adjusted to accommodate large and/or thin wafers;
- if wraparound contacts are used, the cell edges must be polished and coated with an impregnable dielectric layer to support the contact layer;

- if wrapthrough contacts are used, smooth surface holes must be formed and also coated with dielectric to support the contact layer.

Complexities in Production Runs

It can be appreciated from the above list of possible cell properties, that to make limited but possibly large volume production runs of any particular cell type requires maintaining a wide range of processing technology, fixturing and equipment in readiness. For each new run, there is usually a short period required to confirm that all the processes can be combined (under production conditions) to meet all the cell requirements.

In addition, the scheduling of space cell runs is unpredictable, and stockpiling has not been possible. Thus, often several different cell types may have to be processed in parallel, each cell type being optimized with its own particular requirements. For each given materials (Si, GaAs), all the cells produced must share the same general processing facilities and this too makes control of the production run more complex.

Conclusion

We have discussed the factors which make it necessary to have available a wide range of cell processing technologies, and to deploy these technologies as required for theoretical cell runs. There is always the need for parallel processing for "keeping-alive" a set of finely tuned processes, to cope with a mostly unpredictable blend of cell types.

Production conditions require that a set of highly optimized process techniques be applied to meet a complete set of demanding cell properties, and there is little time to perform empirical tests of the type used in laboratory scale development work.

Also the in-line characterization and process controls must provide prompt feedback to allow the line conditions to be monitored and controlled.

We hope we have presented reasons why present space cell production lines require great flexibility.

Large Area Silicon Cells

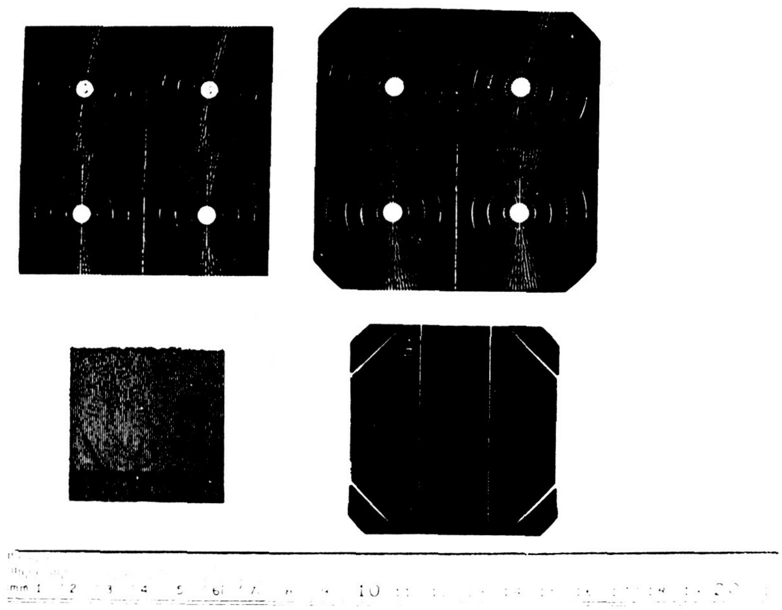

Figure 1

Various Space Cell Size

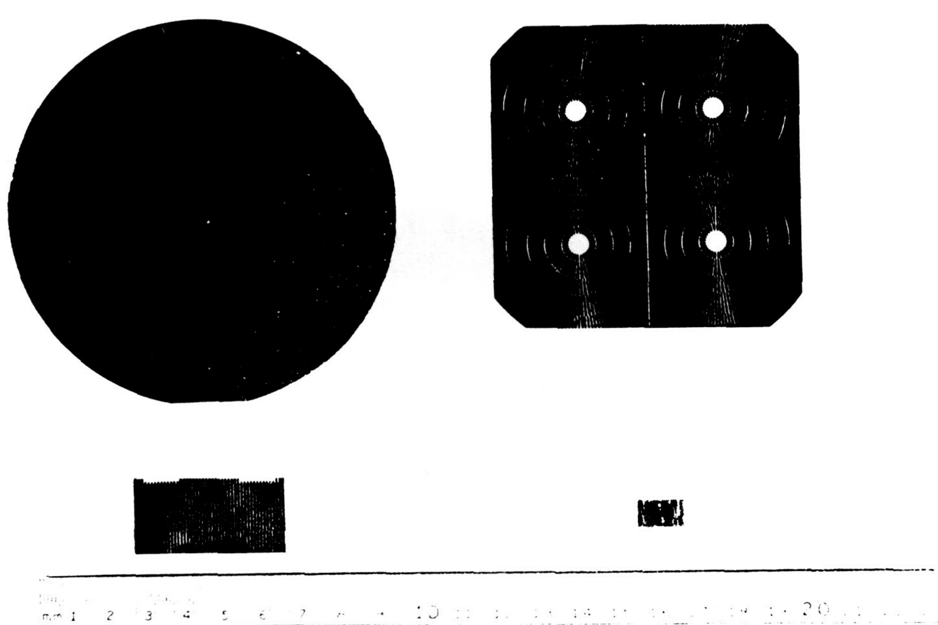

Figure 2

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2x4 and 4x2 Silicon Cells

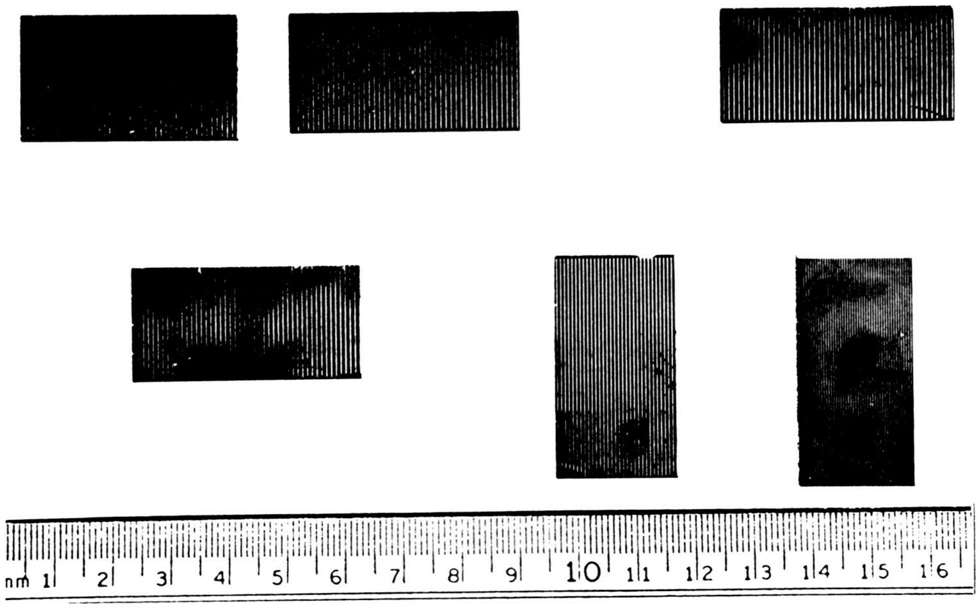

Figure 3

GaAs Wafers and Cells of Different Sizes

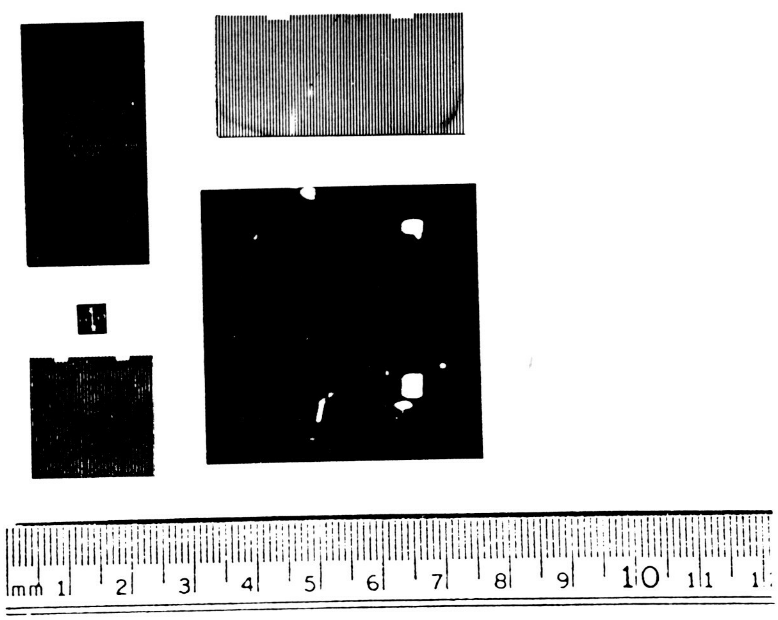

Figure 4