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GETTING THE CURRENT OUT

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INTRODUCTION

Progress of a photovoltaic (PV) device from a research concept to a competitive power-generation source requires an increasing concern with current collection. The initial metallization focus is usually on contact resistance, since a good ohmic contact is desirable for accurate device characterization measurements. As the device grows in size, sheet resistance losses become important and a metal grid is usually added to reduce the effective sheet resistance. Later, as size and conversion efficiency continue to increase, grid-line resistance and cell shadowing must be considered simultaneously, because grid-line resistance is inversely related to total grid-line area and cell shadowing is directly related. Finally, large devices often require bus bars to handle the generated current efficiently.

A PV cell grid design must consider the five power-loss phenomena mentioned above: sheet resistance, contact resistance, grid resistance, bus-bar resistance and cell shadowing. The requirement for competitive power generation adds processing and material cost considerations to the above purely physical concerns. The design of PV cell metallization systems must therefore balance these factors along with other factors such as reliability, materials and end use.

BACKGROUND

Although cost, reliability and usage are important factors in deciding upon the best metallization system, this paper will focus only upon grid-line design and substrate material problems for flat-plate solar arrays.

Extensive literature is available on analyzing power losses associated with the grid patterns on rectangular PV cells (References 1 through 7). There has been only one computer program released (Reference 8) and one paper presented (Reference 9) that focused on optimal (minimum power loss) grid-patrern designs for round or rectangular cells with more than two design variables.

The computer program (Reference 8), CELCAL (see Appendix A), is a FORTRAN program that treats all inputs as variables and calculates a point solution for each input data set. Optimization must be done manually by iteration. Calculation of the sheet-resistance power loss is by sectional integration (Reference 10). This method is an approximation to the more exact but difficult solution of Poisson's equation for the potential as a function of position (Reference 3). The error introduced by this approximation is small. Another attribute of the CELCAL program is the ability to handle up to three bus bars, which may be either coplanar or multilevel*.

*J.R. Davis, Westinghouse R&D Center, private communication.

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Daniel, Burger and Stone (Reference 9) (Appendix B) use nonlinear optimization, a modified Newton-Raphson method, for interactive computer optimization. This program is written in APL and is presently available only at the Jet Propulsion Laboratory (JPL). When documentation is completed, this APL program will be submitted to the NASA Computer Software Management and Information Center (COSMIC) data bank. This program also uses a sectional integration approach; however, it provides a more precise calculation of round-cell power losses and has sensitivity analysis capabilities.

Considerable analytical effort has been expanded in the development of PV-cell grid lines. These efforts have largely been focused upon single-crystal silicon cells, based on wafers cut from Czochralski-grown ingots. High wafer costs have resulted in the development of numerous competitive PV devices. Using these devices for power production will pose some interesting problems.

NEW CHALLENGES

At least three new PV materials are being investigated for power production: amorphous silicon, gallium arsenide and copper indium diselenide. Amorphous silicon (a-Si) has been introduced to the world in solar-powered calculators and wrist watches. Japan now manufactures at least two megawatts per year of a-Si cells for the consumer-product market. These cells are typically only 1% to 3% efficient. Some small research a-Si cells have shown 10% conversion efficiency, but larger devices are usually only 5% to 6% efficient. Part of the problem with a-Si is its very high sheet resistivity. A transparent conductive coating (TCC) is required to lower the sheet resistance, adding another element to the metallization design problem. Some TCCs have shown a contact resistance problem with a-Si. An additional problem with a-Si is its thermal sensitivity. Many metallization systems use a sintering process with temperatures exceeding the allowable a-Si range.

Gallium arsenide (GaAs) has a very high operating temperature range and a reasonable sheet resistivity. Why, then, is there a problem? Compound semiconductors contain, by definition, more than one elemental component and thus present a greater range of possibilities for inter diffusion, reaction and compound formation. In particular, GaAs is now attractive only as a power generator due to its high service temperature, which permits its use in PV concentrator cells. These cells combine high current densitities with high temperatures and thereby impose severe conditions on the metallization system.

A more recent power system contender is copper indium diselenide. Appropriate metallization systems for this material are being investigated.

Other materials, such as cadmium telluride and zinc phosphide, are possible future contenders.

The field of metallization systems design for photovoltaic application will remain very active for at least the next decade as the world gradually converts to renewable energy sources.

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