THE EFFECT OF DIFFERENT SOLAR SIMULATORS ON THE MEASUREMENT OF SHORT-CIRCUIT CURRENT TEMPERATURE COEFFICIENTS

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SUMMARY

Gallium arsenide solar cells are being considered for several high temperature missions in space. Both near-Sun and concentrator missions could involve cell temperatures on the order of 200° C. Performance measurements of cells at elevated temperatures are usually made using simulated sunlight and a matched reference cell. Due to the change in bandgap with increasing temperature at portions of the spectrum where considerable simulated irradiance is present, there are significant differences in measured short circuit current at elevated temperatures among different simulators. To illustrate this, both experimental and theoretical data are presented for gallium arsenide cells.

INTRODUCTION

The use of gallium arsenide solar cells in space is being considered for several reasons. One reason is their high temperature operation, thus allowing near-Sun or high concentration missions. Before high temperature (200° C) gallium arsenide cells can be used, however, further development work will be required. There will also be many required measurements at temperatures ranging from about room temperature to over 200° C. Some recent data have indicated that the increase in measured short circuit current, α, with increasing temperature depends strongly on the type of solar simulator used. The temperature coefficient of α can vary by a factor of more than 5 depending on the incident irradiance. The tentative answer to why α varies with incident irradiance depends on the bandgap of gallium arsenide. As the temperature is increased, the decrease in bandgap is at portions of the spectrum where the irradiance of simulators and sunlight is both fairly high and varies from simulator to simulator. Hence the temperature coefficient can vary widely. In an effort to test this hypothesis, NASA Lewis performed an experimental and theoretical study using gallium arsenide cells, a variety of solar simulators, and the known bandgap temperature characteristics of gallium arsenide.

THEORETICAL CALCULATIONS

The increase in α with temperature results from two effects. The smaller bandgap allows more incident photons to be collected, and secondly, there can be an improvement in the lifetime of the cell material (ref. 1). Since we are concerned here with the effects of different simulators, we will only look at the change in bandgap effect, because any increase in lifetime will give a similar current increase for each simulator. The change in bandgap for gallium arsenide is well known (ref. 2) and can be utilized to generate a series of spectral response curves. In Figure 1 we have plotted spectral response curves for gallium arsenide at several temperatures. The 300 K curve is measured data, and the higher temperature curves are generated by shifting the cutoff wavelength corresponding to the change in bandgap.

The short circuit current can be calculated for any spectral distribution of irradiance by using the following equation:

$$I_{SC} = A \int J(\lambda)R(\lambda)d\lambda \tag{1}$$

where $J(\lambda)$ is the spectral distribution of incident irradiance, $R(\lambda)$ is spectral response, A is cell active area, and the integration is over the solar wavelength (λ) region. Figures 2 to 6 show spectral distributions for AMO sunlight and four solar simulators. Equation (1) was used to calculate α at several temperatures for gallium arsenide solar cells under the different spectral irradiances of figures 2 to 6. Figure 7 shows calculated α as a function of temperature for three of the incident irradiances, AMO, Filtered xenon, and unfiltered xenon. Note that the increase in current is not necessarily linear with increasing temperature. Note also the large differences between the unfiltered xenon curve and the AMO and filtered xenon curves. The curves were normalized to the AMO value at 300 K (112.7mA for a 4 cm^2 cell) for direct comparison.

The temperature coefficients of α were calculated using the data of figure 7 and similar data for the two other simulators (pulsed xenon and dichroic filtered tungsten (ELH) and are presented in table I. The AMO value near $20 \mu A/cm^2$-K is in agreement with published data on similar cells (refs. 3 and 4). In all cases the temperature coefficient is higher in the 400 to 500 K range than in the 300 to 400 K range. Note the extremely high values of temperature coefficient for the unfiltered xenon simulator. This is due to the very high irradiance in the wavelength interval near the gallium arsenide bandgap for the unfiltered xenon simulator.

MEASURED DATA

In an effort to experimentally verify the calculated data, measurements were made on two gallium arsenide cells at various temperatures and under different simulators. The cells were manufactured by Hughes Research Lab under an existing NASA Lewis contract, using the liquid phase epitaxy growth technique. They are p/n cells with an AlGaAs window. At Lewis measurements were made at 200° C (473 K) using a xenon pulsed simulator and at 150° C (423 K) using a filtered xenon simulator and an ELH lamp simulator. Data at 200° C (473 K) under an unfiltered xenon simulator were supplied by Hughes. The measured data are summarized in table II with current at the highest temperature measured for each simulator and the calculated temperature coefficients reported. Data were taken only to 150° C under the filtered xenon and ELH simulators due to limitations in the temperature capabilities of the test apparatus.

The measured data are in fairly good agreement with calculated data of table I. For the three xenon simulators, filtered, unfiltered, and pulsed, the measured temperature coefficients are 10 to 30 percent higher than the calculated values. However, the calculated values do not reflect any increase in α due to improved lifetime at higher temperatures. Accounting for this would make the measured and calculated temperature coefficients agree quite well for the three xenon simulators. For the ELH lamp simulator, the calculated value of temperature coefficient is larger than the measured value.

This is attributed to variations in output of ELH lamps. The spectral distribution of figure 6 may not be the same as that of the ELH lamp used in the measurements. In any case, the temperature coefficient measured using an ELH lamp simulator is considerably lower than the true value.

CONCLUSIONS

Both calculated and measured data indicate a strong dependence on incident spectral irradiance for the measured temperature coefficient of short circuit current for GaAs solar cells. Values of as high as 80μA/cm^2 K using an unfiltered xenon simulator, or as low as 10μA/cm^2 K using an ELH lamp simulator may be obtained. The reason for the spread in values results from the bandgap change with temperature occurring at portions of the spectrum where simulators can differ widely.

REFERENCES

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4. Swartz, C.K., and Hart, R.E., Jr.: Temperature and Intensity Dependence of the Performance of an Electron-Irradiated (AlGa) As/GaAs Solar Cell. Solar Cell High Efficiency and Radiation Damage, 1979. NASA CP-2097, 1979, pp. 217-22.

TABLE I.- CALCULATED VALUES OF SHORT-CIRCUIT CURRENT

TEMPERATURE COEFFICIENTS

Spectrum	Temperature coefficients, ?A/cm^2 K, at -	
	300 - 400 K	400 - 500 K
AMO	18.6	21.2
Filtered xenon	15.6	22.7
Unfiltered xenon	49.2	62.2
Pulsed xenon	20.9	27.2
ELH	10.4	10.8

TABLE II.- SUMMARY OF MEASURED DATA

Simulator	Short circuit current I_{sc}, mA	Temperature coefficient, ?A/cm^2 K
Filtered xenon	125.2 at 150° C	25.0
Unfiltered xenon	168.9 at 200° C	80.3
Pulsed xenon	134.0 at 200° C	30.4
ELH	116.2 at 150° C	7.0

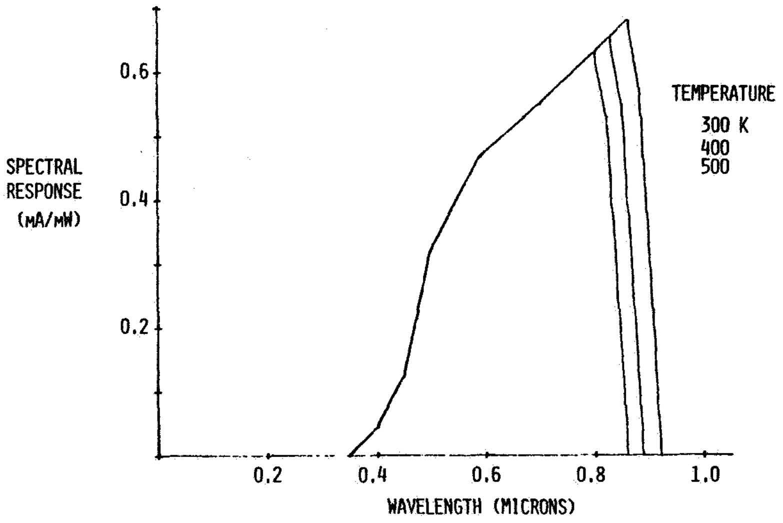

Fig. 1 Spectral response of gallium arsenide

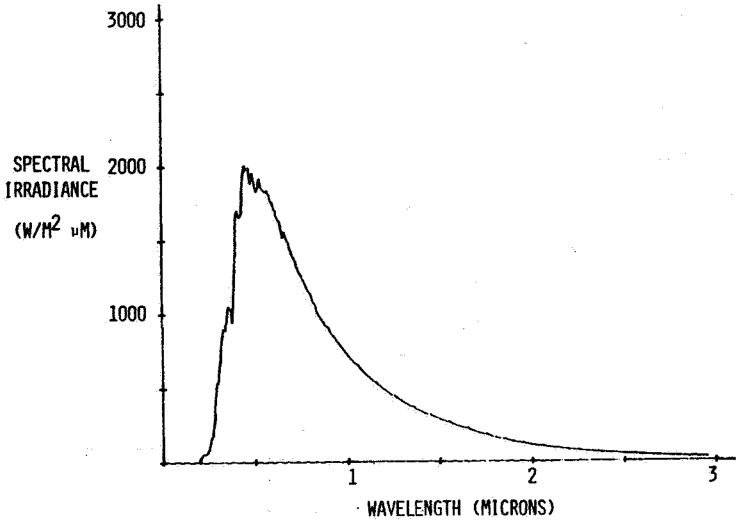

Fig. 2 Labs & Neckel AMO spectrum

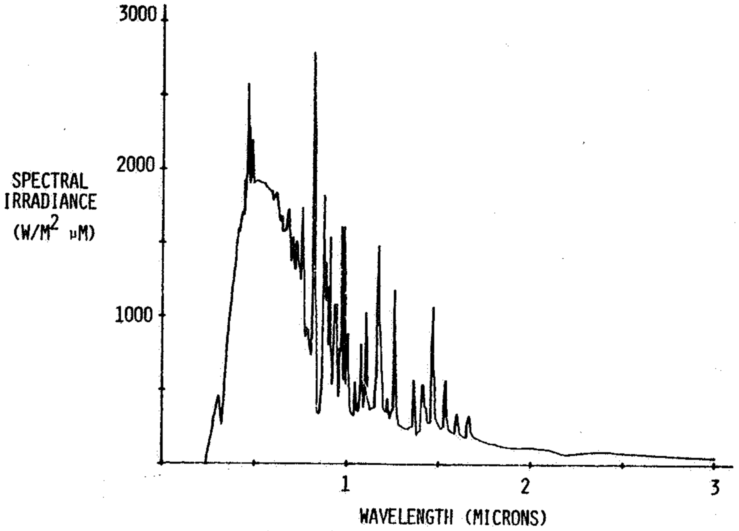

Fig. 3 Filtered xenon spectrum

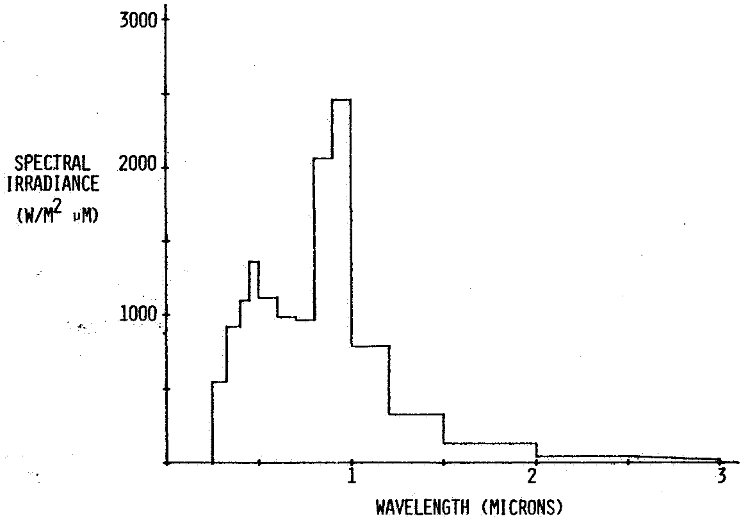

Fig. 4 Unfiltered xenon spectrum

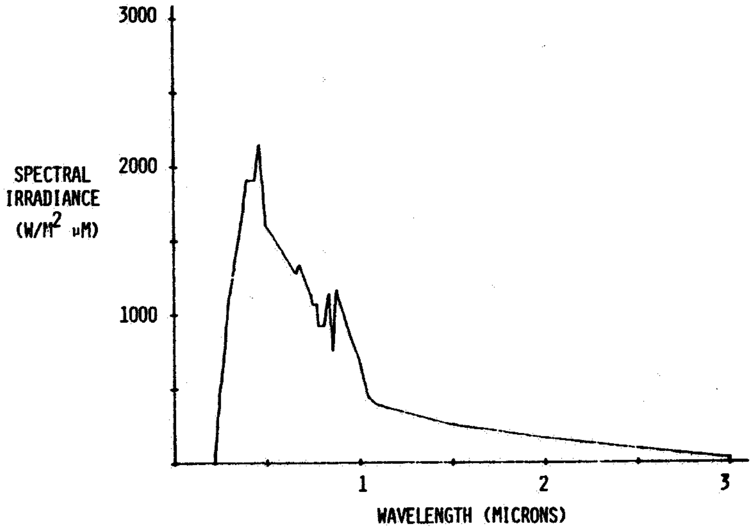

Fig. 5 Pulsed xenon spectrum

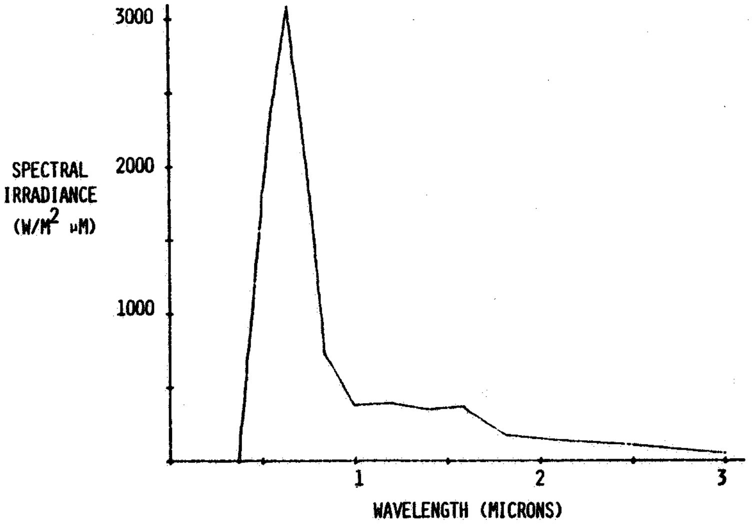

Fig. 6 ELH lamp spectrum

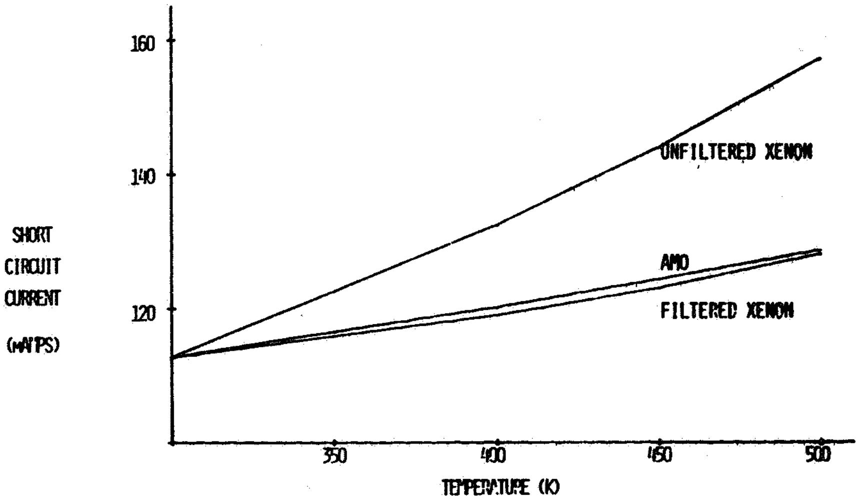

Fig. 7 Variation of calculated I_{sc} with temperature