Analysis of Conversion Efficiency of Large Area a-Si:H Solar Cells
H. Haruki, Y. Uchida, H. Sakai, M. Nishiura and M. Kamiyama
Fuji Electric Corporate Research and Development Ltd.
2-2-1 Nagasaka, Yokusuka, Kanagawa 240-01

Introduction
We have developed large area hydrogenated amorphous silicon (a-Si:H) solar cells with ITO/nip/SS structure as shown in Fig.1. The conversion efficiencies (η) of 6.47%, 5.2% and 4.2% were obtained for 1.2 cm², 49 cm² and 100 cm² cells under AM1 light, respectively. Cell area dependence of η was investigated by comparing the characteristics of 1.2 cm² cell with that of 49 cm² cell. The incident power (Pin) dependence of the cell characteristics is also studied.

Experimental
The decrease of η with increasing cell area relates to the decrease of Jsc and FF as shown in Fig.2. The decrease can be caused from (1) areal inhomogeneity of a-Si:H layers, (2) series (Rs) and (3) shunt (Rsh) resistances existing in the cell. We prepared 25 small cells (1.2 cm²) made on a 49 cm² substrate. Each 1.2 cm² cell was electrically isolated in order to compare its characteristics with 49 cm² cells. Figure 3 shows the J-V characteristics of cells. The solid lines represent the characteristics of 1.2 cm² cells with the maximum and minimum η's among the 25 cells. The Jsc lies between 9.8 mA/cm² and 11.78 mA/cm² while Voc is almost constant. The dotted line was obtained when those twenty-five 1.2 cm² cells were parallel-connected. Jsc of the parallel-connected cell is 10.79 mA/cm² and is equal to the mean value of Jsc in small cells. This result indicates that areal inhomogeneity of the a-Si:H layer in the 49 cm² cell causes the area dependence of Jsc.

The effect of Rs was evaluated by calculating FF from the output power vs. current relation, which was derived by subtracting the calculated power loss in Rs (due to the ITO film and the grid electrodes) from the generated power. The output power of 1.2 cm² cell was taken as the generated power because the power loss was calculated to be less than 0.4% of the generated power and FF was measured as 0.659. FF of 49 cm² cell was calculated as 0.615, while the measured value was 0.576 as shown in Fig.2. About a half of the decrease in FF with increasing cell area can be attributed to the effect of Rs.

The Rsh of the 49 cm² cell having the η of 5.2% was measured as 145 Ω from the dark J-V characteristics. From the power loss by the Rsh, we calculated Voc and FF to be 0.875 V and 0.650 for the 49 cm² cell, respectively. These results indicate that about 10% of decrease in FF from 1.2 cm² to 49 cm² cells can be
attributed to the effect of Rs.

The Pin dependence of \( \eta \) and FF of 1.2 cm\(^2\) and 49 cm\(^2\) cells were measured to estimate the effect of Rs on cell characteristics. \( J_{sc} \) and Voc of both cells increased with the increase in Pin. FF of 1.2 cm\(^2\) cell is independent of Pin and that of 49 cm\(^2\) cell decreases with increasing Pin due to the effects of Rs as shown in Fig.4. In 1.2 cm\(^2\) cell, \( \eta \) increases with Pin due to the increase in Voc but that of 49 cm\(^2\) cell slightly decreases, which is caused by the decrease in FF with increasing Pin.

Conclusion

Factors influencing the area dependence of the characteristics of a-Si:H solar cell have been studied. Analytical studies indicate that the \( J_{sc} \) lowering is entirely attributed to areal inhomogeneity of the a-Si:H layers, and the main factor for the FF lowering is the Rs which comes from the ITO film and the grid electrodes in the cell. The \( \eta \) of 49 cm\(^2\) cell slightly decreases with increasing Pin due to this Rs. These results suggest that the cell characteristics of the large area a-Si:H solar cells can be further improved by an optimization of the grid electrode design and precise optimization of the a-Si:H film deposition conditions for uniformity.

This work was supported by the Agency of Industrial Science and Technology as Sunshine Project.


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**Fig.1** Schematic structure of a-Si:H solar cell

**Fig.2** Cell area dependence of output characteristics

**Fig.3** The output characteristics of 1.2 cm\(^2\) cell

**Fig.4** The Pin dependence of \( \eta \) and FF