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Efficiency Improvement in Amorphous SiGe:H Solar Cells by the Use of a Graded Bandgap Layer at the i/n Interface

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The conversion efficiency of a-Si:H/a-SiGe:H tandem type solar cells has been limited by the poor performance of a-SiGe:H cells. For achievement of high efficiency, it is therefore necessary to improve the performance of a-SiGe:H cells. Recently, high quality a-SiGe:H films have been prepared by using a photo-CVD and a triode glow discharge technique[1),2)]. It has been reported that the conversion efficiency of a-Si:H and a-SiGe:H p-i-n type solar cells could be effectively improved by introducing a graded bandgap layer at the p/i interface, which reduces the interface recombinations[3),4)]. In this paper, we report on a drastic improvement of the conversion efficiency of photo-CVD a-SiGe:H p-i-n type solar cells by introducing a graded bandgap a-SiGe:H layer at the i/n interface.

As reported previously[5)], we have succeeded to prepare high photoconductive($>10^{-4}$S/cm under AM1,100mW/cm^2 insolation) and high photosensitive($\Delta\sigma_{ph}/\sigma_d \simeq 3*10^4$) a-SiGe:H films by using a photo-CVD system with three separated chambers. The p-i-n type solar cells used in this study were fabricated with these high quality a-SiGe:H films. The cell structure was glass/TCO/p(a-SiC)-i(a-SiGe)-n(a-Si)/Ag with graded bandgap a-SiGe:H layers at the p/i and i/n interfaces, as shown in Fig.1. The graded bandgap a-SiGe:H layers at the p/i and i/n interfaces were prepared by increasing (for the p/i interface) or by decreasing (for the i/n interface) the gasous ratio of GeH_4 to Si_2H_6 during deposition.

First, the preparation conditions of p and p/i graded bandgap layers were optimized without introducing the i/n graded bandgap layer. A conversion efficiency of 7.80% was obtained with 1.57eV bandgap materials. Then, a-SiGe:H solar cells with graded bandgap a-SiGe:H layers at the p/i and i/n interfaces were fabricated. As shown in Fig.2, a conversion efficiency of 8.40% was obtained particularly due to an improvement in the fill factor (FF).

For a-SiGe:H solar cells, an abrupt change of composition at the i/n hetero-junction may induce a large amount of defects at the i/n interface, as it is the case with the p/i interface. These defects may enhance the recombinations of carriers photo-generated in the i layer near the i/n interface. The result suggests that the defect density was reduced by introducing the i/n graded bandgap layer and the recombination velocity at the i/n interface was minimized. The conversion efficiency of 8.65% under AM1,100mW/cm^2 insolation obtained with 1.57eV bandgap materials by optimizing deposition conditions(Fig.3) is the highest value reported to date for a-SiGe:H solar cells.

In conclusion, we have showed that the conversion efficiency of a-SiGe:H solar cells could be effectively improved by introducing a graded bandgap layer at the i/n interface. It is expected that high performance tandem type solar cells will be fabricated by applying these a-SiGe:H solar cells as the bottom cells.

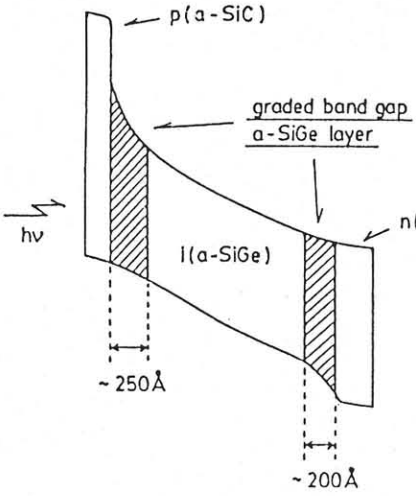

Fig.1: Schematic structure of the p-i-n a-SiGe:H solar cell.

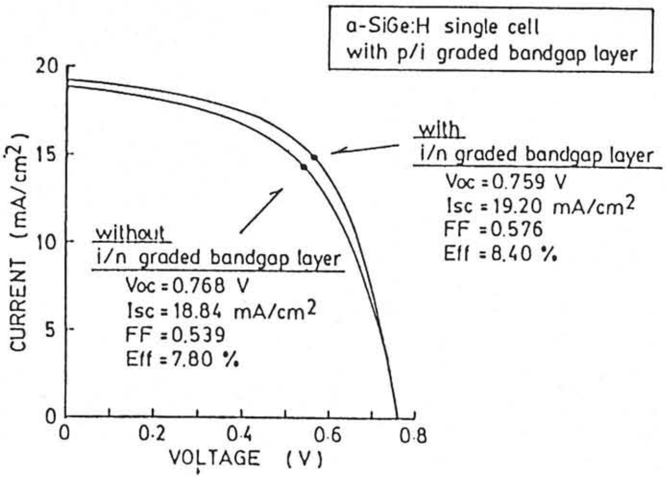

Fig.2: Illuminated I-V characteristics of a-SiGe:H solar cells with and without the graded bandgap layer at the i/n interface.

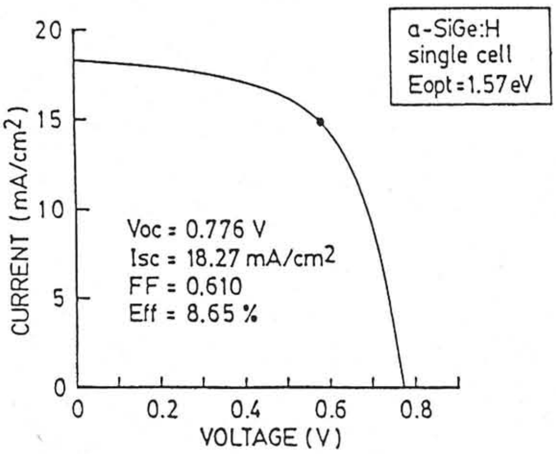

Fig.3: Illuminated I-V characteristics of the highest efficiency a-SiGe:H solar cell obtained in this study.

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