Microcrystalline silicon oxide p-layer and its application to solar cell

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Abstract

As microcrystalline silicon oxide (μc-SiO) is reported to be more promising material than microcrystalline silicon carbide for the application to solar cells, both of high efficiency amorphous (top cell) and microcrystalline (bottom cell) silicon solar cells fabricated on tin oxide coated glass substrate have been developed by using μc-SiO p-layer and buffer i-layer. High VHF frequency of 60 MHz and carbon dioxide gas are used for their deposition. ZnO deposited by DC sputtering is coated on Asahi's type U tin oxide in order to promote the crystallization of the μc-SiO p-layer. It was found that the top cell with this novel μc-SiO p-layer has higher cell efficiency than the one with normal SiO p-layer. Furthermore, the microcrystalline bottom cell with novel μc-SiO p-layer and μc-SiO buffer layer has higher performance than the one with normal c-Si p-layer. Up to now, an efficiency of more than 15% has been achieved with a-SiO/a-SiGe/mc-Si tandem cell.

Keywords: microcrystalline silicon oxide, VHF, triple cell

1. Introduction

Microcrystalline silicon oxide (μc-SiO) was reported to be more promising material than microcrystalline silicon carbide (μc-SiC) for the application to solar cells by author since its microcrystallization could be occurred more easily than μc-SiC (Sichanugristet al.,1994). At that time, it was deposited by 13.56 MHz and was applied to the p-layer of nip-type solar cell fabricated on metal substrate. There is no work done after that on pin-type glass substrate.

On the other hand, mc-SiC deposited by ECR has been developed and applied to the device fabricated on glass (Hanaki et al., 1987). Higher efficiency was achieved, but its scale up to the manufacturing was somehow difficult.

Recently, Mitsubishi Heavy Industries has developed mc-SiC using VHF (Very High Frequency) glow discharge and has applied to the microcrystalline bottom cell (Saneyuki et al., 2003.). They achieved 8.1% with higher Voc of 0.573 V, but there is no work done with the top a-Si cell.

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In our present work, we have developed mc-SiO p-layer and buffer layer using VHF for the first time and have applied them to both top, middle and bottom cell fabricated on the glass substrate for a-SiO/a-SiGe/mc-Si tandem type solar cell.

2. Experimental

A cluster-type, multi-chamber system in which various films (Ag, ZnO, a-Si, mc-Si and mc-SiO films) can be deposited on 30 cm x 40 cm area without breaking the pressure has been used. Our detailed cell structure for the top cell is glass / SnO_2 / ZnO / p(μc-SiO) - buffer i(SiO or μc-SiO) - i(a-Si) - n(μc-Si) / ZnO / Ag while the same cell structure is used for bottom cell except i (μc-Si) and n(a-Si) were used instead of i(a-Si) and n(μc-Si).

High VHF frequency of 60 MHz and carbon dioxide gas are used for μc-SiO deposition with higher VHF power and higher hydrogen dilution. ZnO deposited by DC sputtering is coated on Asahi's U-type tin oxide in order to promote the crystallization of the μc-SiO p-layer. The thick of the top cell is fixed to be around 150-200 nm while the thickness is around 1.5 - 2 mm for the bottom cell. Cell performance was measured under AM1.5, 100 mW/cm^2 at 25 °C.

3. Results

3.1. Conductivity vs CO_2 gas doping ratio

Figure 1 shows the relationship between the film conductivity of p(mc-SiO) and CO_2 gas doping ratio ($CO_2/(SiH_4+CO_2)$). As expected, the conductivity decreased with more CO_2 doping ratio. At the gas ratio of 0.9, the conductivity is around $1.0 x 10^{-2}$ $(\Omega.cm)^{-1}$.

3.2. Application to the top cell

By applying μc-SiO to the p-layer of the top cell instead of conventional a-SiO p-layer, it was found that cell efficiency was increased. The detailed cell parameters are shown in Table 1, comparing with the conventional SiO p-layer. The CO_2 doping gas is around 0.9. Higher Voc and efficiency is expected by optimizing the deposition condition of the μc-SiO p-layer and the buffer layer.

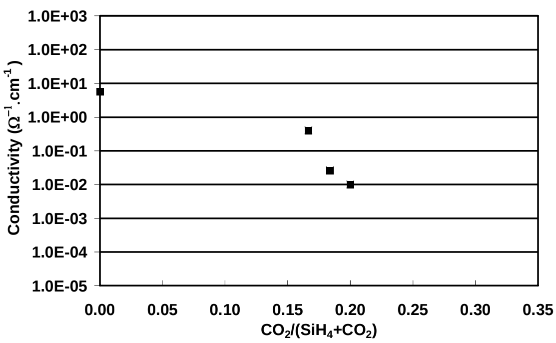

Figure 1. Film conductivity of p(μc-SiO) vs CO_2 gas doping ratio

Table 1 Detailed cell parameters for the top cell

	Voc	Jsc (mA/cm^2)	FF	Eff(%)
p(a-SiO)	0.92	17.5	0.64	10.2
p(μc-SiO)	0.90	17.8	0.69	11.0

3.3. Application to the bottom cell

By applying mc-SiO to the p-layer and buffer layer of the bottom cell, it was found that cell efficiency was increased, comparing with the conventional one with mc-Si p-layer. The detailed cell parameters are shown in Table 2. Here, the CO_2 doping gas is around 0.9. Higher efficiency is expected by optimizing the deposition condition of the mc-SiO p-layer and mc-SiO buffer layer.

Table 2 Detailed cell parameters for the bottom cell

	Voc	Jsc (mA/cm^2)	FF	Eff(%)
p(μc-Si)	0.48	25.10	0.61	7.24
p(μc-SiO)	0.52	24.40	0.66	8.25

3.4. Application to the tandem cell

A-SiO/a-SiGe/μc-Si tandem cells have been fabricated using μc-SiO p-layer. Up to now, the cell efficiency of more than 15% has been achieved. This result shows that μc-SiO is the promising material for the application of a-SiO/a-SiGe/μc-Si tandem cell.

4. Conclusion

μc-SiO has been deposited by VHF plasma using CO_2 gas. It was found that the top cell with this novel μc-SiO p-layer has higher cell efficiency than the one with normal a-SiO p-layer. Furthermore, the microcrystalline bottom cell with novel μc-SiO p-layer and μc-SiO buffer layer has higher performance than the one with normal μc-Si p-layer. Up to now, an efficiency of more than 15% has been achieved with a-SiO/a-SiGe/μc-Si triple cell. The results shows that μc-SiO fabricated by VHF plasma is the promising material for the application to a-Si type solar cell fabricated on the glass substrate.

References

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