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MOS solar cells with oxides deposited by sol-gel spin-coating techniques

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The metal–oxide–semiconductor (MOS) solar cells with sol-gel derived silicon dioxides (SiO_2) deposited by spin coating are proposed in this study. The sol-gel derived SiO_2 layer is prepared at low temperature of 450°C. Such processes are simple and low-cost. These techniques are, therefore, useful for large-scale and large-amount manufacturing in MOS solar cells. It is observed that the short-circuit current density (I_{sc}) of 2.48 mA, the open-circuit voltage (V_{os}) of 0.44 V, the fill factor (FF) of 0.46 and the conversion efficiency (η%) of 2.01% were obtained by means of the current–voltage ($I-V$) measurements under AM 1.5 (100 mW/cm^2) irradiance at 25°C in the MOS solar cell with sol-gel derived SiO_2.

1. Introduction

The cost of production of solar cells is still an important issue in the photovoltaic application. The pre-deposition and drive-in steps used to form a $p-n$ junction are high-temperature and long-term processes. Thus an alternative to the diffused $p-n$ junction structure for solar cells is to use a simple MOS structure [1]. Due to the low-temperature fabrication process, MOS solar cells have an inherent cost advantage compared to $p-n$ junction solar cells [2]. Moreover, the important advantage of MOS solar cells is compatible with CMOS technology. Therefore, MOS structure is a cost-competitive option for silicon solar cells. Furthermore, owing to excellent homogeneity, ease of composition control, low heat-treatment temperature, and film uniformity over large area, the sol-gel technique is extensively applied to deposit thin films for various applications [3–6]. In addition, the spin-coating process is a rapid thin-film deposition process. Hence the sol-gel spin-coating method is not only simple and inexpensive but suitable for low-thermal-budget and large-amount applications [7]. In this study, sol-gel spin-coating method was adopted to deposit SiO_2 layers of MOS solar cells. The properties of MOS solar cells with oxides prepared by sol-gel spin-coating technology were investigated .

2. Experimental

MOS solar cells used in this study were fabricated on a (100) p-type Si substrate. The resistivity of the Si substrate used in this study is $1-10\,\Omega\cdot\mathrm{cm}$. Sol-gel solutions were prepared by the acid catalyzed hydrolysis of tetraethylorthosilicate (TEOS) in alcohol solution [8]. The solutions were diluted by water and were aged. The wet silica thin films were spin-coated on Si substrate, and then dried at 60°C. Finally, the sol-gel SiO_2 layers were heated at 450°C for 1 h. The flow of the sol-gel spin-coating preparation process is shown in Fig. 1. After these treatments, the aluminum electrode was fabricated by thermal evaporation. Aluminum was also used as the backside contact. The schematic cross-sectional diagram of MOS solar cells is depicted in Fig. 2. Moreover, it is emphasized that MOS solar cells employ no antireflection coatings, back surface fields and textured surface in this study. Structural and chemical composition properties of sol-gel derived SiO_2 layers were characterized with the scanning electron microscopy (SEM) and the second ion mass spectroscopy (SIMS), respectively. Cesium (Cs) ion beams were used for SIMS measurements in this study. Current–voltage ($I-V$) measurements were carried out by using HP 4140B pA meter/dc voltaged source under AM 1.5 (100 mW/cm^2) illumination at 25°C. Furthermore, all conversion efficiencies reported in this study are based on total area.

3. Results and Discussion

Oxides prepared by the sol-gel technology exhibit microstructural features. The coarse microstructure of the oxides were investigated by SEM. Figure 3 shows the porosity in the sol-gel derived SiO_2 layer. It is observed that

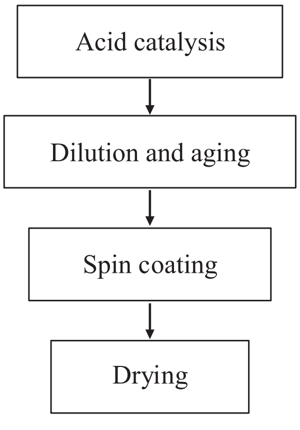

Figure 1. The procedure of sol-gel spin-coating technique.

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there are no large pores in SiO_2 films. Larger amount of water in sol-gel solutions results in smaller pore size. SEM micrograph of the sol-gel derived SiO_2 film is presented in Fig. 4. Crack-free sol-gel derived SiO_2 films were obtained in this study.

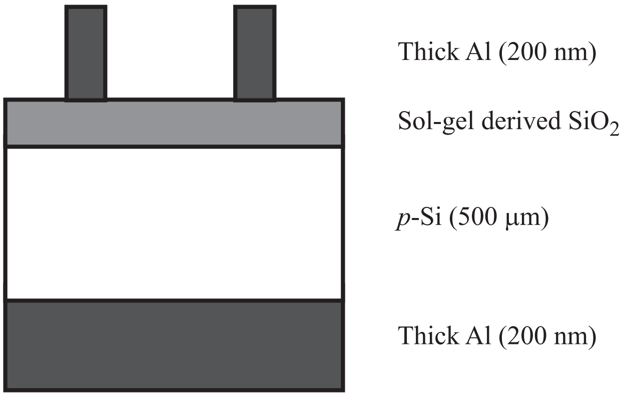

Figure 2. The schematic diagram of the MOS solar cell.

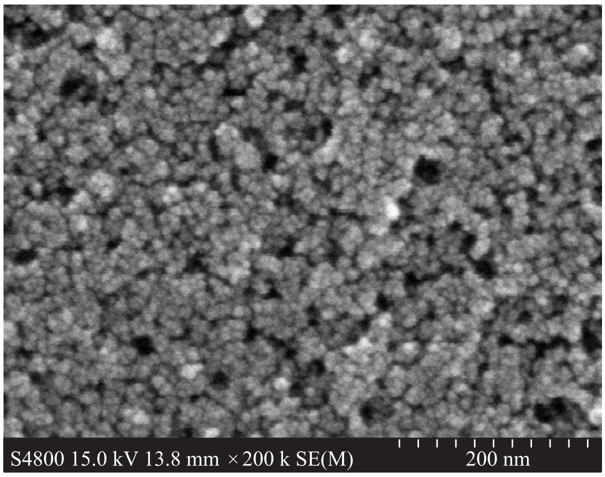

Figure 3. The porosity of the sol-gel SiO_2 layer.

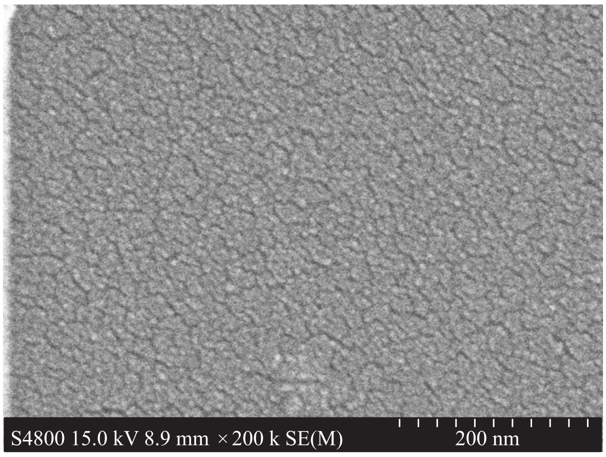

Figure 4. The surface morphology of the sol-gel SiO_2 layer.

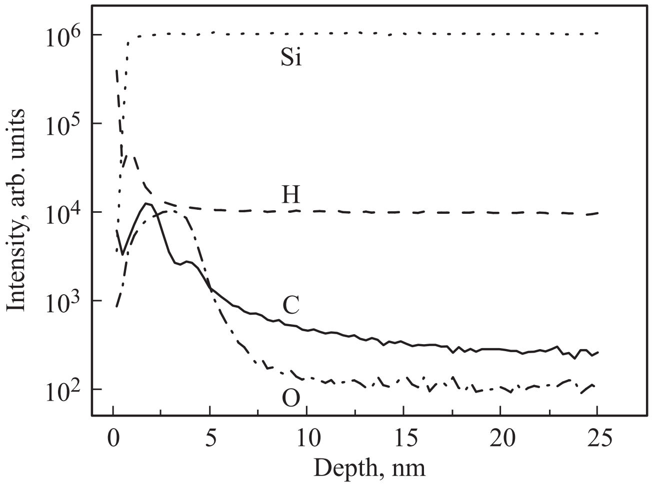

Figure 5. The composition depth profiles of the sol-gel SiO_2 layer.

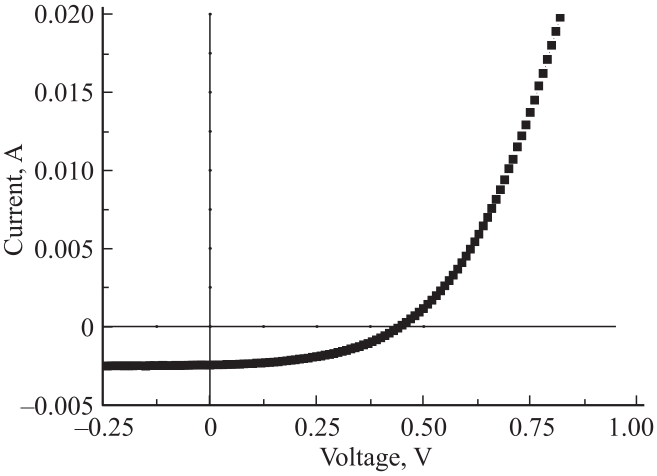

Figure 6. The $I-V$ characteristic of MOS solar cells with the sol-gel SiO_2 layer under AM 1.5 $(100\,\text{mW/cm}^2)$ illumination at 25°C.

The composition depth profiles of the SiO_2 film derived by sol-gel spin-coating techniques were obtained by measuring the concentration versus depth as illustrated in Fig. 5. Some carbon and hydrogen exit at the surface of the sol-gel derived SiO_2 layer is seen. It shows that the solvent wasn't completely removed after heating at lower tempereture $(450°\text{C})$.

Fig. 6 shows the $I-V$ characteristic of the MOS solar cell with sol-gel oxide layers under simulated AM 1.5 illumination of $100\,\text{mW/cm}^2$ at 25°C. It is found that I_{sc} of 2.48 mA, V_{oc} of 0.44 V, FF of 0.46 and the conversion efficiency of 2.01% are obtained in the MOS solar cell with the sol-gel derived SiO_2 layer. These results demonstrate that sol-gel spin-coating method with low-temperature and low-cost features is a promising technology for MOS solar cells.

4. Conclusion

The sol-gel derived SiO_2 films on Si were prepared by spin-coating technology. MOS solar cells with such SiO_2 layers have been fabricated. Sol-gel spin-coating technology is a simple, inexpensive, lower-temperature and shorter-time process. Such process is especially suitable for a large-scale and large-amount manufacturing. From the above results, it is found that a sol-gel SiO_2 layer is an alternative to a thermal grown oxide layer for MOS solar cells. It also shows that the sol-gel technology is able to apply for MOS solar cells with thin oxides.

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