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Copper indium gallium selenide (CIGS) solar cell devices on steel substrates coated with thick SiO2-based insulating material

The development of flexible substrates for producing electronic devices, such as solar cells and displays using roll-to-roll processes, has recently attracted considerable interest. Stainless steel (STS) substrates are commonly used in flexible substrates in roll-to-roll processes. STS substrates have many advantages over polymer substrates, such as enhanced chemical stability and lower thermal expansion coefficients.

In this study, a solution-based SiO2 material ("sol-SiO2"), which is more adaptable to roll-to-roll processes than dry vacuum coating, was adopted as an insulating diffusion barrier layer and a planarization layer. For the fabrication of copper indium gallium selenide (CIGS) solar cells, the insulating material was deposited on the STS substrates by silk screen printing methods.

We prepared and compared three solar cells with different structures: CIGS/Mo/PE-SiO2/MoNa/STS, CIGS/Mo/sol-SiO2/STS, and CIGS/Mo/SLG. The first cell and the second cell have identical substrates. Both structures can be obtained from CIGS/Mo/STS. While depositing CIGS layers, the performance of solar cell devices can deteriorate due to the penetration of Fe atoms in the CIGS films. Therefore, barrier layers such as PE-SiO2 or sol-SiO2 are needed in addition to insulation between the solar cell device and the STS substrate. The device characteristics fabricated by CIGS/Mo/PE-SiO2/STS would be lower than that of CIGS/Mo/sol-SiO2/STS due to Na doping in the CIGS films by sol-SiO2, although the PE-SiO2 film blocked the penetration of Fe. To improve the electrical properties of solar devices formed on CIGS/Mo/PE-SiO2/STS structures by the Na doping in CIGS films, a MoNa layer was used between the PE-SiO2 film and the STS substrate. However, the performance of the diodes fabricated on these structures was still lower than on CIGS/Mo/sol-SiO2/STS. Next, CIGS/Mo/STS and CIGS/Mo/SLG structures with different substrates are compared. As expected, the solar cell fabricated on CIGS/Mo/STS would show poorer characteristics than that of CIGS/Mo/SLG due to Fe atoms in the CIGS films. To increase cell efficiency, we used a sol-SiO2 layer as an insulating diffusion barrier layer and as a Na doping source layer between the Mo film and metal foil. As a result, the solar cell devices having the highest efficiency were obtained in CIGS/Mo/sol-SiO2/STS structures.

A soluble SiO2-coated insulating film containing oxygen, aluminum, silicon and sodium was investigated. The addition of insulating layers assisted the decrease in surface roughness of the STS substrate. The Ga grading was well preserved in the CIGS films grown on the STS substrates, possibly due to the lower heat capacity compared to the glass substrate. Furthermore, the CIGS films grown on the sol-SiO2 coated STS substrate contained a sufficient amount of Na supplied form the Na-containing sol-SiO2 layer and were free of detrimental Fe impurities. As a result, solar cells with 14 % efficiency were achieved on the SiO2-based layer/STS sample with a Fe atom diffusion barrier and external Na incorporation. This efficiency was higher than the 9.5 % and 12.8 % observed for solar cells on the SiO2/MoNa/STS and SLG, respectively. Therefore, the sol-SiO2 layer is an excellent material for global planarization, diffusion barriers, and for use as a Na supply source.

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