Novel low temperature pulsed d.c. magnetron sputtering of single phase β-In_2S_3 buffer layers for CIGS solar cell application

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This work explores the possibilities of using the pulsed d.c. magnetron sputtering (PDMS) process for depositing the buffer layer for copper indium diselenide - $CuInSe_2$ (CIS) - based solar cells. The use of PDMS can give a high plasma density and provide long term arc-free operation for the reactive sputtering of dielectric materials. This in turn can produce films with good crystalline properties, even at low substrate temperatures (Jonsson *et al.*, 2000;43-8; Bradley and et al., 2002;165). However, this has not previously been applied to solar cell fabrication. A typical CIS based cell consists of a glass/Mo/$CuInSe_2$/CdS/i-ZnO/Al-ZnO multi-layer structure (Jackson *et al.*, 2011;doi: 10.1002/pip.78). Mo forms the back contact layer, the CIS layer is the absorber layer, CdS acts as a buffer layer, the highly resistive i-ZnO layer reduces the leakage current and the Al-ZnO top layer is a transparent conductive oxide window layer. At present these layers are deposited using a variety of different deposition techniques, often at high substrate temperature. The main problems are with the CdS layer; firstly due to its toxic nature and secondly because it is normally deposited using a chemical bath technique. These factors make it difficult to incorporate into in-line production. Our previous works successively produced different component layers such as Mo, CIS and In_2O_3 layers (Karthikeyan *et al.*, 2011;3107-12; Karthikeyan *et al.*, 2011, Karthikeyan *et al.*, 2010;31). It is the aim of continuous research to find a compatible method to deposit the buffer layers. In order to avoid the toxicity of a CdS buffer layer, a substitute layer – an In_2S_3 film sputtered from a powder target - was investigated. Films were deposited at different substrate temperatures ranging from no heating to 250^0C. The deposition of single phase β-In_2S_3 without substrate heating/annealing has not previously been reported but the films deposited by the PDMS technique were found to be single phase without any additional heating. The grain size increased with increase in substrate temperature. However, this led to a decrease in the sulphur content and as a result the band gap decreased. For solar cells applications, the CdS buffer layer (optical bad gap ~ 2.5 eV) needs to be replaced with a material which has a band gap wider than 2.5 eV for improved performance and reduction of absorption loss in the blue wavelength region (Sterner *et al.*, 2005;179-93). Ideally the band gap should be between 2.6 and 3.0 eV. PDMS room temperature deposition of In_2S_3 has produced a band gap of 2.77 eV. The room temperature deposition can help to reduce the possibility of temperature-induced damage in the other layers during the subsequent deposition. These factors suggest that PDMS In_2S_3 buffer layers can usefully be employed for the commercial production of CIS/CIGS solar cells without the incorporation of chemical bath deposition processes into the in-line production.

References

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