Influence of Cu-delay time on obtaining preferred orientation of CIGS thin films during a 3-stage co-evaporation process

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Solar cells based on the $Cu(In,Ga)Se_2$ (CIGS) compound semiconductor have recorded the highest conversion efficiency (20.9%) among Cd-free thin film solar cell technologies.[1] For the growth of the CIGS layer itself, the main debate is between co-evaporation from elemental sources and sequential deposition by sputtering and salinization technique. While the latter is better for large scale production, the best performance was proven using the co-evaporation method, which allows the control of preferred orientation.[2] It has been shown earlier that the degree of (220)/(204) orientation, which is probably favorable for higher efficiency, depends on the Se flux in the first stage of the growth as well as Na content during the CIGS growth by the 3-stage process.

In this study, we propose a new view of preferred orientation of CIGS layers by controlling the time of Cu-delay which defines the time between the 1st stage end and the 2nd stage start. We compared CIGS films deposited using different processes, which includes 1940 seconds of Cu-delay time with Se flux of 0.6 nm /sec, 300 seconds of Cu-delay with Se flux of 0.8 nm/sec, and 0 second of Cu-delay with Se flux of 1.0 nm /sec. The deposition of CIGS layers was performed by three stage co-evaporation and the Ga/ (Ga+In) ratio was 0.32.

It has been believed that CIGS (220) orientation can be obtained by increasing Se flux during $(In,Ga)_2Se_3$ growth, which is the 1st stage of the 3-stage process. However, in contrast to this, (220) orientation was greatly dependent on the Cu-delay time rather than the Se flux. The longer the Cu-delay time, the stronger (220)/(112) ratio. This was attributed to recrystallization of the $(In,Ga)_2Se_3$ grown at low temperature during the Cu-delay, when the substrate was maintained at a high temperature and no element supplied. In three kinds of the processes, the best performance of 14.4% conversion efficiency from CIGS grown with 1940 seconds of Cu-delay time with Se flux of 0.6 nm /sec. The characteristics of the CIGS films obtained in this study will be discussed based on the analytic results obtained from X-ray diffraction, scanning electron microscope, and secondary ion mass spectroscopy.

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References

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