INVESTIGATION OF Cu$_2$ZnSnS$_4$ (CZTS) AND Cu$_2$SnS$_3$ (CTS) CELLS WITH HIGH PHOTOVOLTAIC PROPERTIES

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We continued research for the development of the Cu$_2$ZnSnS$_4$ (CZTS) and Cu$_2$SnS$_3$ (CTS) system as potential next-generation photovoltaic cell materials because of the abundance of its various elements and its suitable band gap. Generally, it is considered that the fabrication of Cu-sulfide system solar cells with high properties would be more difficult compared to Cu-selenide system. In particular, the reported conversion efficiency ($\eta$) of CZTS and CTS cells is below 10%.

By investigations on an interface of buffer layer/absorption layer and an absorption layer with gradient composition, we had fabricated the CZTS cell with the conversion efficiency $\eta = 9.4\%$ [1, 2]. In addition, the CTS cell with conversion efficiency $\eta = 6.7\%$ could be achieved by the formation of gradient conduction band in CTS layer [3]. However, the values were still lower than that of Cu-selenide system cell. The main problem in the low conversion efficiency of the cells is a lower open circuit voltage (Voc). The lower Voc could be caused by a high recombination rate at the interface of buffer layer/absorption layer (CdS/CZTS in case of CZTS cells).

To reduce the recombination at the interface of CdS/CZTS, we investigated a double buffer layers which was composed of a ZnSnO/CdS. As a result, the cells showed high Voc (0.81 V) as shown in Figure 1 [4]. Figure 2 shows temperature dependence of Voc of CZTS using various buffer layers. Generally, in case of CZTS and CTS cells, the extrapolation to 0 K was below the band gap of the absorption layer. On the other hand, the CZTS cells using ZnSnO/CdS buffer layer had the similar value to the band gap of CZTS. Therefore, the reason for the high Voc could be decreasing the recombination at the interface of buffer layer/absorption layer. The high Voc would make a breakthrough to achieve high efficiency CZTS cells. However, the Voc is lower than that expected by the band gap of CZTS. We would like to discuss the way to higher Voc of CZTS and CTS cells on the day.

References

Figure 1: J–V curves of the CZTS cells fabricated using ALD-Zn$_{0.90}$Sn$_{0.10}$O$_y$ (thickness: 50 nm)/CdS (thickness: 10 nm, annealed at 603 K) double buffer layer at $\eta = 7.3\%$ and a high Voc of 0.81 V ($J_{sc} = 17.3mA/cm^2$ and FF = 0.53) under illumination at 298 K. [4]

Figure 2: Temperature dependence of Voc of CZTS cells fabricated using Zn$_{0.91}$Sn$_{0.09}$O$_y$/CdS, Zn$_{0.81}$Sn$_{0.19}$O$_y$/CdS, and ZnO/CdS double buffer layer (CdS, thickness: 10 nm, annealed at 603 K), and Zn$_{0.5}$Sn$_{0.5}$O$_y$ single buffer layer. The solid line is an extrapolation to 0K. [4]