Area: Thin-Film Compound Semiconductor PV

CHARACTERRIZATION OF CU2ZNSNSE4 SOLAR CELL WITH CONVERSION EFFICIENCY OF 11.7%

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$Cu_2ZnSn(S,Se)_4$-based (CZTSSe) kesterite solar cells are gathering much attention because they are consist of earth abundant materials, therefore feasible for tera-watt scale mass production. CZTSSe materials are derivative of CIGS solar cells without rare metals of group III, and have many common advantages, however, the conversion efficiency of CZTSSe solar cells (12.6%) are still lower compared to that of CIGS cells (22.6%). One of the most significant issues for kesterite solar cells is a large open circuit voltage (V_{OC}) deficit ($E_g/q - V_{OC}$), which is attributed to the poor qualities of the CZTSSe bulk and heterointerface.
To solve the problem, a simple and promising method is to improve the bulk quality of absorption layers, e.g., by replacing host materials, such as by a Ge-incorporated $Cu_2Zn(Sn,Ge)Se_4$ (CZTGSe) alloy, and we have demonstrated a high conversion efficiency CZTGSe solar cell (12.3%) with low V_{OC} deficit [1]. Another method of improvement of bulk quality is alkaline doping. We have demonstrated the improvement of bulk quality in which the minority carrier lifetime increased from 2 to 15 ns with Na incorporation in $Cu_2ZnSnSe_4$ (CZTSe), and the conversion efficacy of 9.57% was obtained. However, the CZTSe surface (CdS/CZTSe heterointerface) recombination was found to limit the minority carrier lifetime, which imply the limitation of the V_{OC} improvement [2].
In this study, we conducted various surface treatments to suppress the recombinations at CZTSe surface, and the treatments are conducted after a thermal treatment. It was found that V_{OC} was improved by oxygen plasma treatment and V_{OC} monotonically increased from 0.416 to 460 V with treatment time of CZTSe. Moreover, we have optimized thickness of CdS buffer layer to improve short circuit current density J_{SC}. As a result, we have obtained best performing CZTSe cell with conversion efficiency of 11.7% (V_{OC}=0.423 V, J_{SC}= 41.7 mA/cm^{-2}, FF=0.666). The J-V curves were characterized using a single diode model, and the extracted parameters are listed in Table I. We found that almost all device parameters were almost identical between IBM reported CZTSe champion cell [3] and our CZTSe cell.

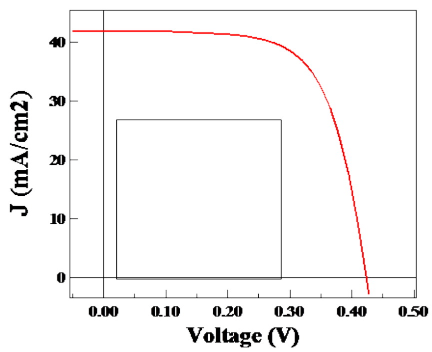

Fig. 1, *J-V* curve of our best performing CZTSe cell

Table I, comparison of device parameters to IBM reported CZTSe champion cell

	eff (%)	V_{OC} (V)	J_{SC} (mA/cm^2)	*FF*	n	j_0 (Acm^{-2})	R_s (Ω cm^2)	R_{sh} (Ω cm^2)
IBM-CZTSe[3]	11.6	0.423	40.6	0.673	1.57	1.38×10^{-6}	0.32	602
AIST-CZTSe	11.7	0.423	41.7	0.666	1.56	1.15×10^{-6}	0.38	1000

References

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