Investigation of metastable behavior on cesium fluoride-treated CIGS solar cells

[1)]Research Institute for Science and Technology, [2)]Faculty of Science and Technology, Tokyo University of Science
Ishwor Khatri[1)*], Takahiko Yashiro[2)], Tzu-Ying Lin[2)], Mutsumi Sugiyama[1,2)], Tokio Nakada[1)]
*E-mail: i_khatri@rs.tus.ac.jp

Introduction: State-of-the-art CIGS solar cells are fabricated using heavy alkali metal treatments[1,2)]. Additional post-treatments such as heat-light soaking (HLS) and heat-bias soaking (HBS) to these types of solar cells has further guaranteed the improvement in efficiency and open-circuit voltage (V_{OC}) under the suitable condition[3)]. Such improvement has a turn-on time constant in the order of a few minutes and turn-off time constant in the order of a day or months. The mechanism for such metastable behavior has not yet been fully investigated. Therefore, here, we analyzed the metastable behavior of CsF-treated CIGS solar cells at various CGI (Cu/[In+Ga]) ratio using J-V, C-V, SIMS, and AS measurements.

Experimental details: The solar cell fabrication and alkali treatment processes have been described elsewhere[3)]. Metastable behavior of the solar cells was investigated by HLS.

Results and discussion: Figure 1 shows the improvement in V_{OC} on CsF-treated CIGS solar cells (filled circles) as a function of CGI ratio under HLS. For comparative analysis, ΔV_{OC} for CsF-free CIGS solar cells (unfilled circles) are also presented. Suppression of V_{Cu} and V_{Se} in the thin-film by increasing CGI ratio and performing PDT on Se vapor did not mitigate V_{OC} improvement. These results argue the traditional concept of V_{Se}-V_{Cu} divacancy complex for the total beneficial effect of HLS in the heavy alkali-metal treated CIGS solar cells. Additional factors resulted from heavy alkali-metals was also found to play important role for the metastable behavior. The detail will be presented during the conference mainly based on SIMS and AS measurements.

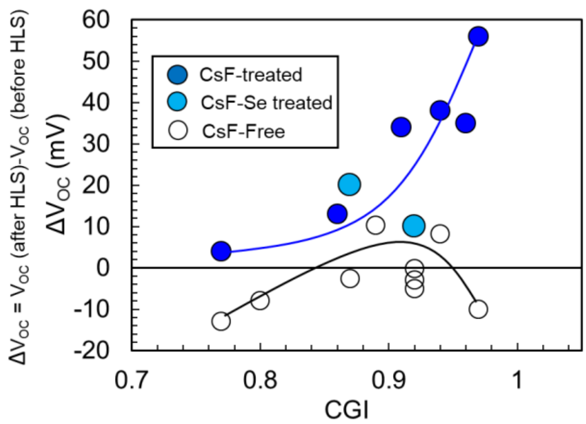

Figure 1. Effect of heat-light soaking on CsF-free (unfilled circles) and CsF-treated CIGS solar cells (filled circles) as a function of CGI ratio. The ΔV_{OC} on the vertical axis represents the gain in V_{OC} by HLS. Light blue circles represents ΔV_{OC} gain for the CsF-Se treated CIGS solar cell by HLS.

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References: [1] M. Nakamura et al. IEEE Journal of Photovoltaics 9,1863, 2019 [2] P. Jackson et al. Phys. Status Solidi RRL 2016; 10: 583-586 [3] I. Khatri et al. Prog. Photovolt. Res. Appl. 2019; 27:22-29.