ELABORATION OF WIDE BANDGAP CIGS ON SILICON BY ELECTRODEPOSITION OF METAL PRECURSORS AND SULFUR ANNEALING FOR TANDEM SOLAR CELLS

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A process was developed for the fabrication of CIGS directly on silicon, for future application as Si / CIGS tandem solar cells. The process consists in the electrodeposition of metallic precursors on (100) silicon, followed by a sulfur annealing. The precursors are prepared by first depositing a thin layer of Ag on the silicon's surface. This layer serves as contact for the electrodeposition, and will ultimately be incorporated in the CIGS to form (Ag,Cu)(In,Ga)S_2 (ACIGSu) during sulfurization. Cu, In and Ga are then sequentially electrodeposited, following a method which already proved to be very efficient on glass/Mo substrates [1]. This electrodeposition process offers the advantages of an easy control of the layer composition by adjusting the thicknesses of the elemental layers, of being easily upscalable and also very fast, the whole stack being deposited in less than three minutes. After optimization of the precursors, a sulfurized film with a composition of (Cu+Ag)/(In+Ga)=0.95 and Ga/(In+Ga)=0.3 was achieved, which is very close to the target composition for 1,7eV ACIGSu. The layer shows very good adhesion and compactness (see figure 1a), and XRD measurements confirmed the phase to be ACIGSu together with $CuGaS_2$, with spontaneous gradients of In, Ga and Ag leading to the formation of an upper indium-rich layer and a lower gallium-rich layer (see figure 1b).

A further investigation of annealing parameters shows that a similar segregation of indium and gallium occurs at temperatures between 400°C and 600°C. A migration of Ag from the back of the thin film at 400°C to the front layer at 600°C is observed, resulting in an improvement of crystallinity of the front layer at 600°C. At 700°C, thanks to the thermal stability of silicon as compared to Mo, a remarkable homogenization of elements is observed (see figure 1c), which leads to the formation of a homogeneous ACIGSu with the required composition and a luminescence peak at 1.8eV which is the target for the top cell of a tandem device. This study thus demonstrates that the method investigated is suitable for the deposition of wide gap CIGS on Si, and that increasing the temperature to 700°C, or higher, seems to be a very convenient route for the formation of tandem silicon / CIGS solar cells. On going work deals with the formation of complete ACIGSu cells using p+ (100) Si substrates acting as back contact, instead of the Mo substrate in classical cells.

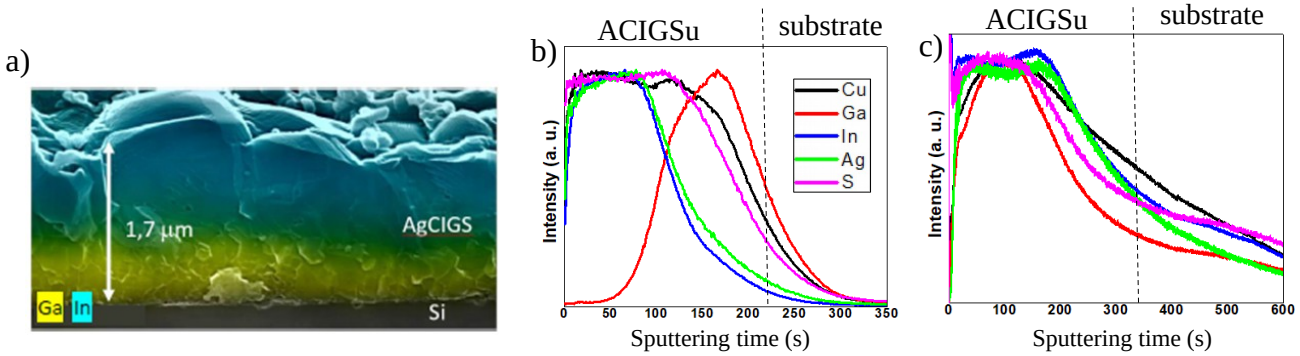

Figure 1: a) SEM cross section of Si/Ag-Cu-In-Ga sulfurized at 600°C, with EDX color mapping, b) GDOES analysis of ACIGSu sulfurized at 600°C, c) GDOES of ACIGSu sulfurized at 700°C, with normalized intensities.

Reference [1] C. Broussillou *et al., IEEE 42nd Photovoltaic Specialist Conference (PVSC),* USA 2015.