Stable CIGS thin film solar cells for indoor PV application

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Indoor photovoltaic (PV) harvesters are photovoltaic devices whose absorber is adapted to artificial light spectra such as those emitted by LEDs. Unlike the solar spectrum, artificial light is emitted in the spectral range in which the human eye is sensitive. For indoor PV converters, the optimum bandgap for efficient energy conversion lies between 1.5 and 2.0 eV[1]. Several inorganic or hybrid materials can achieve high PV performance, including III-V alloys, perovskites and $Cu(In,Ga)Se_2$ or $Cu(In,Ga)S_2$ thin films. The latter offer many advantages, such as proven long-term stability, a well-established supply and compatibility with flexible substrates. However, one remaining obstacle to the use of CIGSe cells for indoor PV is their low shunt resistance (R_{sh}). Under low-light conditions, the impact of R_{sh} becomes critical. A threshold value of R_{sh}>10kΩ.cm^2 has been put forward [1,2] for standard. To increase the R_{sh} of CIGS absorber, a first lever is the quantity of Cu within the film [2], but others will also be analyzed, such as the thickness of the absorber and that of the CdS layer.

In this contribution, we will first present the specificities of indoor PV devices, in particular the different spectra to which they are exposed. Then we will show our experimental results on the fabrication and characterization of CIGSe cells for indoor PV. Power conversion efficiency over 10% have already been achieved (Figure 1 a) and b)) under white LED (4000K) at 950 µW.cm^{-2} (~3000 lux). This first step has been reached by increasing R_{sh} (Figure 1 a)). To further increase the conversion efficiency of the cells at such low irradiance level, the absorber bandgap and R_{sh} will be optimized by refining the growth process. In this context, particular attention will be given to the copper and gallium content. A comprehensive loss analysis of the cell and a microstructural characterization will be performed based on advanced characterization tools (IV(T), MEB, EDX…). A study of the evolution of efficiency as a function of the irradiance will also be presented.

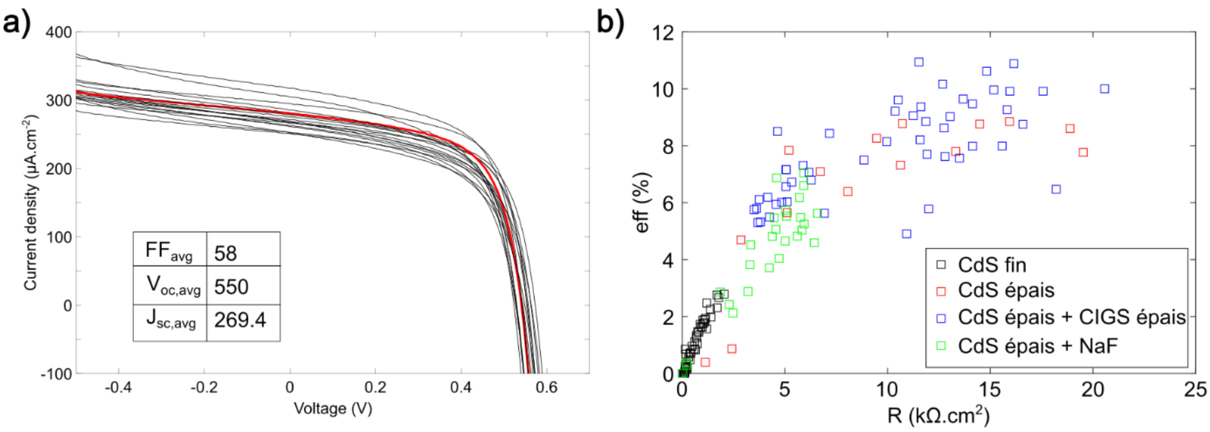

Figure 1 : a) IV curves (black line) measured under white LED (4000K) spectra for the thick CIGS and CdS sample. The gray area along the curve is the variability between all devices. b) Evolution of power conversion efficiency as a function of the shunt resistance for samples with various CdS and CIGS thicknesses.

[1] Muller et al., « Indoor Photovoltaics for the Internet-of-Things – A Comparison of State-of-the-Art Devices from Different Photovoltaic Technologies », *App.Ener.Mat*, 2023.

[2] Virtuani et al. « Influence of Cu content on electronic transport and shunting behavior of $Cu(In,Ga)Se_2$ »,*J.App.Phys.*, 2006.