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Photoluminescence imaging of top-layer non uniformity in solar cells

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We present an imaging technique to detect defective areas and thickness variations of the top layers in thin-film solar cells. We demonstrate the method worthiness by investigating CdS buffer layers on CIGS solar cells which constitute a particularly interesting exemple. Indeed, recent improvements in CIGS technology have been posible by use of thinner CdS layers. The homogeneity of this layer is critical to maintain a high quality CdS/CIGS heterojunction.

The method is based on the ratio of photoluminescence (PL) images taken under a short-wavelength and a long-wavelenth excitation. The short- and long- wavelengths are shoosen such as the the top layer is transparent to the long-wavelength excitation while partially absorbs the short-wavelength excitation. Both excitation lead to PL form the absorber layer (CIGS in our case). As a result, long-wavelength PL image contains information on the CIGS defects, while the short-wavelength PL image contains information on both CIGS and CdS non uniformity. Taking the image ratio allows remove the contribution of CIGS and to extract CdS features. Modelling and experiments both show that the technique can reveal variations in CdS thickness, which can lead to poor heterojunction properties. Figure 1 depicts both PL images and PL ratio images of CdS/CIGS/Mo sample where the CdS has been intentionnally thined down by acidic etching in area A and B. Using appropriate combination of short- and long-wavelength combination lead to high rise of the PL ratio for area with thinner CdS and gives high detectivity of potentially defective heterojunction.

The method can be used for quantitative measurements. If the CIGS maintains a uniform ratio of the internal yield for the short- and long-wavelength excitation, the normalized PL ratio can be used to extract the thickness using optical modelling. Thickness data extracted in that fashion show good agreement with scanning electron microscope (SEM) measurements as shown in Figure 2. The PL method has the advantage of providing a high resolution 2D image of the CdS thickness over a large scale in a matter of seconds. However the quantitative analisys may fail if the CdS/CIGS present different surface recombination properties or if the CdS produces spurious PL. These aspect will be discussed in more details.

As PL imaging is contactless this dual excitation wavelength PL imaging method could be implemented in both R&D and in high volume manufacturing to quickly detect various buffer or transparent contact inhomogeneities at an early stage and over potentially large sample areas.

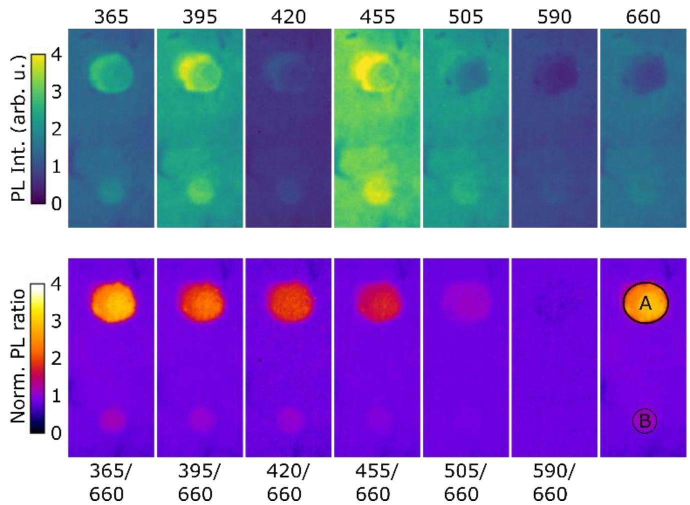

Figure 1. PL images (InGaAs detector) and normalised PL image ratio of a CdS/CIGS/Mo sample for different excitation wavelength. The CdS has been thinned down by HCl etching for 30-s and 1-s in area A and B respectively.

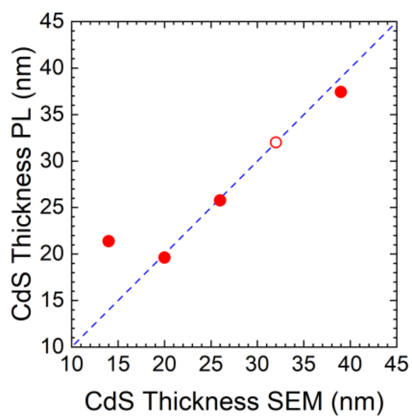

Figure 2. Comparison between the CdS thickness measured by transmission electron microscope (SEM) and by PL image ratio. The 32 nm thick sample has been used as reference.