The influence of interface recombination on quasi-Fermi level splitting and open circuit voltage

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Interface recombination represents a non-radiative loss and reduces the open-circuit voltage of any solar cell. However, its influence on the quasi-Fermi level splitting qFls can be much less pronounced, particularly in thick absorbers with a somewhat short diffusion length. In this case, interface recombination leads to a gradient in the minority quasi-Fermi level. Thus, deep inside the absorber the qFls is higher than near the interface. We determine qFLs from luminescence measurements. The emission flux depends exponentially on the qFls, thus the emission from the region with the high qFls will always dominate the emission spectrum. VOC is given by the difference between the electron quasi-Fermi level at the n-contact and the hole quasi-Fermi level at the p-contact. Therefore, the gradient in the minority quasi-Fermi level reduces the VOC below the maximum qFls. In very thin absorbers, compared to the diffusion length, this difference can disappear, because a gradient in the quasi-Fermi level cannot be sustained.

Often however, the difference between VOC and qFls can give an indication of the severity of interface recombination [1]. In chalcopyrite solar cells, we can compare rather similar cells with (Cu-rich) and without (Cu-poor) interface recombination and demonstrate the influence of interface recombination on the difference between VOC and qFls. A significant difference (> ~10meV) is only found in cells which are dominated by interface recombination. The dominance of interface recombination is also demonstrated in the electrical behaviour: the activation energy of the saturation current is lower than the band gap. This behaviour can be caused by an interface band gap lower than the bulk band gap (i.e. unfavourable band alignment) or by a high density of defects, that cause Fermi level splitting [2]. A then surface layer with a high density of defects will also cause all signatures of interface recombination, including a large difference between qVOC and qFls [1].

References:

[1] M. Sood, A. Urbaniak, C. K. Boumenou, H. Elanzeery, F. Babbe, F. Werner, M. Melchiorre, A. Redinger, and S. Siebentritt, Progress in Photovoltaics 30, 263 (2022).
[2] R. Scheer and H. W. Schock, Chalcogenide Photovoltaics: Physics, Technologies, and Thin Film Devices (Wiley-VCH, 2011).