Minibands modeling in strain-balanced InGaAs/GaAs/GaAsP cells

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In photovoltaics, the use of multi quantum wells (MQW) enables to tailor the optical absorption. This is particularly interesting in multijunction solar cells [1] but it can also improve the efficiency of a single junction solar cell [2]. This approach has proven to be efficient with the strain-balanced materials approach, which, to a well under compressive strain, associates a barrier under tensile strain. This allows the stacking of a large number of wells while preventing the formation of dislocations during crystal growth.

On the other hand, the use of barriers hinders the collection of the photo-generated carriers and more generally impedes the electronic transport in the MQW region. Indeed, since transport is a succession of thermal escape, assisted tunnel escape and, at best, direct tunneling across a barrier, the average carrier velocity is low (of about 10^4 cm s^{-1}) [3]. Finally this results in a large recombination rate and impacts both open-circuit voltage and short-circuit current.

However, in some conditions, minibands can occur in MQW regions [4]. The wave function of carriers in minibands being Bloch waves, this means that propagation can be made efficient. Our theoretical study, based on quantum simulation (Green functions formalism) in InGaAs/GaAs/GaAsP cells, sheds light on minibands in which the average velocity of carriers is around 10^7 cm s^{-1}. However, we also show that, without an adapted design, such minibands are inefficient since they connect only a few wells. We will present some improvements related to the distance between barriers and the positioning of the MQW inside the cell to overcome these issues.

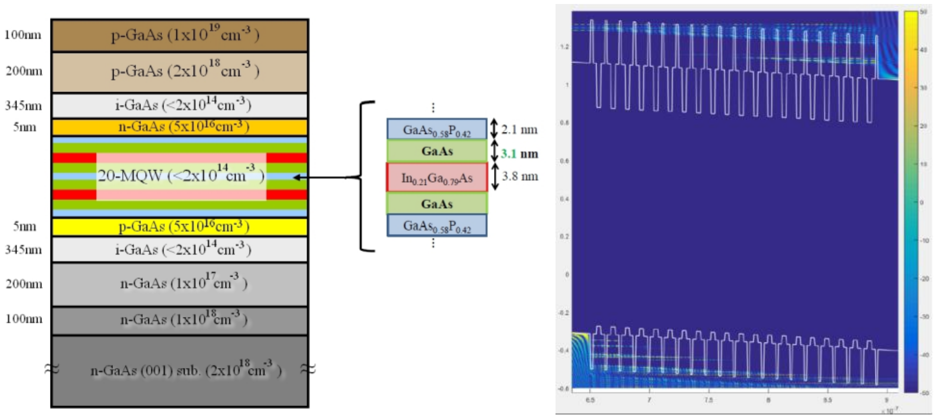

Figure 1. Schematic representation of the cell considered in this work and the local density of states versus position and energy obtained in the MQW. This last result exhibits minibands in both valence and conduction bands.

[1] B. Browne *et al*., 9th International Conference on Concentrator Photovoltaic Systems, 2013, 3–5.
[2] J.G. Adams *et al*. Prog. Photovolt: Res. Appl. 19(7), 865–877 (2011).
[3] K. Toprasertpong *et al*., IEEE Journal of Photovoltaics 5(6):1-8, September 2015.
[4] T. Usuki *et al*, Proceedings of SPIE West 2016.