Dependence of internal radiative efficiencies on radiative damages in multi-junction tandem solar cells via absolute electroluminescence measurements

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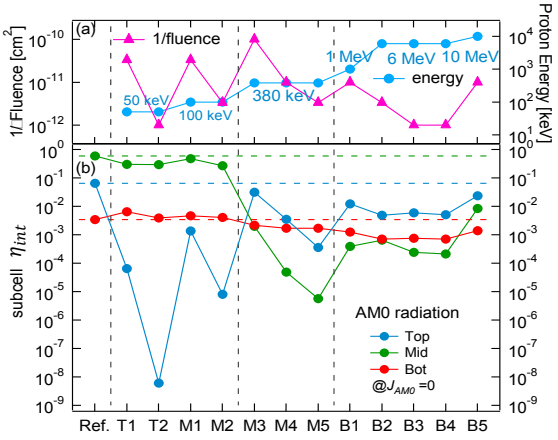
In multi-junction (MJ) tandem solar cells for space use, the degradation by radiation is a serious problem. The high-energy particles in space colliding with atoms in cells cause atomic displacements, which can act as non-radiative recombination centers. This leads to significantly reduced minority carrier lifetimes and the cell performance. Therefore, the basic understanding of radiation effects is very important for space-cell development.

The dependences of subcell characteristics (short circuit current, open circuit voltage, and efficiency, etc.) on the incident particles' type, energy and fluence have been reported previously.[1, 2] In this work, we characterize proton and electron-induced degradations of internal radiative efficiency (η_{int}) in subcells of GaInP/GaAs/Ge triple-junction and GaInP/GaAs double-junction solar cells, respectively, via absolute electroluminescence (EL) measurement method.[3] We discuss their dependence on energy and fluence (ϕ), and explain them by a simple calculation model. Figure 1 shows that η_{int} is a sensitive and quantitative indicator of radiation damage, since it purely represents material-quality changes due to radiation damage, independently from small differences in the band-gap energy due to alloy composition fluctuations. A detailed fluence-dependence study on 2-junction cells in Fig. 2 shows that the data of η_{int} versus ϕ in moderate and high ϕ regions are very similar and almost independent of the subcell material, while the difference in beginning-of-life values of subcell η_{int} causes dominant difference in sensitivity to the low radiation damages.



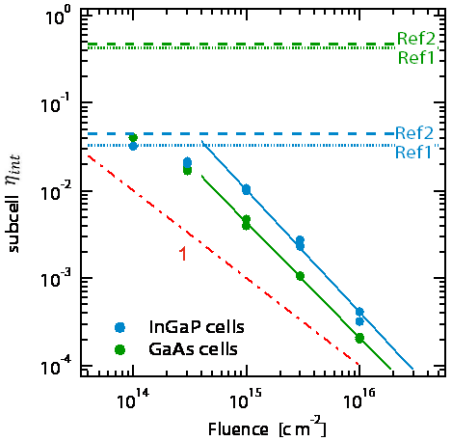


Fig. 1 (a) Plot of incident proton energy and fluence of reference sample and 12 proton-irradiated 3-junction samples (b) Plot of evaluated top-, middle, bottom-cell η_{int} at the open-circuit condition under AM0.

Fig. 2 Plot of evaluated InGaP- and GaAs-cell η_{int} in electron damaged 2-junction samples and two reference samples: Ref1 (dotted line) and Ref2 (dashed curve) at the open-circuit condition under AM0.

[1] J. C. Bourgoin et al. Semicond. *Sci. Technol*. 17.5 (2002): 453. [2] T. Nakamura et al. *38th IEEE PVSC proceedings,* Austin, 2012. [3] S. Chen et al., *Sci. Rep. 5* (2015): 7836.