Extended detailed-balance analysis and light management in high-efficiency solar cells

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We developed an extended detailed-balance-theory analysis of multi-junction solar cells, which enables us to calculate upper-limit efficiencies and optimized band-gap designs of single- and multi-junction solar cells with active materials of realistic quality [1,2]. Light management is very important in solar cells. To obtain high-efficiency, we should care light management not only for incoming sun light, but also for outgoing luminescence light, such as photon recycling and luminescence coupling. The above extended detailed-balance theory includes all these effects, by which we can evaluate contributions of these effects in solar cells with realistic material quality [1,2]. For example, three different types of intermediate reflector designs for light management shown in Fig. 1 cause difference in the optimized efficiency for internal radiative efficiency η_{int}^{*}=1, but almost no difference for η_{int}^{*}=0.1 or below, as shown in Fig. 2.

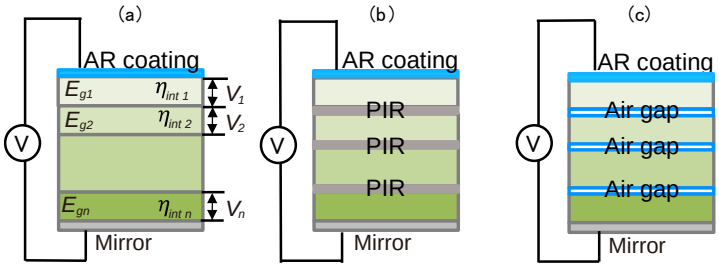

Fig. 1. Structures of the multi-junction solar cells (a) without intermediate reflectors, (b) with perfect intermediate reflectors (PIR) and (c) with air-gap intermediate reflectors.

Our extended detailed-balance theory is useful not only for theoretical predictions and designs, but also for analysis of experimental data [3-6]. In fact, we experimentally characterized external and radiative efficiency and derived contribution of luminescence coupling and photon recycling by analyzing data of absolute electro-luminescence intensity or external radiative efficiency [3,6].

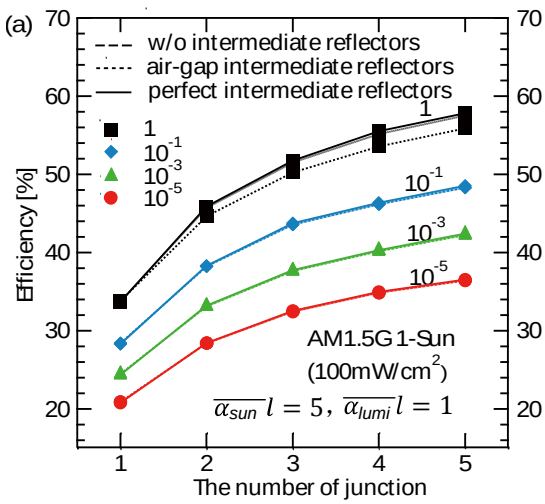

Fig. 2. The optimized efficiency of multi-junction solar cells without intermedium reflectors (solid curves) with air-gap intermedium reflectors (dotted curves) and perfect intermedium reflectors (dashed curves) for various internal radiative efficiency η_{int}^{*}=0.00001, 0.0001, 0.001, 0.01, 0.1, and 1 as functions of junction number under AM1.5G (1-sun).

References:

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