Transport efficiency imaging in multi-junction solar cells by luminescence analysis

Univ. of Tokyo[1], UMR CNRS[2], °Hao Xu[1], Amaury Delamarre[1], Bernice Mae F. Yu Jeco[1], Kentaroh Watanabe[1], Yoshitaka Okada[1], Jean-François Guillemoles[2], Yoshiaki Nakano[1], and Masakazu Sugiyama[1]

E-mail: haoxu@hotaka.t.u-tokyo.ac.jp

Multi-junction solar cells are currently the efficiency leaders among all types of solar cells. However, efficiencies of multi-junction solar cells are limited by various series resistance when they are illuminated under high concentrations. Therefore, a robust evaluation method is necessary for investigating the impact of series resistances.

Current transport efficiency is a technique to measure the series resistance effect [1]. It can be measured with a light beam induced current setup (LBIC), which excites the cell locally and scans the surface. However, such a method is usually time-consuming, especially when high spatial resolution is required. Another approach to obtaining transport efficiency using luminescence measurement was demonstrated [2]. Thanks to the reciprocity relation in [1], transport efficiency by luminescence imaging can be obtained through the equation:

$$f_t(x,y) = \frac{\delta \ln(\emptyset_{(x,y)})}{q\delta V_T/KT}.$$

In this paper, the method of current transport efficiency measured at the real operation condition is tested for MJ cells, where all subcells are properly illuminated. A combination of electrical measurement, optical measurement, and device simulation is used for the validation of the luminescence method. Results in Fig. 1 (a) matches very well, which suggests that luminescence imaging for transport efficiency measurement is valid. At high voltage region, the series resistance results in strong forward bias voltages on each junction, in this case, and carriers tend to be recombined rather than be collected.

An inhomogeneous spatial carrier collection behavior is found with luminescence mapping (Fig. 1 (b)). It is likely that the spatial variation results from perimeter recombination that has higher series resistance effect around the edge. A distributed circuit simulation is expected to help discover the reason later. Additionally, for the first time, the LBIC method is used to compare the spatial variation measured with luminescence (not shown). The LBIC mapping gives very similar variation profile. It is worth mentioning that the measurement time for one image with LBIC (with the best resolution 1000 x 1000 pixel) is 20 min, while for luminescence mapping, the averaged measuring time of a single image takes less than 0.1 min. Luminescence mapping is proved to be highly efficient and accurate.

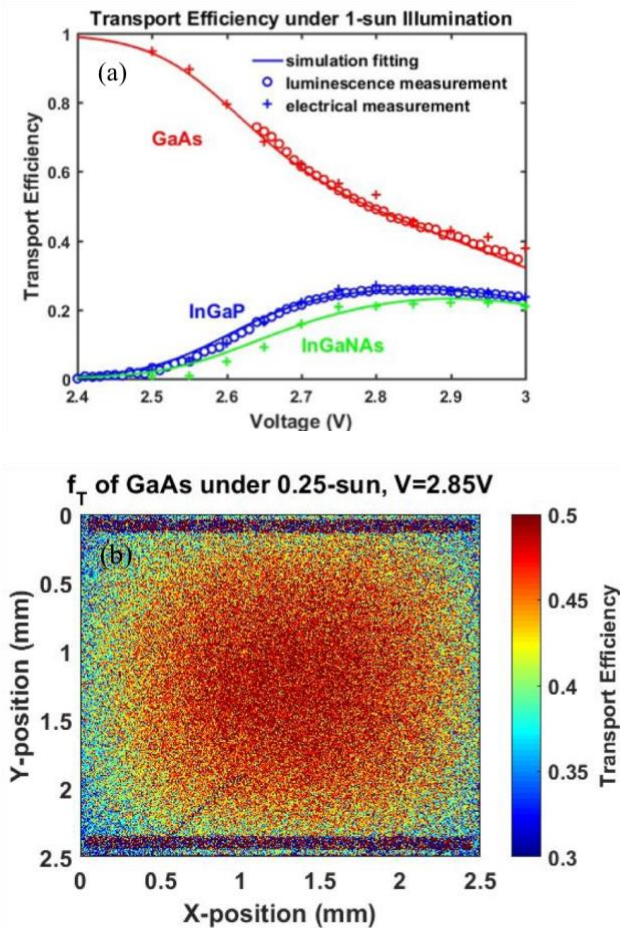

Fig. 1. (a) Spatially averaged transport efficiency for all subcells measured with three methods. (b) Transport efficiency image by luminescence mapping for GaAs subcell.

Reference

[1] J. Wong and M. Green, "From junction to terminal: Extended reciprocity relations in solar cell operation," *Physics Review B*, vol. 85, no. 23, art. no. 235205, 2012.

[2] A. Delamarre, L. Lombez, K. Watanabe, M. Sugiyama, Y. Nakano, and J-F Guillemoles, "Experimental demonstration of optically determined solar cell current transport efficiency map," *IEEE Journal of Photovoltaics*, vol. 6, no. 2, pp. 528-531, 2016.