Analysis of perimeter recombination on multi-junction solar cells using luminescence imaging

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Multi-junction (MJ) solar cells are currently the efficiency leaders among all types of solar cells. A previous study using current transport efficiency imaging reveals that both series resistances and perimeter recombination may affect the performance of MJ solar cells [1]. There are a few studies about perimeter recombination on MJ cells, and most of them were conducted through individual single-junction (SJ) cells [2]. Thanks to the luminescence imaging method, we are able to evaluate the perimeter recombination within intact MJ cells.

In this study, we prepare epitaxial wafers of GaAs SJ, InGaP SJ, and InGaP/GaAs 2J using MOCVD growth. The growth condition for corresponding materials are the same. Each wafer is fabricated into solar cells with different perimeter-to-area (P/A) ratios of 7, 18, 36, 60, 86, and 156. The widths of finger contacts and in between two fingers are controlled for all the cells to eliminate the difference of series resistance on surface. The open-circuit voltages (V_{oc}) under 1 sun are shown in Fig.1. (a)(b)(c). V_{oc} of GaAs SJ cells show an obvious decreasing tendency, which indicates a strong dependency on P/A ratios. Linear dark current density that is related to perimeter (mA/cm) suggests that this tendency mainly results from perimeter recombination (not shown). While for InGaP solar cells, the V_{oc} is almost irrelevant to either cell area or perimeter. The abnormally low V_{oc} of InGaP at P/A of 156 is probably due to the failure of fabrication. V_{oc} of 2J cell combines the P/A impacts from both subcells. Overall it shows a similar tendency as that of GaAs SJ cells, which suggests that perimeter recombination of GaAs subcell is the major cause. However, the large deviation among smaller sizes indicates that the contribution from InGaP subcell may not be negligible. A further study has been implemented using luminescence and transport efficiency mappings. The SJ cells with P/A of 60 under injection of equivalent 200 suns are shown in Figure (d)(e)(f)(g). Metal contacts are shown in the dark color. The luminescence intensity and transport efficiency for GaAs exhibit a diffusing tendency towards the center from low to high (illustrated by the arrows), which confirms the major influence from perimeter recombination. While for InGaP, the active area away from the edges (dash square) shows relatively uniform luminescence and current transport ability. Clearly the series resistance in between finger contacts on the cell surface has higher impact in the case of InGaP, which may overtake the perimeter recombination effect and make the InGaP cell less size dependent. 2J cells are also evaluated in which GaAs subcells exhibit a different shape of luminescence distribution (not shown), which has been found in [1]. Luminescence under illuminations will be studied for 2J cells to investigate the perimeter recombination effect on current transport within each subcell. And a SPICE simulation will be used to numerically evaluate the perimeter recombination effect.

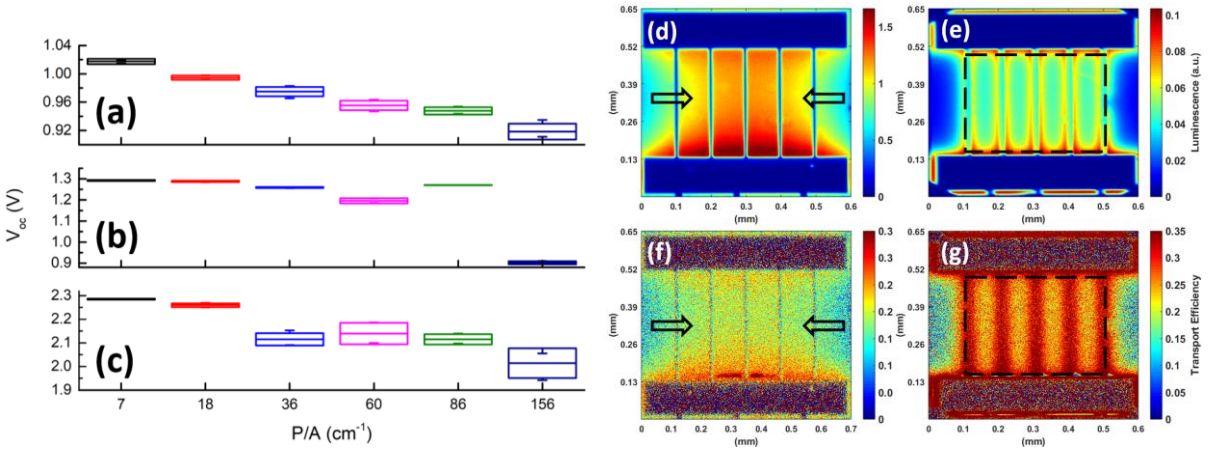

Fig. 1. Voc of solar cells with P/A ratios of 7, 18, 36, 60, 86 and 156 for (a) GaAs SJ, (b) InGaP SJ, and (c)InGaP/GaAs 2J solar cells. Luminescence images of (d) GaAs SJ and (e) InGaP SJ, and transport efficiency images (f) GaAs SJ and (g) InGaP SJ under injection of 200 suns equivalent concentration.

Reference

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