Unravelling the Origins of Contact Recombination for Localized Laser-Doped Contacts

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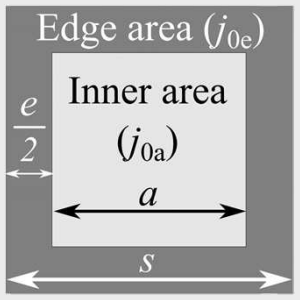
Develop methodology and experiments for separating the edge and area contributions to the lumped recombination parameter of localized contacts

Methodology

❶ Varying **edge-to-area ratio** ($\propto 1/s$) of localized contacts

❷ Determine **lumped recombination parameter** $j_{0,\mathrm{ave}}$ of localized contacts

❸ Extract **edge recombination** $j_{0,\mathrm{e}}$ and **area recombination** $j_{0,\mathrm{a}}$ from slope and y-intercept of $j_{0,\mathrm{ave}} \propto 1/s$



Assumptions

❗ Area-proportional contribution of inner area $j_{0,\mathrm{a}}$ and edge area $j_{0,\mathrm{e}}$ to lumped recombination $j_{0,\mathrm{ave}}$ with $\Delta j_0 = j_{0,\mathrm{e}} - j_{0,\mathrm{a}}$

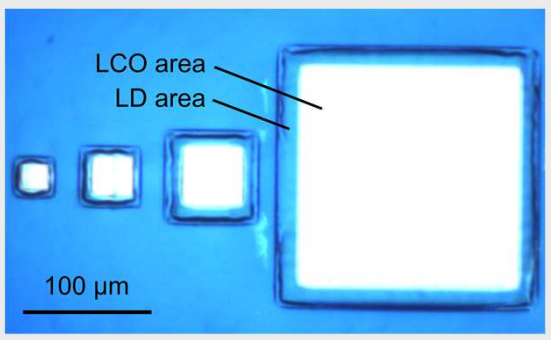
$$j_{0,\mathrm{ave}} = j_{0,\mathrm{a}}\frac{a^2}{s^2} + j_{0,\mathrm{e}}\frac{s^2-a^2}{s^2} = j_{0,\mathrm{a}} + 2e\Delta j_0\frac{s}{s^2} - e^2\Delta j_0\frac{1}{s^2}$$

❗ Total edge width e = 4 ± 2 µm (estimated from micro photoluminescence spectroscopy measurements)

❗ Linear approximation assuming $e \ll s$

Experiment

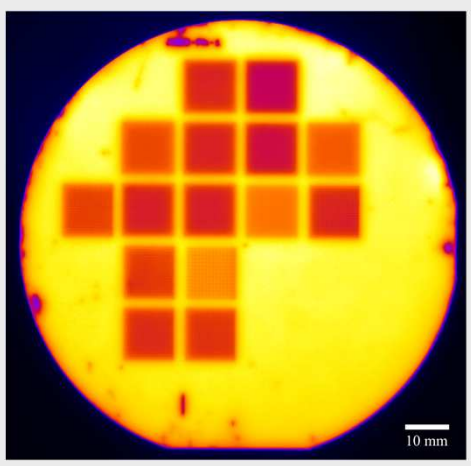
❯ **Localized contacts** with varying edge-to-area ratio fabricated by two-step laser process: **dope** / passivate / **ablate** (248-nm Excimer flat-top laser beam with variable aperture mask)



Microscope image illustrating the variation of laser-doping size after laser-contact opening confined to a region smaller than the laser-doped areas.

❯ Samples with **regular pattern of localized contacts**, varying edge-to-area ratio (contact size) for **constant contact fraction *f*** and two **laser parameters** ϕ

❯ Combination of **calibrated photoluminescence imaging** and **three-dimensional numerical simulations** to **extract** $j_{0,\mathrm{ave}}$ of localized contacts [1]

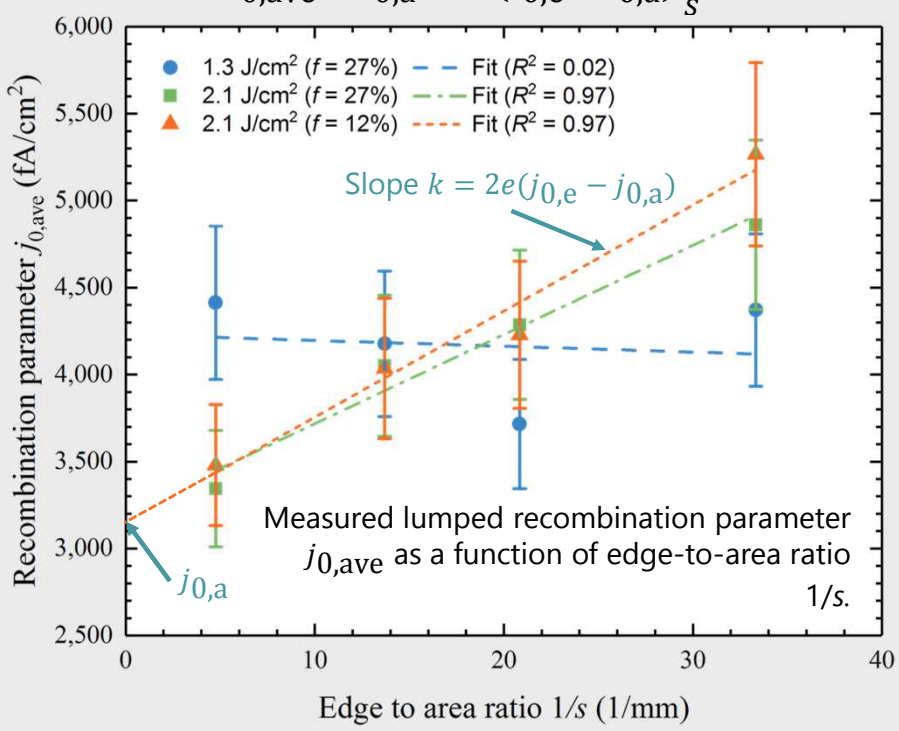


PL image of local laser-doped contacts. The different processed square-shaped areas feature different laser spot sizes, pitches and laser fluences. The bottom right reference quarter is used for calibrating the method using QSSPC measurements.

Results

❯ Fit of measured $j_{0,\mathrm{ave}}$ using linear approximation

$$j_{0,\mathrm{ave}} \approx j_{0,\mathrm{a}} + 2e(j_{0,\mathrm{e}} - j_{0,\mathrm{a}})\frac{1}{s}$$



❯ Due to uncertainty in e we determine the edge recombination using the implicit relation

$$j_{0,\mathrm{e}} \equiv j_{0,\mathrm{e}}(e) = j_{0,\mathrm{a}} + \frac{k}{2e}$$

Fluence ϕ	f	Area rec. $j_{0,\mathrm{a}}$	Slope k	Edge rec. $j_{0,\mathrm{e}}$
(J/cm²)	(%)	(fA/cm²)	(fA/cm² mm)	(fA/cm²)
1.3	12	3,340*	-	-
1.3	27	4,170*	-	-
2.1	7	2,285 ± 115	72.7 ± 5.5	9,550 ± 4,480
2.1	12	2,658 ± 182	55.1 ± 8.7	11,370 ± 5,130
2.1	12	3,206 ± 132	51.2 ± 6.3	9,610 ± 4,600
2.1	27	3,145 ± 155	61.0 ± 7.4	10,770 ± 5,030

*Mean value of $j_{0,\mathrm{ave}}$

Note that the laser doping process has not been optimized in this experiment.

Conclusion

❯ **Varying the edge-to-area ratio** combined with measuring lumped recombination parameters of localized contacts **enables separation of edge and area contributions**

❯ **Edge-recombination exceeds area-recombination by** a factor greater than **3 to 4**

❯ Further analysis required (e.g. by micro PL spectroscopy) to **accurately determine edge width *e***

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References

[1] M. Ernst et al., IEEE J. Photovoltaics **7** (2), 471–478 (2017).

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