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Implications of Local Contact Size on Contact Resistivity and Recombination

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Abstract

With the increasing complexity of solar cell structures, a deeper understanding of the effects on the microscale is becoming more important. We design experiments and numerical simulations to determine the fundamental properties of local contacts, namely contact resistivity and contact recombination. We demonstrate our method of separating the origins of the lumped recombination parameter for localized contacts. The methods developed in this work are independent of the fabrication method of the local features and thus can be applied to virtually any local contact process. Laser processing has proven to be a versatile and cost-effective technology for such applications. Local silicon doping or contact opening by laser ablation are two established process steps. At this conference we will demonstrate and apply our methodology for localized contacts prepared by laser doping. We show that we are able to assign the main source of recombination after laser doping to the edge regions of the laser-doped contacts, while the center areas make a non-negligible contribution.

1. Introduction

Laser contact opening (LCO) via ablation of passivating dielectric layers allows for confined metal-semiconductor interfaces in advanced high-efficiency solar cells. In this work we combine this process with a slightly larger local laser doping (LD) process to create a system of localized laser contacts, which can be utilized in *e.g.* IBC or PERL devices [1]. In such advanced solar cell devices, localized contacts are utilized to substantially reduce the losses through surface recombination.

To minimize electrical losses however, the contacts still need to be optimized in terms of the contact resistivity ρ_C. In this work we investigate the influence of parameters such as laser doping fluence ϕ and spot size s and on this quantity. Furthermore, we present a method to separate the contributions of edge and area regions to the commonly measured lumped recombination.

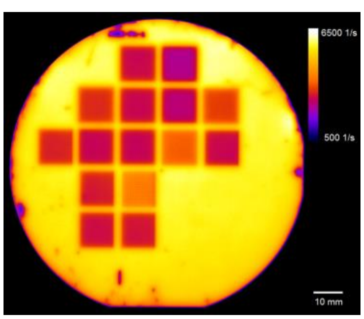


Figure 1. PL image of recombination test pattern with varying laser spot size, pitch and laser fluence.

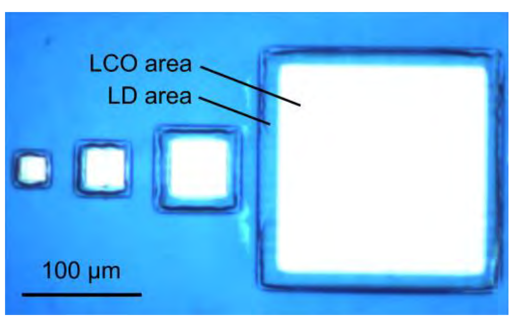


Figure 2. Microscope image of local contacts with varied size.

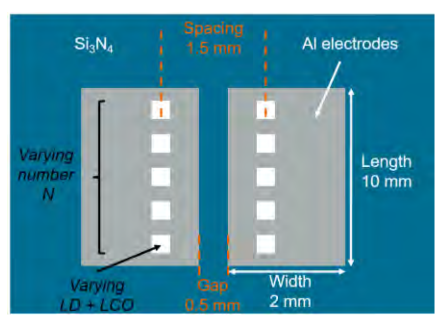


Figure 3. Local contact resistance test structure with varying number of local contacts.

2. Experimental

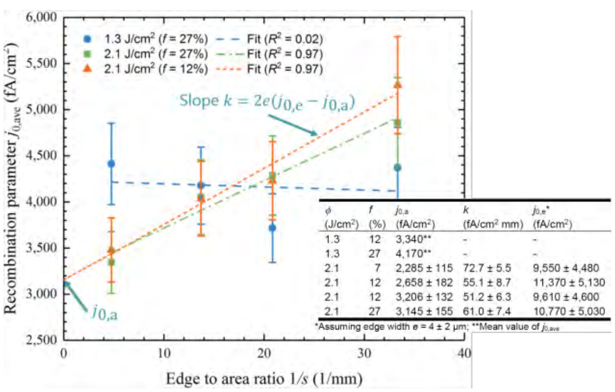
We utilize boron and phosphorus doped silica glass layers (BSG, PSG) as dopant sources in local laser doping (LD). LD is performed using an Excimer laser source (λ = 248 nm, τ = 25 ns), with variable aperture size and varied laser fluences ϕ. Samples for determining the lumped local contact recombination $j_{0,ave}$ are analysed directly after laser-doping. Local contacts are arranged in regular arrays within 12 × 12 mm^2-sized test regions as shown in Figure 1. We vary the spot sizes in different test regions from s = 30 µm to s = 210 µm (illustrated in Figure 2) while adjusting the pitch p to keep the doped area fraction $f = (s^2/p^2)$ constant within each test region. In this way, only the edge to area ratio ($4s/s^2$) of the laser spots is changed. The local contact recombination is then determined from photoluminescence (PL) images, calibrated using QSSPC measurements combined with three-dimensional simulations of the test pattern [2].

The purely ohmic contact resistivity test structures are passivated with a Si_3N_4 layer. Local laser contact opening (LCO) is performed using the same Excimer laser as for LD and aligned to the center areas of the LD regions. Finally, aluminium is evaporated and deposited on the wafer through a shadow mask to give the desired test patterns as illustrated in Figure 3. We vary the number of spots per contact pad, $N \in \{5, 10, 20\}$ and measure the total resistance of the structure. The local contact resistivity ρ_C is then determined by means of Quokka3 simulations of the test structure [3].

3. **Results**

We separate the contribution of edge region ($j_{0,e}$) from the laser doped center ($j_{0,a}$) by varying the size of the laser spot s at constant area fraction. In Figure 4 we plot $j_{0,ave}$ against $1/s$ for three of six parameter variations, the complete results are shown in the inset. From the slope we calculate the edge recombination assuming an edge width of e = 4 ± 2 µm (estimated using micro-PL spectroscopy). The edge recombination parameter $j_{0,e}$ exceeds the recombination parameter of the laser-doped center area $j_{0,a}$ by a factor greater than 3 to 4.

In Figure 5, we plot the measured resistance R against s, for a doping fluence of ϕ = 2.1 J/cm^2 after the same 300 °C FGA. Here, ρ_C was derived from the data points at spot size s = 30 µm and only s was varied in the simulated curves. The simulations agree well with the measurements. We measure contact resistivity values as low as ρ_C = 70 µΩ cm^2 and 30 µΩ cm^2 for Ph and B doping, respectively.



ϕ (J/cm^2)	f (%)	$j_{0,a}$ (fA/cm^2)	k (fA/cm^2 mm)	$j_{0,e}$* (fA/cm^2)
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

*Assuming edge width e = 4 ± 2 µm; **Mean value of $j_{0,ave}$

Figure 4. Lumped recombination parameter $j_{0,ave}$ as a function of edge to area ratio 1/*s*. For the blue (dashed) line, there is no significant dependency, whereas the orange (short dashed) and green (dash-dotted) lines show a clear linear trend.

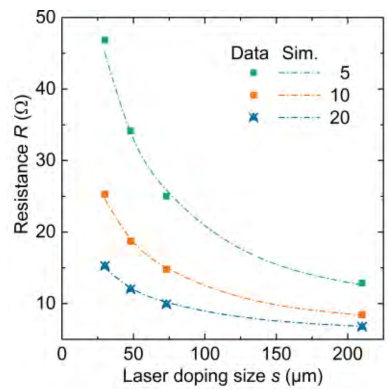


Figure 5. Resistance data for boron doped samples at a fluence of ϕ = 2.1 J/cm^2 after FGA at 300 °C, for different number of contacts *N*. Lines are simulation with constant ρ_C = 40 µΩ cm^2.

References

[1] Ernst, M., Franklin, E., Fell, A., Fong, K., Walter, D., Wang, E.-C., Kho, T., and Blakers, A., 2017, 'Fabrication of a 22.8% Efficient Back Contact Solar Cell With Localized Laser-Doping,' *phys. stat. sol. (a)*, 31, pp1700318.

[2] Ernst, M., Huyeng, J., Walter, D., Fong, K., and Blakers, A., 2018, 'Unravelling the Origins of Contact Recombination for Localized Laser-Doped Contacts,' *WCPEC-7*.

[3] Huyeng, J., Ernst, M., Fong, K., Walter, D., and Blakers, A., 2018, 'Implications of Laser-Doping Parameters and Contact Opening Size on Contact Resistivity,' *WCPEC-7*.