GRIDDLER AI ASSISTED P⁺ LAYER OPTIMIZATION TOWARDS LOWER SCREEN PRINTING INDUCED RECOMBINATION LOSSES FOR INDUSTRIALLY RELEVANT N-TYPE BIFACIAL SI SOLAR CELLS

Mengjie Li 1,2,*, Johnson Wong 1, Ning Chen 1, Armin Aberle 1,2, Rolf Stangl 1

1 Solar Energy Research Institute of Singapore, Singapore
2 Department of Electrical and Computer Engineering, National University of Singapore, Singapore
*Corresponding author: Mengjie Li, E-mail address: mengjie.li@u.nus.edu

N-type Si solar cells are currently extensively researched due to several advantages, including high tolerance of metallic impurities and no light induced degradation due to B-O complexes. However, recent studies show that the contact formation on a p⁺ surface using conventional screen printing induces a huge amount of recombination losses and therefore impacts the device efficiency. Thus, the boron diffused p⁺ layer has to be further tailored to minimize the screen printing induced recombination losses. Conventionally, the metallization induced recombination losses were studied by two diode fitting and device simulation at a cell level. This paper analyzes specially designed test samples, which enable to extract the metal-silicon interface parameters (i.e. the metal recombination saturation current densities $J_{0\text{lim}}$ and $J_{0\text{2m}}$ and the corresponding contact resistance $\rho_c$) directly from measurements of screen printed Ag/Al paste on various boron diffused p⁺ layers. In this work, a test metallization pattern with regions of varying metal contact fractions (Fig. 1a) is screen printed on 6 inch wafers with a symmetric boron diffusion on both sides. Both the screen printed test samples and symmetric double side boron diffused lifetime samples were characterized with intensity dependent photoluminescence (PL) imaging. The metal recombination parameters were extracted by a detailed finite element method (FEM) based simulation assisted by Griddler AI. The corresponding contact resistance of the metal fingers was measured by conventional transfer length method (TLM). The boron diffusion profile was varied in the following way: two baseline boron diffusion recipes with sheet resistance ($R_{\text{shee}}$) of 60 and 40 ohms/sq. were optimized by in-situ oxidation. The $R_{\text{shee}}$ values after optimization are 90 and 65 ohms/sq., respectively. Fig. 1b shows the corresponding profiles as measured by electrochemical capacitance voltage (ECV). To give an example, the extracted metal $J_{0\text{lim}}$ and $J_{0\text{2m}}$ values reduce from ~839 fA/cm² and ~68 nA/cm² to ~466 fA/cm² and ~48 nA/cm², respectively (see Fig. 1c), by comparing the 60 ohms/sq. with the optimized 90 ohms/sq. p⁺ layer. Using the extracted $J_{0\text{lim}}$, $J_{0\text{2m}}$ and $\rho_c$ values, as well as the additionally extracted passivated-area recombination saturation current densities $J_{0\text{1p}}$, $J_{0\text{2p}}$, the potential efficiency improvement can be quantified. As a result, the cell efficiency raise from 19.80% to 20.02% on n-type bifacial front and back contacted (nFAB) cells, by applying the p⁺ layer of 90 ohms/sq. instead of the standard 60 ohms/sq. diffusion process.

Figure 1. (a) (top) Scan of the test pattern used for screen printing of Ag/Al paste on different p⁺ layers. (bottom) PL image, taken at 1 sun illumination intensity, of a test sample exhibiting various regions with different metal contact fractions, ranging from 0% (box 1) to 27% (box 8). The red boxes indicate the different regions of interest (ROIs). The varying metal contact fractions were obtained by printing metal fingers with different finger widths, ranging from 0 to 280 µm. (b) Active doping profiles of the boron diffused p⁺ layer used in this study, two baseline profiles with $R_{\text{shee}}$ of 60 and 40 ohms/sq. were optimized to achieve an $R_{\text{shee}}$ of 90 and 65 ohms/sq., respectively. (c) Metal $J_{0\text{lim}}$ (top) and $J_{0\text{2m}}$ (bottom) values extracted from intensity dependent PL imaging and Griddler AI assisted simulation.