Study motivations

In this work we present the last achievement obtained at ISC-Konstanz within the European HERCULES project.

The concept proposed by the HERCULES project is to develop innovative n-type monocrystalline silicon (c-Si) device structures based on back-contact solar cells with alternative junction formation, as well as related structures including hybrid concepts (homo-heterojunction). Within the framework of the project, ISC-Konstanz has the role to provide Interdigitated-Back-Contact (IBC)-Zebra solar cells, with homo-junction emitter obtained with high temperature process (i.e., diffusion process) and high efficiency in order to fabricate back contacted modules with more than 320 Wp. The work herewith presented was needed to ensure a close connection between cell processing and the corrected specification for the Zebra cells used for the fabrication of these solar cells. We investigate the stability of our process over large variation of base-resistivity such as this condition arises in a standard (batch type pulling process) n-type Cz-Si material as. Moreover we test the quality of the Zebra process using thinner wafer material.

IBC-Zebra solar cells

- The ZEBRA concept is a low-cost IBC cell architecture with front floating emitter (FFE) and screen-printed and fired-through metallization made on 6 inches Cz n-type Si wafers. We implemented the FFE in our cell to diminish the tail caused by large pitch size required in the low average cell efficiency. From the analysis of the data, we can conclude that the efficiency is maximized for thinner wafers (~165 μm). Zebra solar cells made with wafers of ca. 195μm show a drop in average efficiency of 0.43 Nabs.

- The performance of the Zebra cell as a function of wafer thickness is shown in Figure 1a. It is shown that as the thickness of Jsc and Voc for large cells due to the absorption of light and the improved quality of passivation while FF drops since the longer paths travelled by the majority carrier (electron) reaching the base-contacts. The resulted efficiencies are maximized for thinner wafers (~165 μm). Zebra solar cells made with wafers of ca. 195μm show a drop in average efficiency of 0.43 Nabs.

Experimental results: Wafers thickness variation

- The data represent solar cells made out wafers taken from different parts of the n-type ingot. Each group corresponds to different base resistivity. Low values of resistivity correspond to the tail part of the ingot. The data show that the efficiency reach a plateau for resistivity range of 5-7 Ωcm.

Experimental results: Rho Variation

- The PL image of the module is shown on the right side. The data were measured by Norsun wafers (b-right) – only for the reference wafer. The PL images clearly show the influence of the oxygen content on the performance of the cells.

Zebra pilot line results

- We started with 1150 wafers and we finalized 1065 cells, with the remaining 9% yield loss due to manual handling and batch-like process. This is in agreement with the general yield for batch process lines using manual handling. From the IV data we excluded the tail of production of about 5%, Fig.1a shows the efficiencies distribution of the ZEBRA cells. As can be seen, the median efficiency obtained is 21.4% (Fig.1b) on reference material and only 20.15% on Norsun material. The reason for the overall lower performance using Norsun material is caused by particular lower wafers quality of part of the three wafers-lots used in the fabrication. This lot of wafers originates from the top part of the ingot which has high concentration of thermal donors and oxygen induced stacking faults (Fig.2). Nevertheless, best cell efficiencies of about 22% were obtained on both, Norsun and reference wafers. The ZEBRA cells used for the production have final thickness of 150μm.

Conclusions

- The pilot production run of more than 10000 ZEBRA cells was completed at ISC Konstanz. The best cell efficiency close to 22% was obtained. However the resulted median efficiency is about 21.4%. This is due to lower material quality, underestimation of FF measurements, and process variations as a result of manual handling and batching process. The resulted ZEBRA cells have been used to manufacture 60 cell modules in the Eurotron (HERCULES partner) back contact module assembly line. The certified IV data measurements of the first 300 Wp modules assembled using ZEBRA cells produced in this pilot line run

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Fig. 1 (a) Histogram of the ZEBRA cell efficiency from the Norsun wafers (b-right) – only for the reference wafers.

Fig. 2. Zebra cell efficiency versus wafer block. The PL images clearly show the influence of the oxygen content on the performance of the cells.

IV curve of a 300 Wp ZEBRA 60-cell module, as measured by Fraunhofer ISE Calliax.

The PL image of the module is shown on the right side.