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Next – generation interdigitated back-contacted silicon heterojunction solar cells and modules by design and process innovations

NEXTBASE
THE NEXT GENERATION BASELINE

NextBase - Deliverable report

D3.1- Fabrication and delivery of 2'500 high quality n-type Cz wafers per year

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Contents

List of acronyms, abbreviations and definitions

Table 1.1 Acronym table

Abbreviation	Explanation
Cz	Monocrystalline silicon wafers produced using the Czochralski technique
TD	Thermal Donors
ppma	Parts per million atoms

1. Introduction

This document aims at giving a status of the fabrication of high quality n-type Cz ingots at the premises of NC, their sawing into wafers and their distribution amongst the NextBase partners, as well as their quality.

Deliverable Number	Deliverable name	Lead partner	Type	Dissemination level	Due date
D3.1	Fabrication and delivery of 2’500 high quality n-type Cz wafers per year	CSEM	R	PU	M24

2. Production of high quality n-type silicon ingots

Norwegian Crystals delivered several bricks to MB to produce wafers for NextBase partners. Prior to production and delivery of these bricks, trial ingots were grown to characterize and improve the n-type crystal growth process. In particular, the impact of oxygen on as-grown resistivity by thermal donor (TD) formation was monitored. High oxygen content of seed-side (top-part) of Czochralski ingots give rise to in-situ formation of TDs which affect the resistivity profile of the ingots. Since the oxygen content is high at the seed-part (as seen in **Figure 1**), a high concentration of TDs is formed.

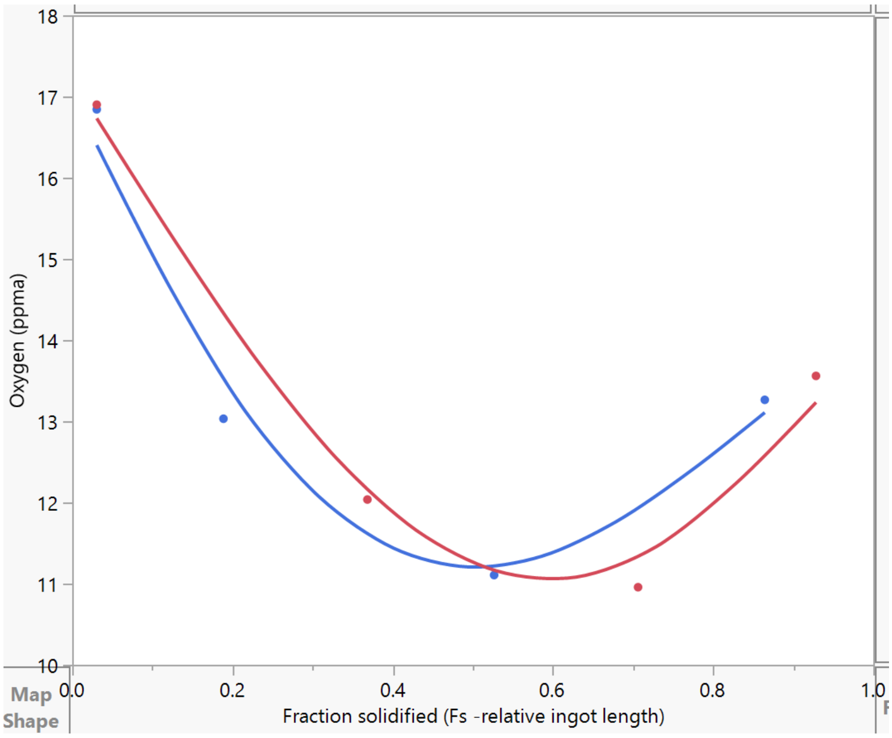

Figure 1. *Oxygen content of two ingots as a function of the relative ingot length (Fs-fraction solidified).*

In presence of TDs, added dopant (phosphorus) concentration should be adjusted to achieve the desired resistivity range. Since TD concentration is a strong function of the oxygen content, the impact is highest at the seed-end of ingots and diminishes towards the tail-end (bottom part) of ingots. Therefore, the resistivity profile of n-type ingots takes an inverse "U" shape with highest resistivity at around the middle as seen in the **Figure 2**.

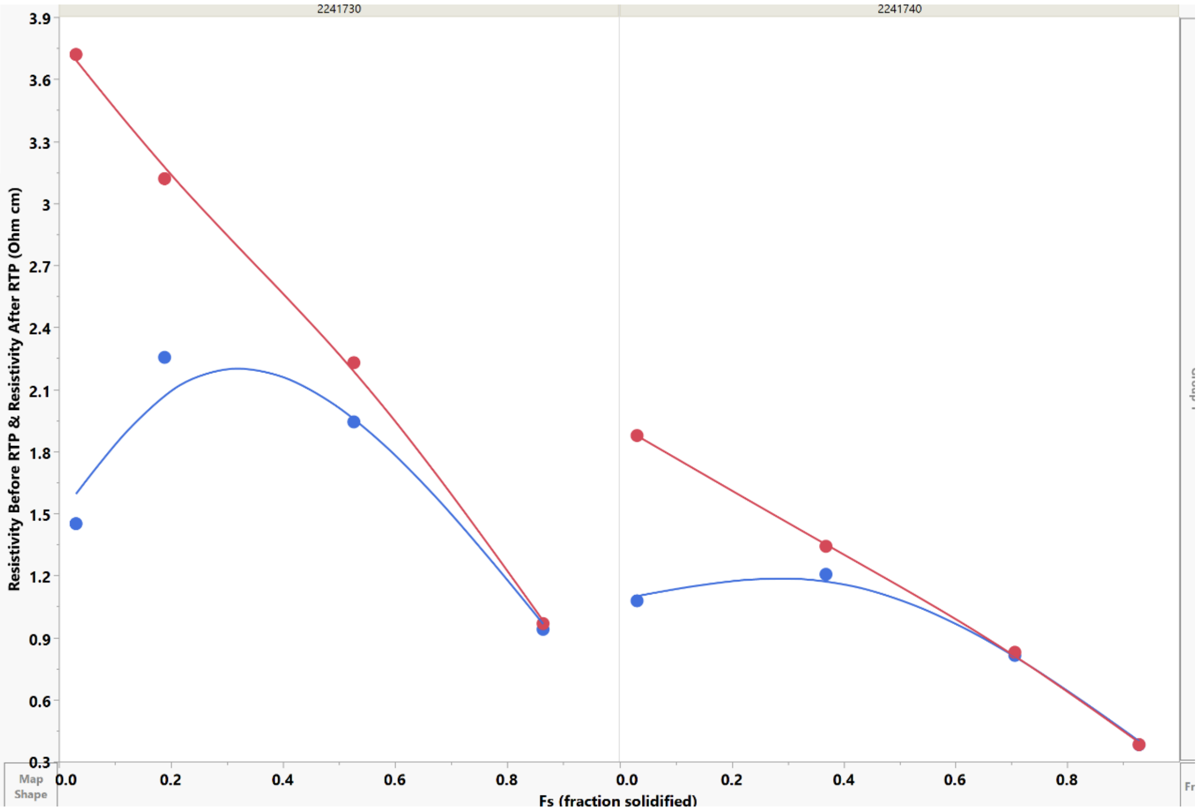

Figure 2. Resistivity profiles of two different ingots named 2241730 (left) and 2241740 (right) as a function of the relative ingot length (Fs-fraction crystallised). The effect of TD on resistivity (blue) is mitigated by rapid-thermal-processing (RTP) (red)

The impact of TDs can be deleted by a short and high temperature treatment. A rapid-thermal-processing (RTP) was used for this purpose: to elucidate the dopant (phosphorus) affecting only resistivity profiles, as seen in the **Figure 2**. The measurements of resistivity with and without the impact of TDs allowed NC to precisely tune the resistivity profiles of ingots delivered to NextBase.

Finally, NC produced two ingots for NextBase partners with differing resistivity ranges: one 1-2.2 ohm·cm while the second one with 0.3-1.2 ohm·cm. Oxygen content of both ingots was below 17 ppma. During production of these ingots, high purity crucibles and virgin polysilicon were used to attain low contaminant, hence high minority-carrier lifetime targets were reached. Bricks from these ingots were delivered to MB for wafering and distribution among Nextbase partners.

Upon delivery of these ingots NC extended the same crystal-growth process to become compatible with multi-ingot pulling: Initially, 2, then 3 and 4, ingots of full length have been grown at a given furnace process. Between each ingot, silicon melt was replenished and a new ingot growth has been initiated. Such an ingot-pulling process, called multi-pulling, has a large potential to reduce cost of crystal pulling while maintaining the high quality of the material produced.

3. Low-cost Si wafers with lifetime-over-resistivity ratio > 2 ms/Ω·cm

NC produced and delivered several n-type Cz ingots to CSEM. These ingots were sawn into wafers at MB facilities. The first delivery consisted of ~3’700 wafers and the second delivery of ~5’000 wafers, hence making a total of 8’700 wafers for the M1-M24 period. The wafers quality was assessed by CSEM and imec as described in T3.1 and T3.2. A lifetime-over-resistivity ratio > 2 ms/Ω·cm was obtained (see **Figure 3**), hence validating the high quality of the NC wafers. Then, CSEM organized the distribution of 1’000 as-cut wafers to imec and 1’000 as-cut wafers to CEA.

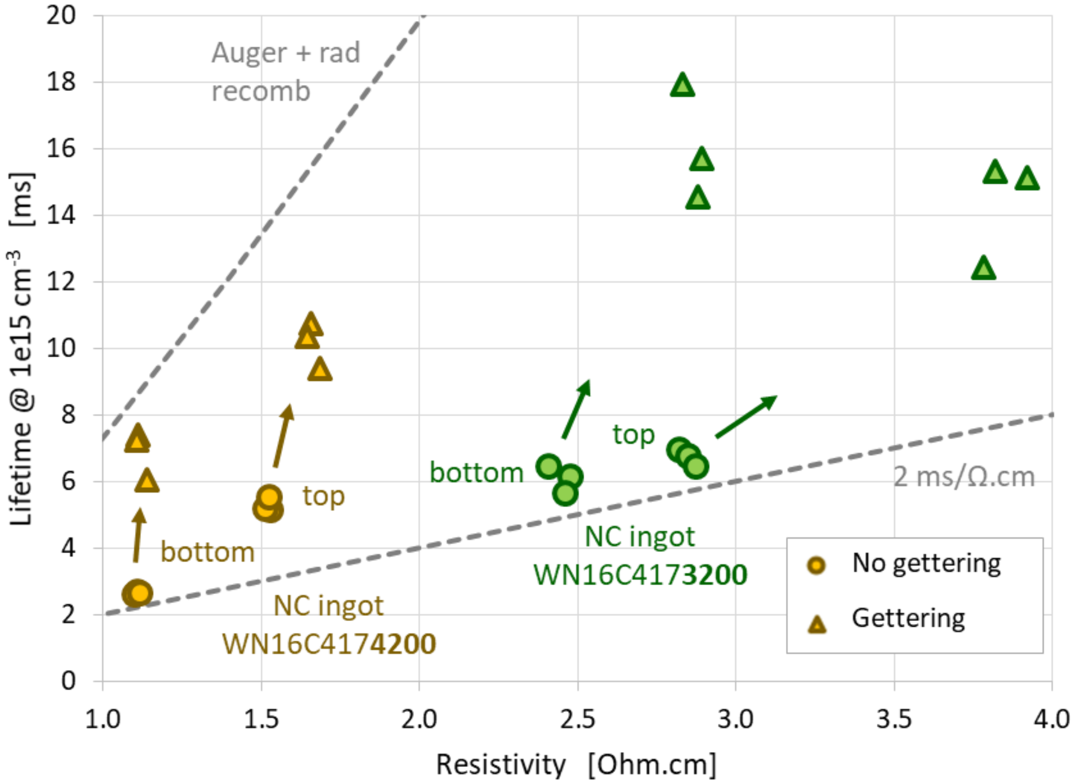

***Figure 3.** Quality evaluation of two ingots from NC before and after thermal treatment.*

4. Risks and interconnections

4.1 Risks/problems encountered

Several risks linked to the materials quality were identified at the beginning of the project, namely:

- High radial variation of the resistivity in n-type wafers affecting performance homogeneity of the final solar cell;
- High oxygen concentration of Si wafer for 26.0% cells;
- Failure to meet with minority carrier lifetime requirement using the multi-pulling process.

However, as already discussed in section 3 above, it has been demonstrated in WP3 that high quality wafers can be pulled, cut and used for high quality passivation, in line with the lifetime-over-resistivity ratio > 2 ms/Ω·cm targeted in the project. Therefore, there is no risk anymore regarding T3.1.

4.2 Interconnections with other deliverables

The wafers produced and qualified within WP3 are used downstream in WP4 for novel layers evaluation, and in WP5 and WP6 for the production of high-efficiency IBC-SHJ devices. As of today, enough wafers with the required properties have been delivered and qualified in WP3, so no delays or changes are expected in the interconnected WPs.

5 Conclusion and next steps

As a conclusion, the deliverable D3.1 “Fabrication and delivery of 2’500 high quality n-type Cz wafers per year” has been fulfilled in due date. No delays or changes related to the production, delivery, quality and shipping of the n-type Cz wafers are expected at this stage of the project.