HIGHLY EFFICIENT LOW CARBON FOOTPRINT SOLAR CELLS: IMPACT OF HIGH TEMPERATURE PROCESSING ON EPITAXIALLY GROWN P-TYPE SILICON WAFERS

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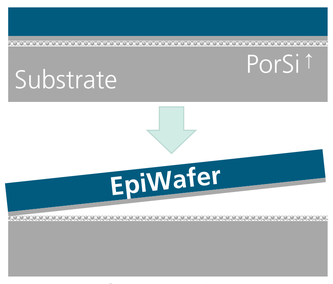
Introduction

- Epitaxially grown wafers ‚**EpiWafers**' with a low carbon-footprint and low costs are suited for highly efficient solar cells
- Cell efficiencies above 25 % predicted for **TOPCoRE** solar cells on p-type Si EpiWafers[1]
- Remaining quality limitation of EpiWafers are **structural defects**



Concept of epitaxially grown wafers with reusable substrate.

We investigate the influence of high temperature treatment during TOPCoRE solar cell fabrication on the material quality of EpiWafers focusing on structural defects.

Material quality of EpiWafers after high temperature treatment

EpiWafers

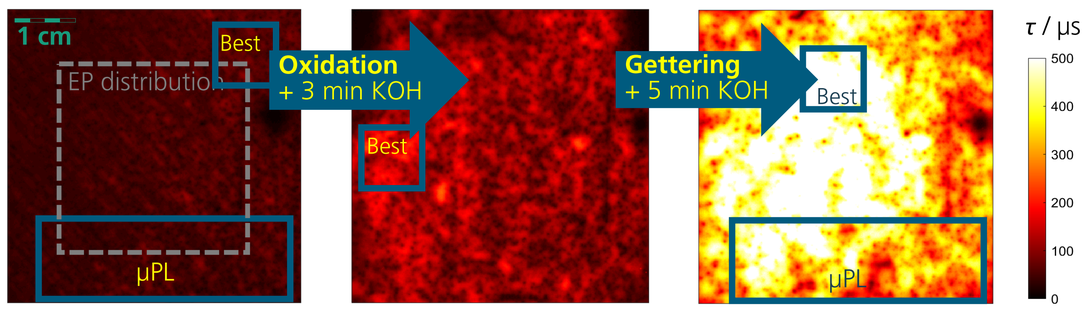
- Epitaxially deposited in an APCVD batch reactor of microelectronic standard
- 3 Ωcm p-type Si, 5x5 cm², 135 µm thick, KOH etched, Al_2O_3 passivated

High temperature treatment representing TOCoRE cell fabrication[2]

- Oxidation at 1050°C for 1h (+ 3 min KOH etching)
- $POCl_3$-Gettering at 840°C for 1h (+ 5 min KOH etching)

Material quality accessed by

- Photoluminescence imaging with lifetime calibration by modulated photoluminescence (modulum at Fraunhofer ISE)
- Efficiency limiting bulk recombination analysis (ELBA)
- µPL-mapping with a high resolution of ~ 20 µm



Lifetime images of the initial EpiWafer (left), after oxidation (middle) and after subsequent gettering (right) detected at an illumination of 0.05 sun eqs illumination.

Predicted solar cell efficiency η calculated by ELBA based on injection dependent PLI. The TOPCoRE solar cell efficiency limit is 26.6 % considering only intrinsic recombination.

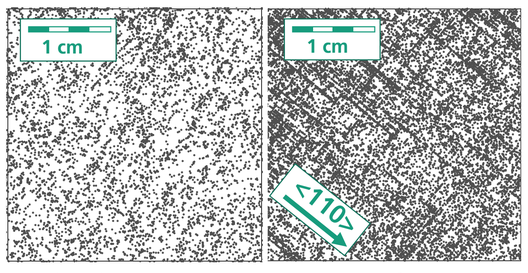
	Initial EpiWafer	After Oxidation	After Gettering
η / %	20.7	22.0	23.8
η_{Best} / %	21.2	22.6	24.4

µPL-maps of the initial EpiWafer (left) and after oxidation and after subsequent gettering (right) unveil a drastic change in structural defects: from a line-wise orientation to a random distribution.

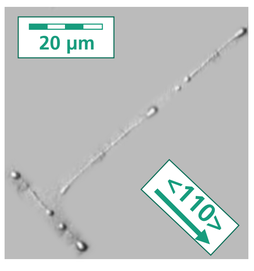
Structural defects in initial EpiWafer

Dislocations detected as etch pits (EP)

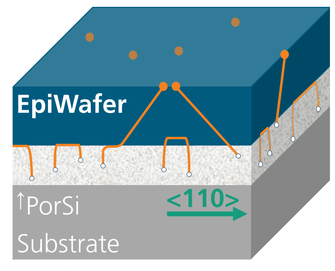
- Appear randomly distributed at the front side
- Arrange in lines along <110> and form pairs at the back side



EP distribution on as-grown EpiWafer's front side (left) and back side (right).



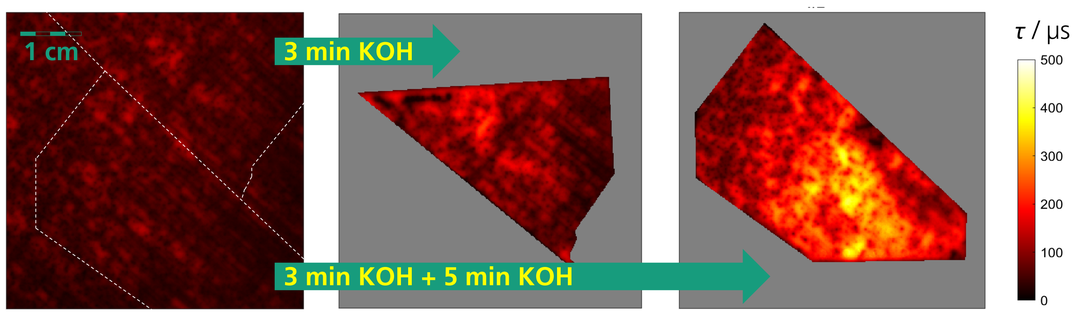
Microscope image of EPs at the back side.



Idea for dislocation model with pairwise connected EPs.[3]

Quality of EpiWafer after KOH etching

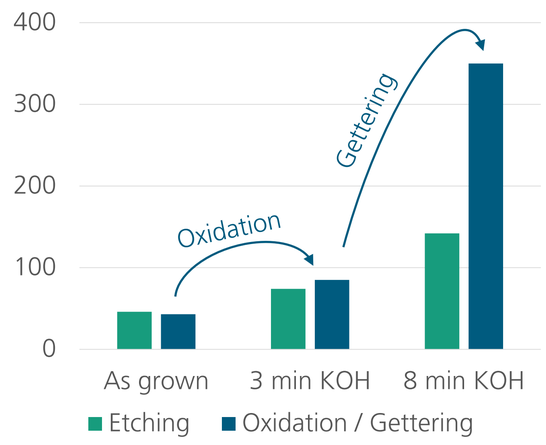
- Testing the effect of solely KOH etching in comparison to high temperature treatment and KOH etching



Lifetime images of the initial EpiWafer (left), after 3 min (middle) and after 8 min of KOH etching (right) detected at an illumination of 0.05 sun eqs. Illumination.

- **KOH etching** removes structural defects at the back side and hence improves material quality significantly
- The positive effect observed for the **oxidation** may mostly be due to the KOH etching
- **Gettering** has a positive influence on the material quality in direct comparison to KOH etching

Mean lifetime τ / µs (evaluated at 0.05 suns).



Results

- EpiWafers are well suited for high temperature treatment during high-efficiency solar cell fabrication
- In the initial EpiWafer, quality limiting structural defects are mainly located on the backside
- Structural defects at the backside can be removed by KOH etching
- $POCl_3$-gettering has an extremely positive effect on the material quality with predicted solar cell efficiencies exceeding 24 %

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1 C. Rittmann et al., Solar RRL, 2022.
2 A. Richter et al., Nature Energy, 2021.
3 A. Bioud et al., Nature Communications, 2019.

Poster content will be published as a Solar RRL research article soon!