S. Kirner, S. Calnan, K. Frank, O. Gabriel, K. Mack, S. Neubert, C. Schwanke, M. Zelt, B. Stannowski, B. Rech, R. Schlatmann
PVcomB / Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Schwarzschildstr. 3, D-12489 Berlin, Germany
Email: simon.kirner@helmholtz-berlin.de

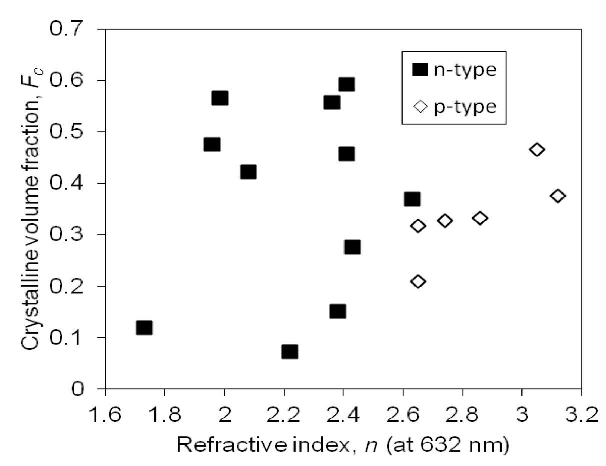
pvcomB
Competence Center Thin-Film- and Nanotechnology for Photovoltaics Berlin

An Improved Silicon-Oxide-based Intermediate-Reflector for Micromorph Solar Cells

1. Summary

- To increase the current in our top cell, we are developing a silicon oxide intermediate reflector (SOIR) experimenting with both n- and p-type silicon oxide.
- We found that the deposition of a thin (n) µc-Si recombination layer (ReLay) behind the SOIR improves the conductivity of the tunnel recombination junction significantly. At the moment, we are trying to understand this in further detail using the simulation software Afors-Het
- So far, the best cell on commercial SnO_2:F with SOIR has an efficiency of 9.5% after 168h light soaking, which is a 2 % increase relative to a comparable cell without SOIR

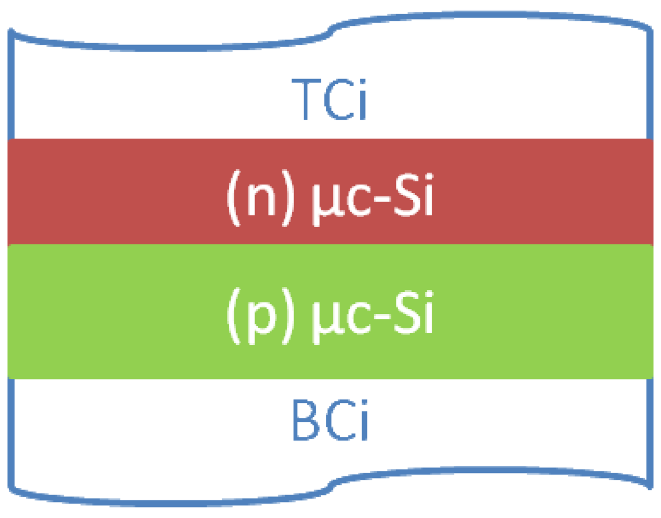
2. Microcrystalline Silicon Oxide Single Layers



- We are depositing p– and n-type microcrystalline silicon oxide (µc-SiO_x) by PECVD on an industrial like AKT1600.
- The material working best so far as the SOIR has an refractive index of about 2.2.
- So far we found that (n) µc-SiO_x can be prepared with a lower refractive index at a sufficiently high crystallinity than (p) µc-SiO_x, which makes it more applicable as an IR.

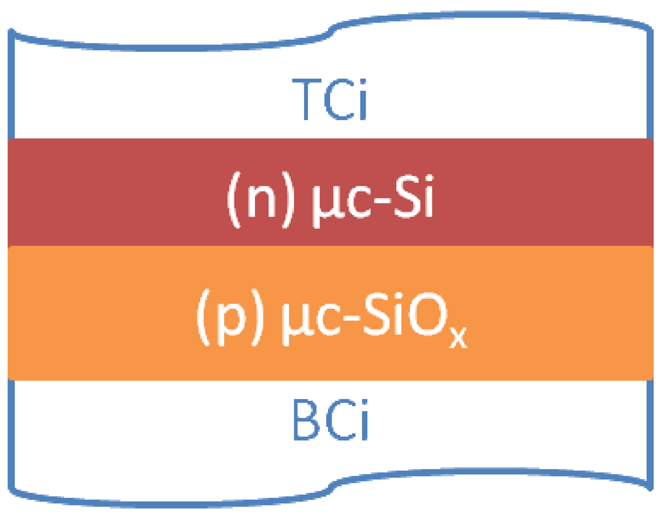
3. Tunnel Recombination Junction Structures

Type A



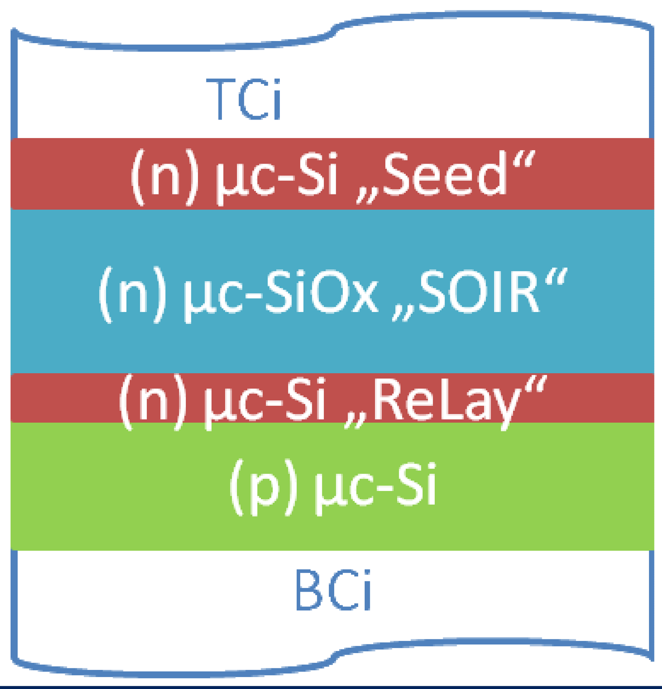
- Reduction of parasitic absorption in bottom cell p-layer
- Increase of V_{oc} and FF
- Slight increase of TC current

Type B



- Significant reflection of light back into the top cell
- Reduction of parasitic absorption in top cell cell n-layer
- Slight decreas of V_{OC}

Type C



Next Steps:

- Implementation of SOIR demands adapting the (p) µc-SiOx (currently in progress)
- First results showed increased series resistance

4. The Role of the Recombination Layer

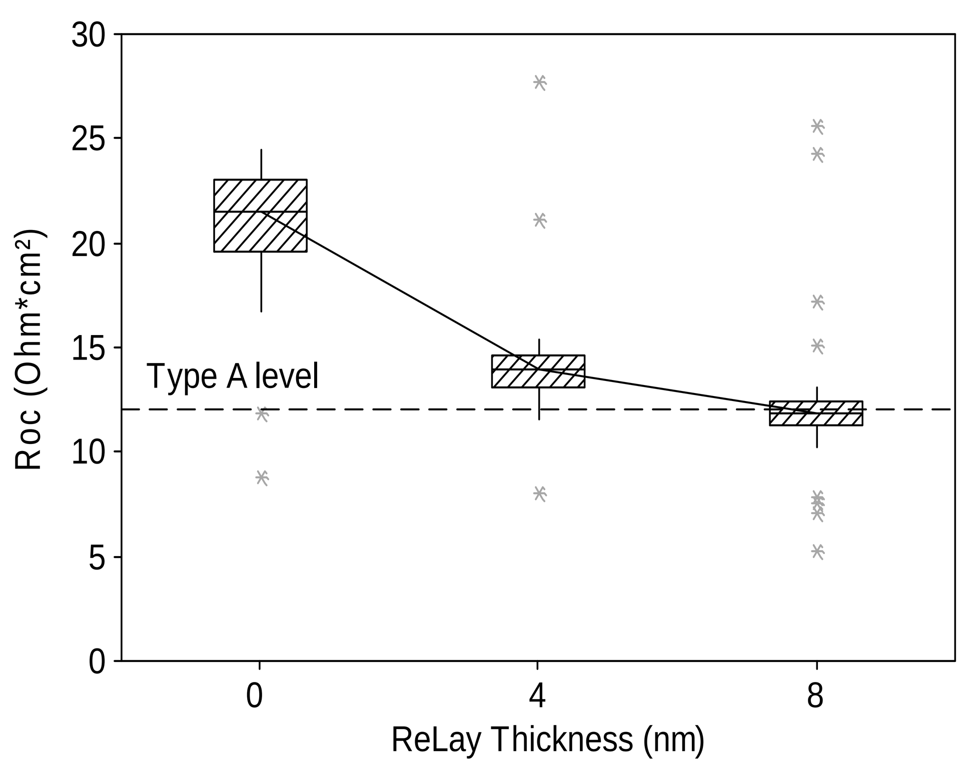
Until now, the positive influence of the recombination layer has not been fully understood.

One explanation could be the forming of a thin oxide-rich layer at the end of the SOIR -deposition leading to a barrier (see scheme below):

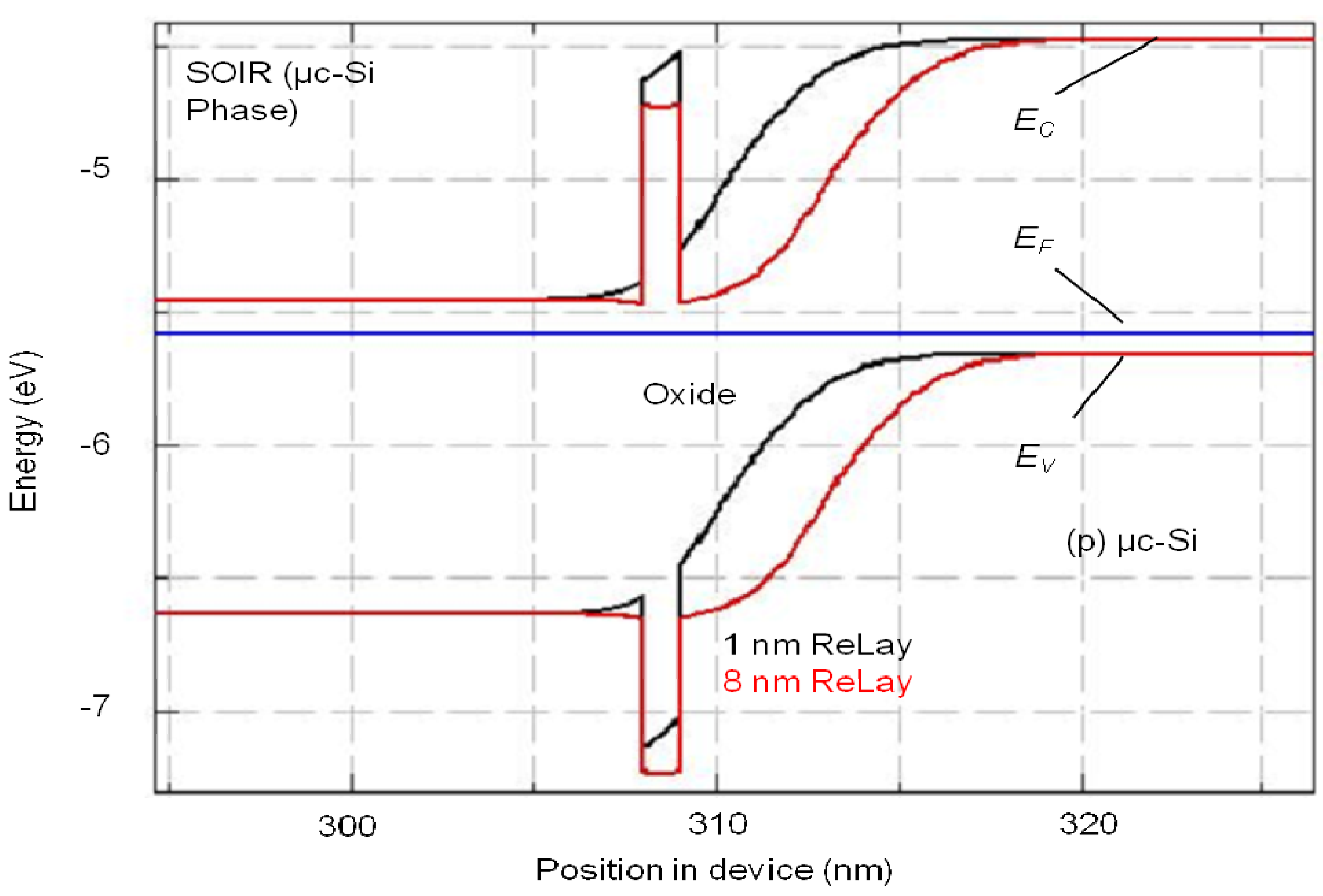
Using the ReLay, charge carriers can tunnel through the oxide first, before recombining. Without the ReLay, the trap-assisted-tunneling process is hindered by the oxide.

Other explanations we are discussing at our lab are an insufficient activation energy of the SOIR or the poor interconnection of the c-Si phase within the SOIR with the adjacent p-layer.

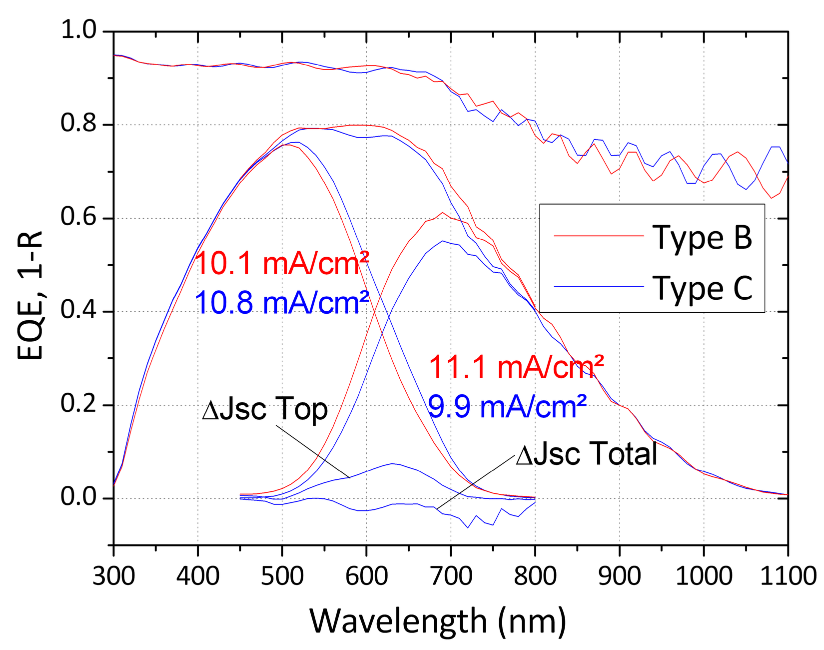
Series resistance determined experimentally from light IV at open circuit voltage (R_{OC}) for different ReLay thickness (Type C)



Band diagrams of the TRJ (Type C) with an oxide barrier calculated for different ReLay thicknesses



5. Cell Results on Commercial SnO_2:F

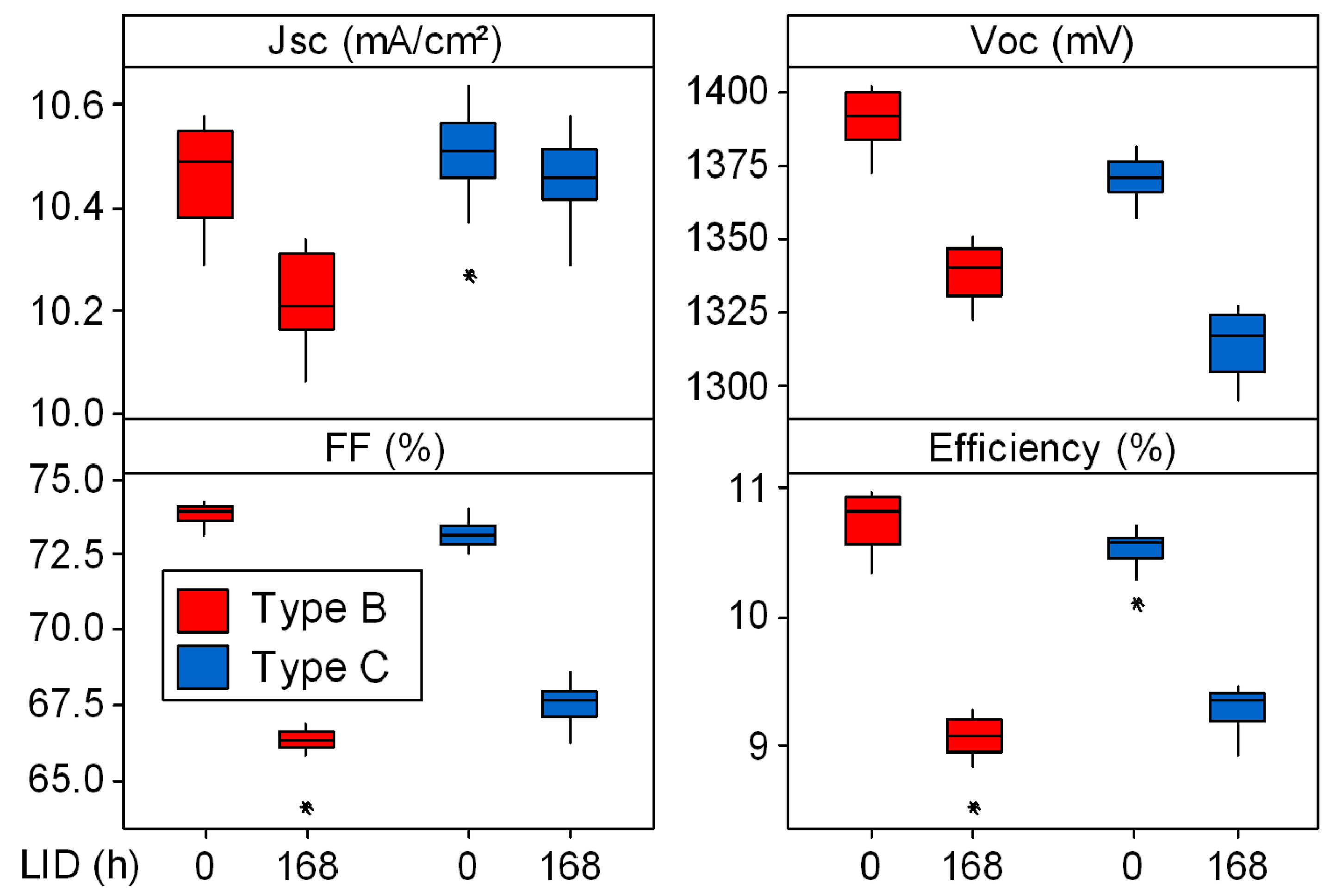


The cells shown are nominally same except for the TRJ (Type B vs. Type C) and a bottom cell thickness adaption from 1600 nm to 1850 nm for the cell with SOIR.

It is shown that top cell current increases by 0.7 mA/cm², with only minor additional reflection losses.

Due to the improved top cell, stable cell efficiency increases by about 2% relative.

J-V parameter statistics based on 20 (1cm²) cells for each category



6. Outlook

- Re-implementation of the adjusted µc-SiO_x p-layer
- Comparison of a-Si/SOIR/µc-Si with triple cell devices
- Combined electrical and optical simulations using Afors-Het and Sentaurus TCAD to further investigate our devices

Acknowledgements

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