Sputtered and otherwise deposited a-Si for *f*abricating passivated screen-printed contacts for an ind*u*strially feasible productio*n* - *FUN*

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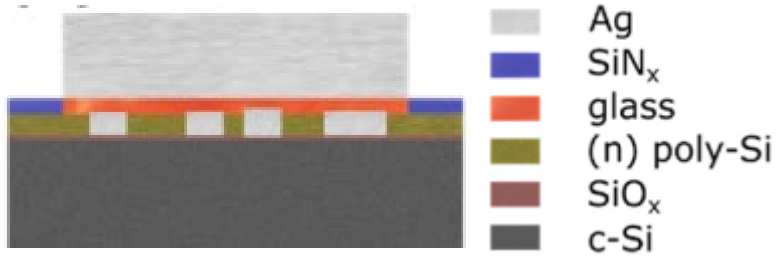
Challenges addressed

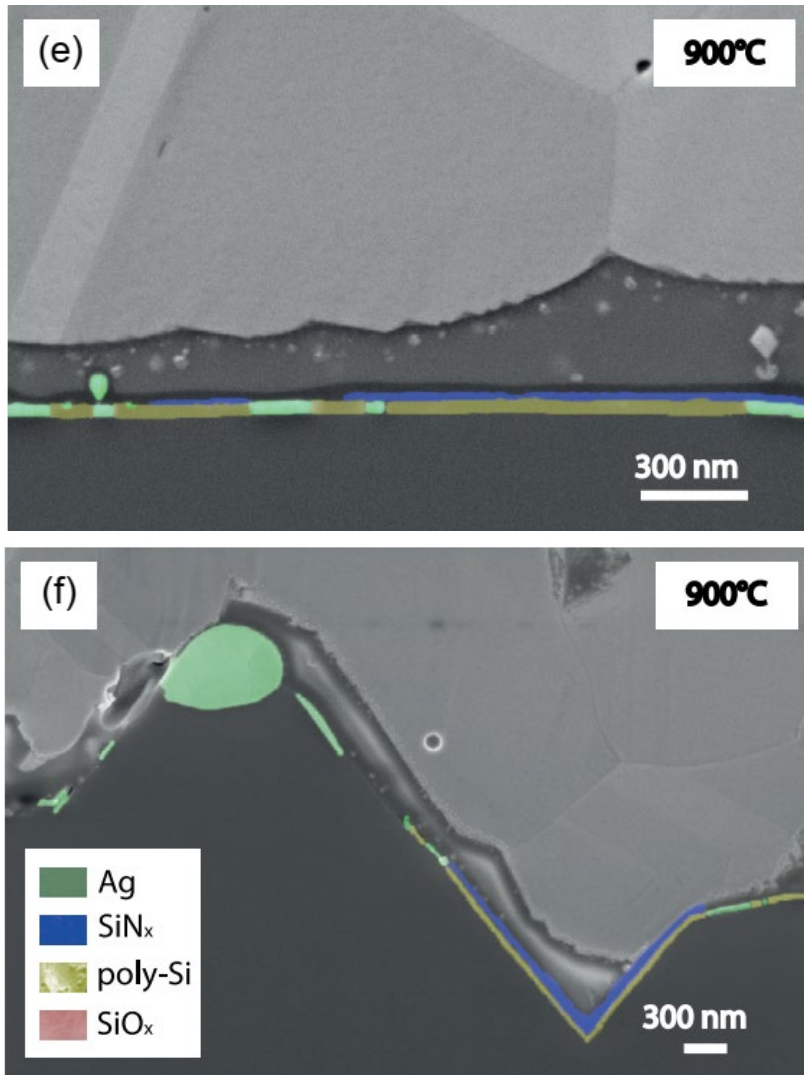
Provide highly performing photovoltaics and reduce the cost of solar technology by

- selecting highly *cost-effective, epitaxially grown silicon wafers* from partner **NexWafe**
- combine them with *passivating contacts* solar cell process from **UKON**
- and a suitable *Ag metallization paste* from partner **FENZI**
- as well as *laser crystallization* from partner **IPHT**

Challenge 1 Ag contact formation to planar and textured surfaces coated with polySi



Ag-pastes from partner FENZI screen-printed, dried, fired and characterized by partner UKON
SEM images taken after wet chemically removing Ag metal finger



Glatthaar, Raphael; Huster, Frank; Okker, Tobias; Cela Greven, Beatriz; Seren, Sven; Hahn, Giso; Terheiden, Barbara (2022): Contact Formation of Silver Paste and Atmospheric Pressure Chemical Vapor Deposition (n) Poly-Silicon Passivating Contacts on Planar and Textured Surfaces. In: *Physica Status Solidi (a)*, S. 2200501. DOI: 10.1002/pssa.202200501.

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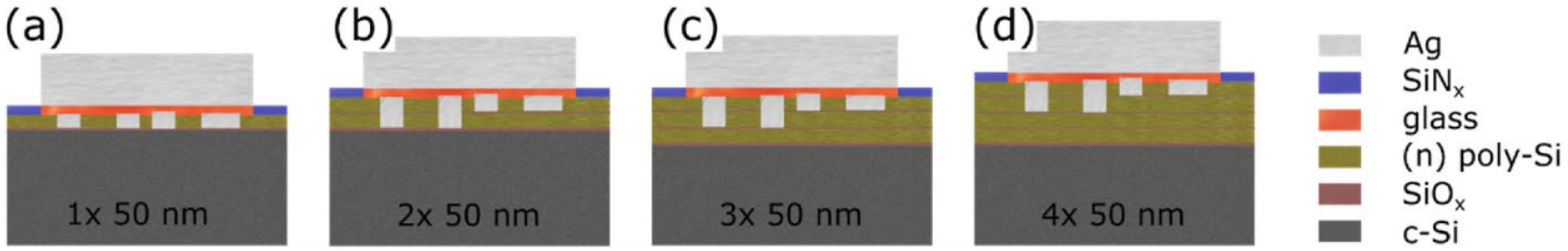
Ag contact formation between polySi and Ag paste



- Multiple Drive Throughs (DT) in an inline APCVD tool lead to multiple thin oxide layers stopping Ag.
- When the etching mechanism is driven by the glass, primarily at temperatures around 600°C and longer process times, non-selective etch imprints and penetrations through the SiO_X, thermal into the c-Si substrate observed.
- No differences in etching behavior of glass frit containing Pb or Te.

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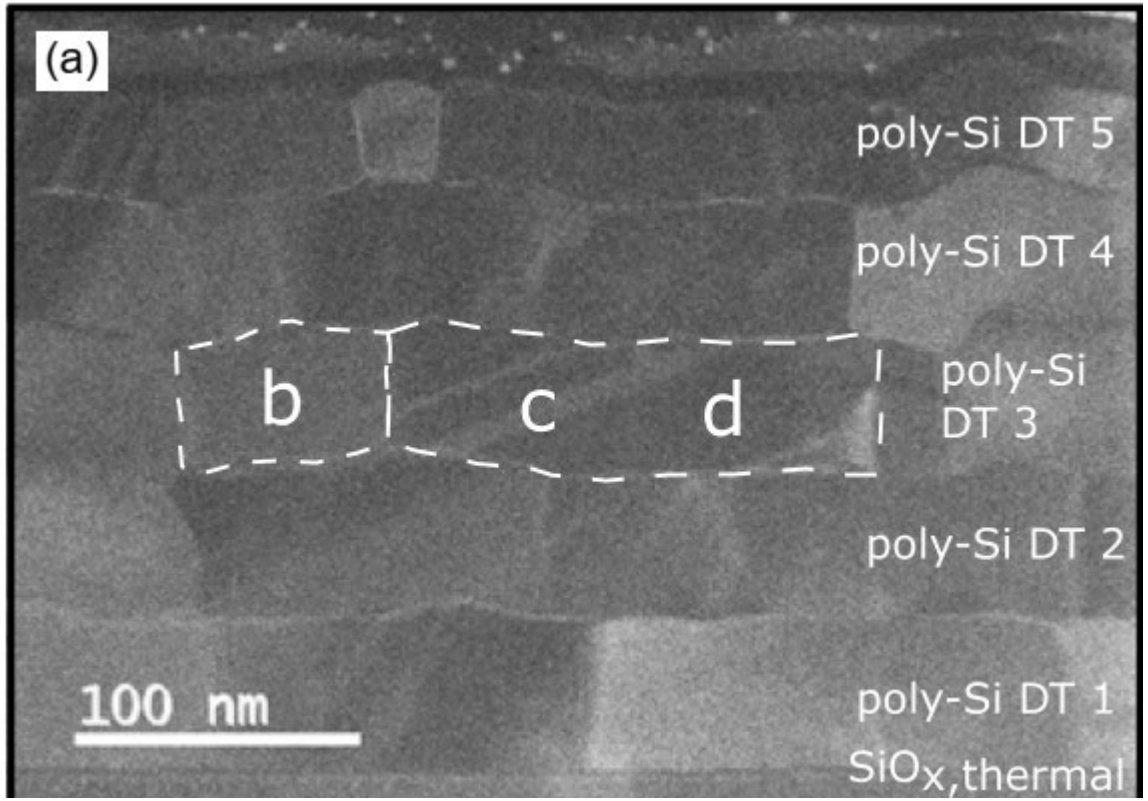
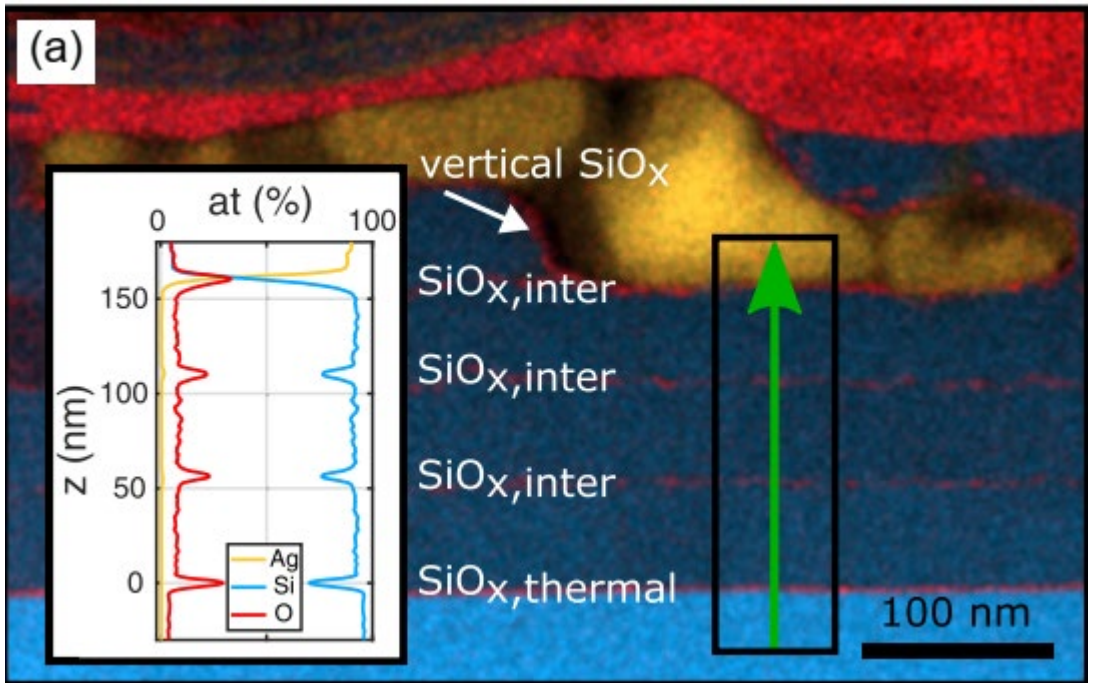
Controlled Etch Stop for Ag paste Using SiO_X Layers in Passivating Contacts





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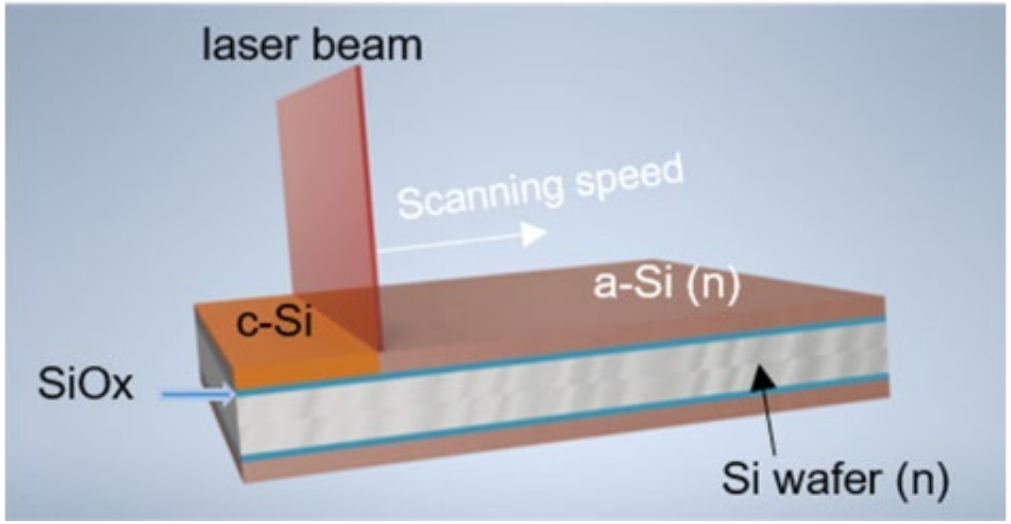
Challenge 2 Laser crystallisation without damaging interface oxide

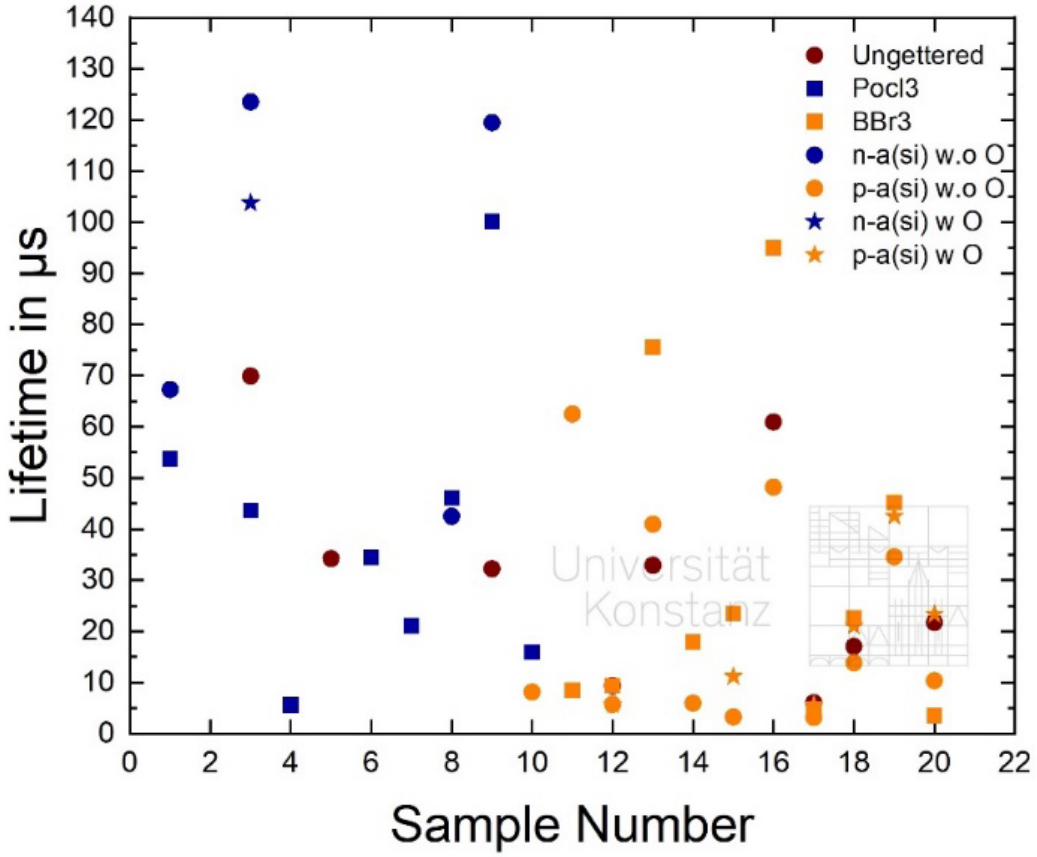


Scan speed [mm s^{-1}]	Laser power [W]	T_{fit} [µs]	iV_{OC} [mV]	J_0 [fA cm^{-2}]
15	145	2720	705	32
15	150	4060	711	27
20	185	3484	709	27
20	190	3275	707	30

- Laser crystallisation of the whole back side or selectively for metallization on front side
- Damage to the interface oxide small
- Final development led to iV_{OC} of 730 mV for n-type polySi

Gawlik, Annett; Glatthaar, Raphael; Dellith, Andrea; Jia, Guobin; Dellith, Jan; Terheiden, Barbara; Plentz, Jonathan (2022): Diode Laser-Crystallization for the Formation of Passivating Contacts for Solar Cells. In: *Physica Rapid Research Ltrs* 16 (5), S. 2100537. DOI: 10.1002/pssr.202100537.

Challenge 3 Gettering processes for n-type Si EpiWafer



- Phosphor-gettered samples compared to boron-gettered samples show higher lifetimes independent if the phosphorous comes from amorphous silicon or phosphor silicate glass ($POCl_3$)
- Gettering seems to be reduced by the interface oxide

- Gettered and non-gettered samples are not the same piece of Si but sister samples from the same large EpiWafer.
- Lifetimes are measured after removing polySi and interface oxide and repassivating with AlO_X.

Barbara Terheiden, Raphael Glatthaar, Yashwanth Reddy Manda, Hermann Kromer, Tobias Okker, Frank Huster. Integration von Siebdruck-basierter Metallisierung und Getterprozessen von EpiWafern in einen Solarzellenprozess mit passivierten Kontakten, Schlussbericht der Universität Konstanz, 2022

Summary

- ✓ Successful development of a screen-printed Ag paste that contacts n-type and p-type polySi with low, required contact resistivity and at least in case of n-type polySi with an only low increase in saturation current density.
- ✓ Development of polySi deposition for gettering and passivating contacts in the inline APCVD tool.
- ✓ Development of gettering processes for EpiWafers and CZ-Si wafers based on polySi.
- ✓ Development of laser crystallization processes in combination with electron beam evaporated Si for passivating contacts leading to an iV_{OC} value of 730 mV and 703 mV for n- and p-type poly Si respectively.
- ✓ Demonstrating the integration of the new solar cell features as polySi in combination with the newly developed Ag paste leading to 20% solar cell efficiency that is not limited by the passivating contact.

Thank you very much for your attention

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Publications

Martin, Isidro; Lopez, Gema; Garin, Moises; Ortega, Pablo; Voz, Cristobal; Jia, Guobin et al. (2021): Thin c-Si Solar Cells Based on VO x Heterojunctions With Texturized Rear Surface. In: *IEEE J. Photovoltaics* 11 (6), S. 1358–1362. DOI: 10.1109/JPHOTOV.2021.3110308.

G. Jia, A. Gawlik, J. Dellith, A. Dellith, G. Andrä, R. Glatthaar, B. Terheiden, J. Plentz, *Local laser crystallization of a-Si on tunneling SiO_x for passivated contacts of solar cells*, Proceedings of the 37th European Photovoltaic Solar Energy Conference (2020)

Gawlik, Annett; Glatthaar, Raphael; Dellith, Andrea; Jia, Guobin; Dellith, Jan; Terheiden, Barbara; Plentz, Jonathan (2022): Diode Laser-Crystallization for the Formation of Passivating Contacts for Solar Cells. In: *Physica Rapid Research Ltrs* 16 (5), S. 2100537. DOI: 10.1002/pssr.202100537.

Glatthaar, R.; Okker, T.; Huster, F.; Cela Greven, B.; Seren, S.; Hahn, G.; Terheiden, B. (2022): APCVD (N) Poly-Si Passivating Contacts on Textured and Planar Surfaces. 4 pages / 8th World Conference on Photovoltaic Energy Conversion; 79-82, S. 79–83. DOI: 10.4229/WCPEC-82022-1DO.11.5.

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Contents – What to Present about your Transnational Project

- Scientific, technical, commercial challenge(s) addressed
- Key outcomes, results and benefits
- Experiences gained in transnational set-up
- Critical factors and lessons learned for future successful transnational R&I projects

«Guidelines»

- Speak up to **10 minutes maximum**
- Use illustrations and concise text
- Be specific about the challenges and outcomes (not too general nor too detailed)
- Share positive and critical aspects of the transnational set-up you experienced
- Present up to 8 slides maximum
- Send your presentation (ppt) to era-energia@aei.gob.es by 20 September the latest