Light absorption enhancement of crystalline silicon wafers by direct laser texturing for heterojunction solar cells

D. Canteli [1], A. Marquez [1], R. Barrio [2], I. Torres [2], S. Lauzurica [1], Javier Gandía [2], C. Molpeceres [1]

[1] *Centro Láser, Universidad Politécnica de Madrid.*

[2] *Departamento de energías renovables, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT).*

Contact: david.canteli@upm.es

Abstract

Light trapping strategies is a direct way to improve solar cells behavior. The **texturization** of one or more surfaces is an industry standard in solar cells manufacturing, **usually achieved by a chemical etching**. But the control of the final morphology is limited, especially in **multicrystalline silicon** wafers where the etching rate in basic solutions is dependent on the crystal orientation of the silicon grains.

This work shows the changes in the incident light total reflection of silicon samples when they are textured by direct laser beams. We compare them with similar samples textured by standard chemical etching that was optimized in a previous work[1] for its use in silicon heterojunction solar cells.

Results

Texturing process

- **Samples**

  Silicon wafers, three types:
  - Polished monocrystalline
  - As-cut monocrystalline
  - As-cut polycrystalline

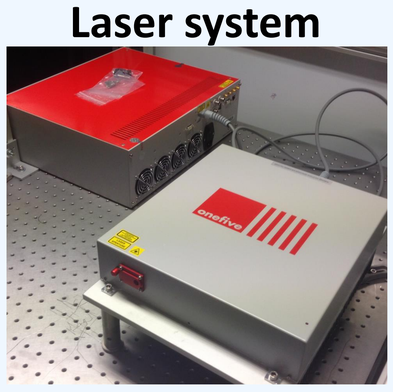
- **Laser texturization**

  -Previous optimization of scribes: 10 µm wide, 8 µm deep
  - -Frequency: 50 kHz
  - -Pulse energy: $13 \cdot 10^{-6}$ J
  - -Speed: 17 mm/s

  -1D & 2D patterns

  -Inter-scribe distance from 15 to 30 µm

Laser system



Katana HP, from OneFive pulsed laser source.
Gaussian pulses
35 ps
1064 nm

- **Characterization**

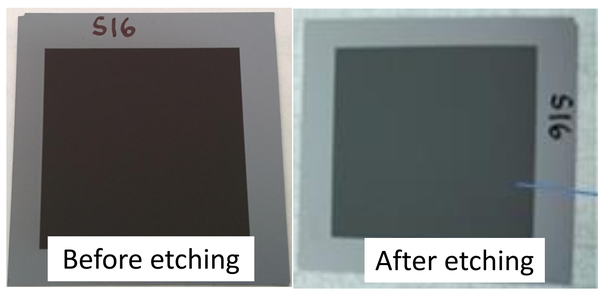
  Confocal and SEM microscopy
  Reflectance spectra
  XPS

→ Silicon oxide layer (~50 nm) appears on the textured surface

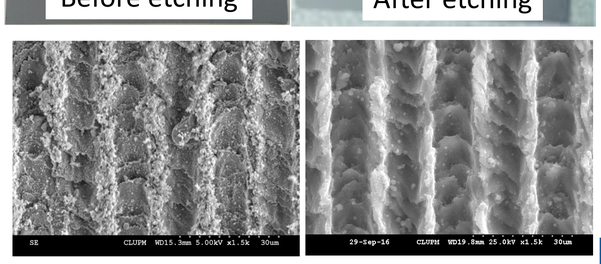
Cleaning process

- **Chemical etching to eliminate oxide layer**

5 minutes with 10 % HF
or 10 minutes with 5% HF



Rising of total reflectance after the etching

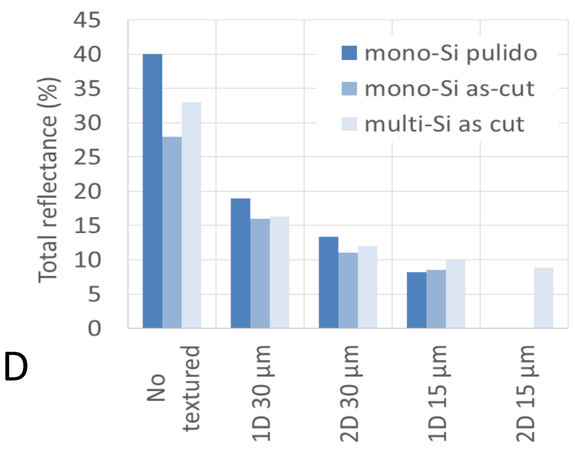


Little morphologic differences induced by the chemical etching

Reflectance values

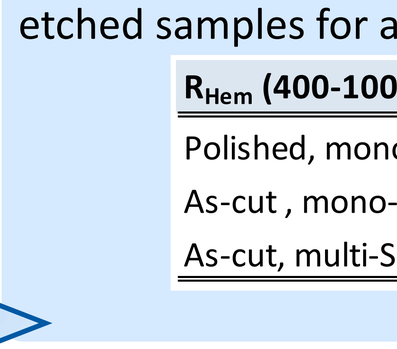
Tendency

For a same groove width and depth the total reflectance drops as:
- the inter-scribe distance diminish
- 2D pattern better than 1D

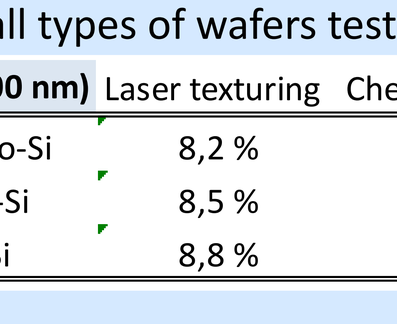


Best results

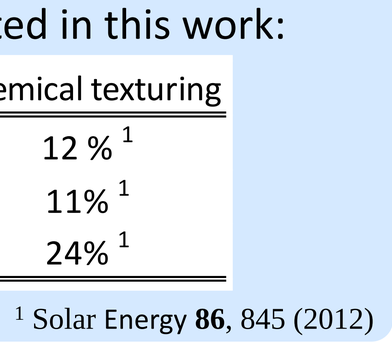
Polished mono-Si 1D pattern, 15 µm

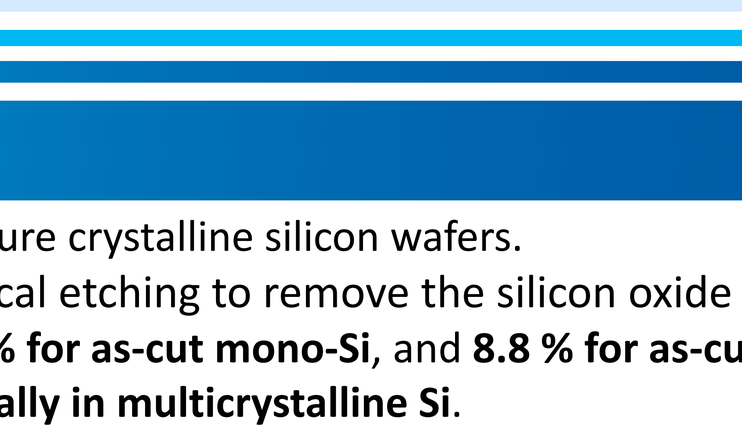


As-cut multi-Si 2D pattern, 15 µm



As-cut mono-Si 1D pattern, 15 µm





Average total reflectance (400-1000 nm)

The laser textured samples show better results than chemical etched samples for all types of wafers tested in this work:

R_{Hem} (400-1000 nm)	Laser texturing	Chemical texturing
Polished, mono-Si	8,2 %	12 % [1]
As-cut , mono-Si	8,5 %	11% [1]
As-cut, multi-Si	8,8 %	24% [1]

[1] Solar Energy **86**, 845 (2012)

Conclusions

- A **picosecond pulsed laser** source emitting at 1064 nm has been used to texture crystalline silicon wafers.
  - Scribes 10 µm wide and 8 µm deep with a 1D or 2D pattern + a chemical etching to remove the silicon oxide layer.
- **Best results:** Total reflectance values about **8.2 % for polished mono-Si**, **8.5 % for as-cut mono-Si**, and **8.8 % for as-cut multi-Si** respectively. **Improvement in light absorption** in all silicon wafers, but **specially in multicrystalline Si**.
- The laser textured **surface free of impurities** obtained after the chemical cleaning with HF is specially interesting for **heterojunction solar cells**. Future work will be focused in surface passivation.

Acknowledgments. Partial financial support for this work has been provided by European Commission under the project APPOLO (FP7-2013-NMP-ICT-FOF. 609355) and the Spanish Ministry of Science and Innovation under the project HELLO (ENE2013-48629-C4-3-R, ENE2013-48629-C4-4-R).