LARS: LASER-ASSISTED RECYCLING OF SILICON SOLAR MODULES

Quentin Mottet[1,2], Remi Aninat[1], Toon IJzermans[1], Johan Bosman[1], Bart Geerligs[1], Ando Kuypers[1], Maarten van der Vleuten[1], Mirjam Theelen[1]

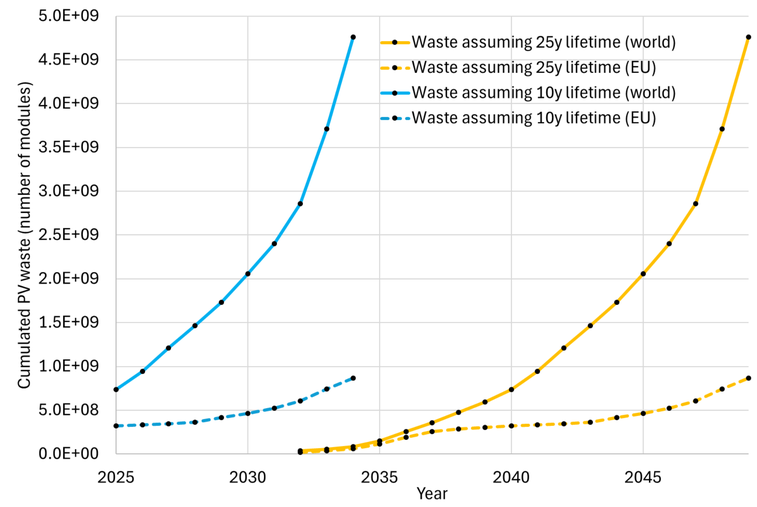
[1] TNO, The Netherlands [2] ESPCI Paris – PSL

INTRODUCTION

A need for PV recycling method

- A large increase of PV waste in the coming years (see graph)
- Access to high value materials (silver, high purity silicon with embedded energy) & toxic materials (PFAS & Lead):
    - Geopolitical independence
    - Environmental and financial benefits

Develop an energy-efficient, versatile, sustainable and economically viable recycling method to access valuable and toxic materials in silicon solar modules



Projected cumulative waste (based on IRENA data, ignoring reuse)

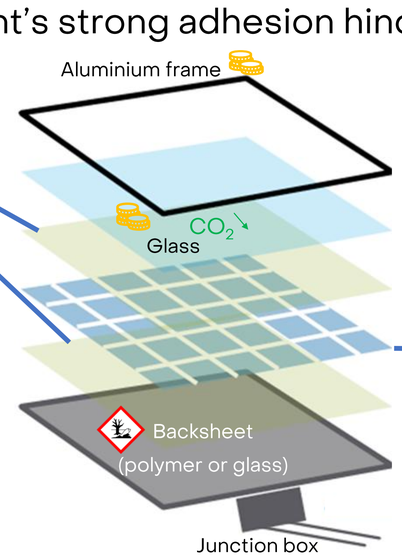
Main challenge: The encapsulant's strong adhesion hinders delamination

The encapsulant (e.g. EVA)

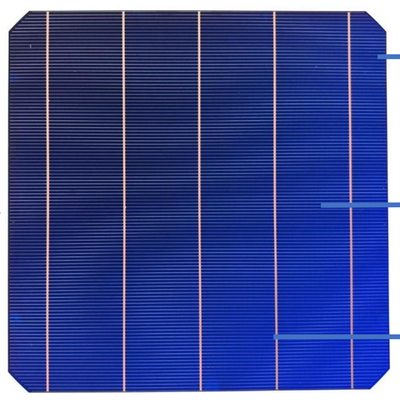
Our solution

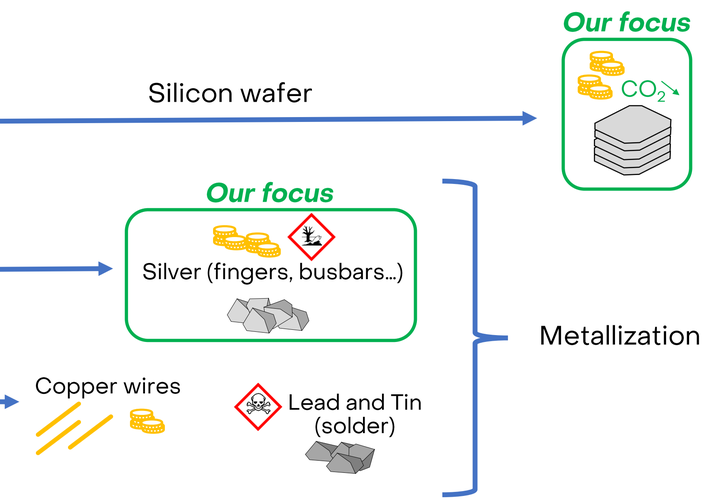
Delaminate the front and back sheets by **weakening the adhesion** between encapsulant and wafer **using laser treatment**

Video Demonstration of the LARS Method



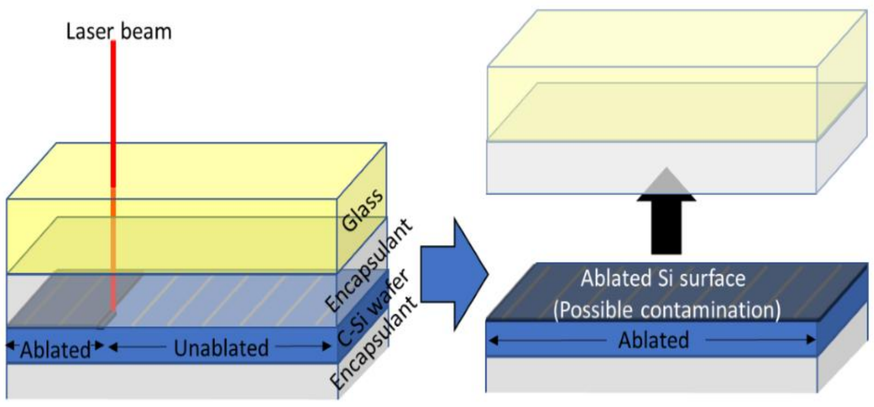
The **silicon** wafer & **metallization**



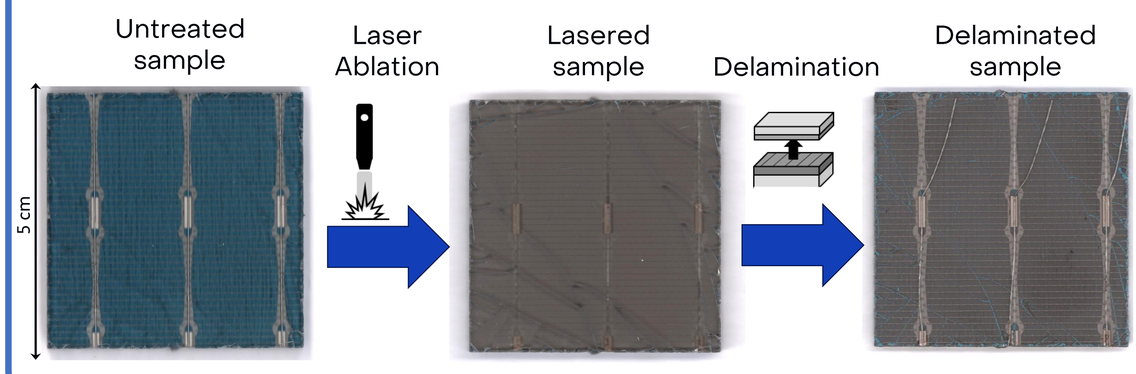


LASER-SEPARATION

We use laser-ablation to achieve **clean separation of the encapsulant and the silicon wafer**. A pulsed laser (picosecond or nanosecond laser) selectively ablates the top surface of the silicon wafer, weakening the adhesion between the encapsulant and the wafer. A subsequent **mechanical separation step** allows access to the valuable materials.



This method is applied on 5x5 cm^2 samples cut by water-jet **from commercial modules**

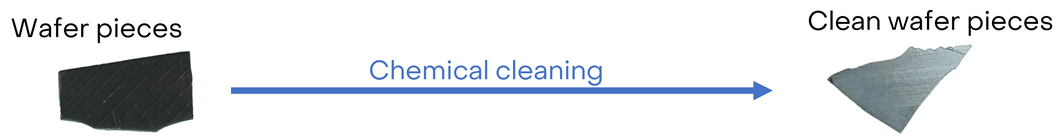


RESULTS

Ablation and easy-separation of commercial modules

- **Energy-efficient** with optimized lasering parameters (pulse duration, wavelength, frequency, focus, speed, patterning…) for low energy ablation and **easy separation**
- **Versatile** across different module types (PERC, Al-BSF, TOPCon) and can be tuned to industrial needs
- Enables **rear and front side** separation
- **No silver loss** was observed after the lasering process

Chemical cleaning step



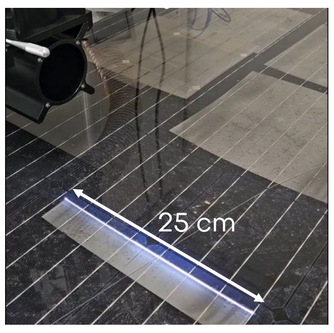
- Recover silver and isolate toxic materials (lead, tin…) by chemical treatment (KOH, HNO_3) under **mild conditions**
- Achieve **high-purity*** and **high yield** silicon recovery with a purity exceeding 99,99% (4N)

*analyzed by ICP-MS

UPSCALING

Successfully switched from picosecond **to industry-ready nanosecond** pulsed laser ablation

Full-module laser treatment on a 25x25 cm^2 treated areas



CONCLUSION & OUTLOOK

Laser Assisted Recycling of silicon Solar module proves to be a versatile, energy efficient and scalable process which allows the recovery of high-purity, scarce and valuable materials.

Future work

- Apply to cell technologies with a significantly different layer architecture, such as SHJ
- Optimize the mechanical separation step, especially for upscaling purposes
- Investigate the use of LARS recycled silicon for applications like batteries
- Optimise laser parameters for industrial application (throughput, OPEX)

CONTACT US

Mirjam Theelen
E-mail: mirjam.theelen@tno.nl

Quentin Mottet
E-mail: quentin.mottet@espci.fr