Enabling Thermal Laser Separation of Silicon Wafers while Interconnected with Aluminum Foil

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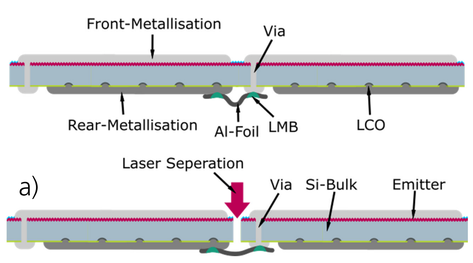
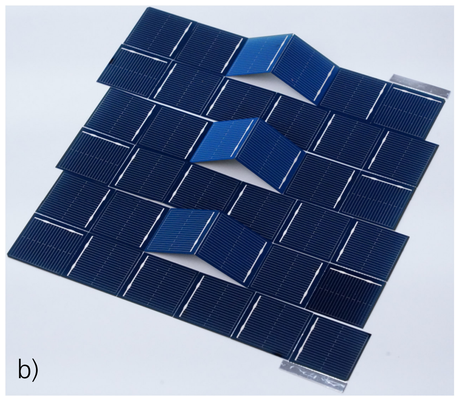
The production of small appliances PV modules benefits from interconnecting sub-cells using aluminum foil before separating them. This eliminates the need of handling sub-cells, allows for high voltage values without step-up conversion, and substitutes environment harmful materials. This approach has been proposed earlier [1], albeit separation via thermal laser separation was not yet established. The present work developed solutions for thermal laser separation in said samples, by introducing an elongation into the Al-foil, and demonstrates that deformation appears in the Al-foil if there is insufficient spatial freedom.

Introduction

- Earlier work proposes interconnecting sub-cells with aluminum foil (Al-foil) before cell separation. Key messages were [1]:
  - Eliminates need for handling sub-cells and substitutes harmful materials
  - Al-foil to wafer attachment [2] via Laser Metal Bonding (LMB) [3]
  - Thermal Laser Separation (TLS) [4] hindered by insufficient spatial freedom

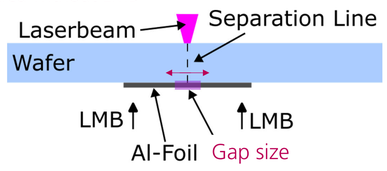




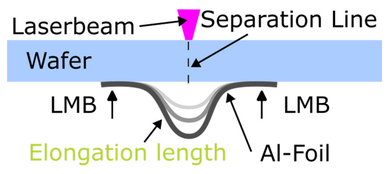
a) Schematic of separation process after interconnection with Al-foil [1]; b) Example of possible sub-cells separation design.

Methodology and Approach

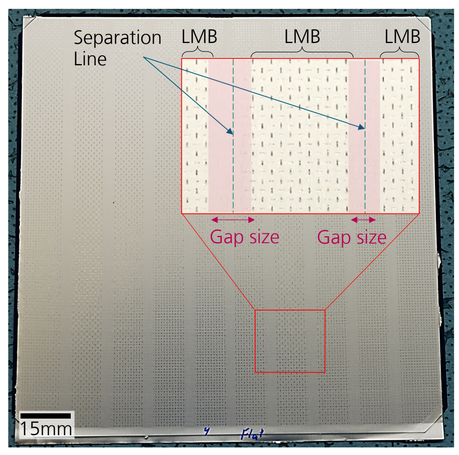
1. Al-foil thicknesses: 9 µm and 12 µm
2. Al-foil to wafer attachment by LMB
3. Spatial freedom increase by varying
   1. Gap size* between LMB
      *Area without LMB



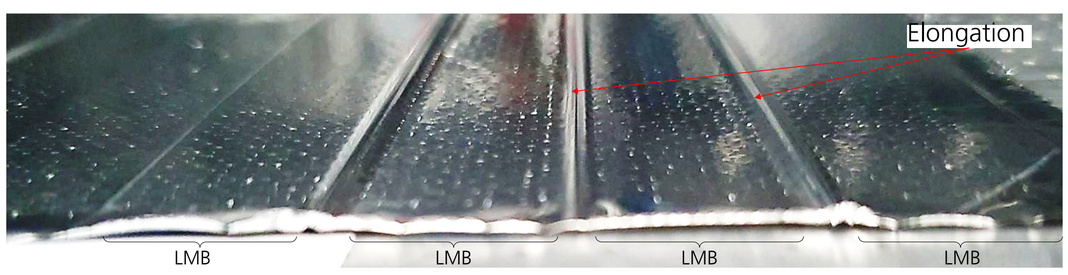
   2. Elongation length to Al-foil



4. Thermal Laser Separation

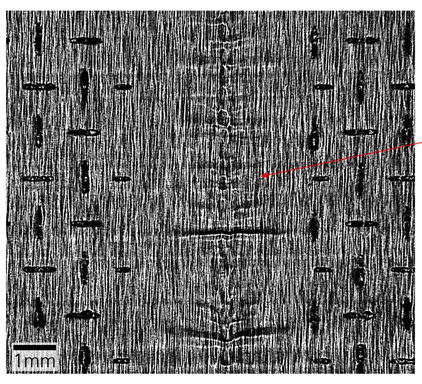


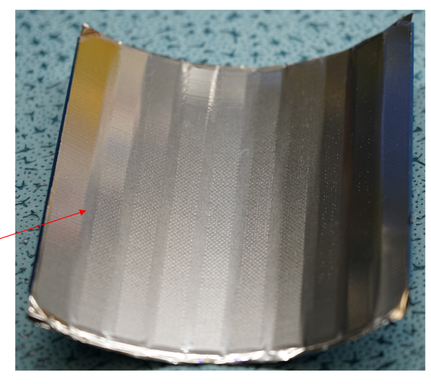
Rear side of sample. The Al-foil is attached to the wafer by LMB, and the space in-between groups of LMB is varied (gap size).



Photograph of rear side of sample with varied elongation lengths before separation.

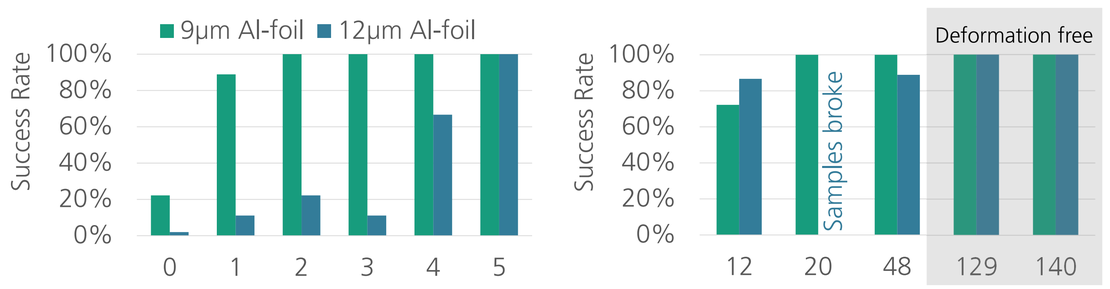
Results





Observable deformation and curvature in Al-foil due lack of spatial freedom.

- Cells need to move and mechanically separate during TLS
- Lack of spatial freedom leads to:
  - Al-foil deformation
  - Sub-cells string curvature due foil relaxation after TLS
- Sufficient spatial freedom eliminates these effects



Success rate of TLS process on sub-cells pre-interconnected by Al-foil. a) Varied gap size; b) Varied elongation length; Shaded area) No observable deformation in samples.

- Experimental dataset (9 separation lines for each variation)
  - 108 separation lines with varied gap size
  - 90 separation lines with varied elongation length
  - Filtered out broken samples
- Elongation lengths ≤ 48 µm show deformation and curvature due lack of spatial freedom during relaxation
- Elongation lengths ≥ 129 µm allow for reliable separation and are deformation free for both Al-foils thicknesses

Summary

- Proposed an approach for separating sub-cells interconnected with Al-foil before separation by means of Thermal Laser Separation
- Varied spatial freedom by manipulating gap size and elongation length of Al-foil
- Elongations ≤ 48 µm show deformation and curvature in samples
- Elongations ≥ 129 µm are deformation free and allow reliable separation

Link to Fraunhofer ISE contributions of the 40th EU PVSEC, available as of 20.09.2023

Contact the authors!

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[1] J. Paschen et al., "*Eliminating the Need for Handling Individual Sub-Cells for Small Appliance PV Modules with Voltage Demands Above 12V*", 2023 IEEE 50th Photovoltaic Specialists Conference (PVSC), 2023.
[2] J. Paschen et al., "*FoilMet ® -Interconnect: Busbarless, electrically conductive adhesive-free, and solder-free aluminum interconnection for modules with shingled solar cells*", Progress in Photovoltaics, vol. 30, no. 8, pp. 889–898, 2022.
[3] O. John et al., "*Laser Metal Bonding (LMB) - low impact joining of thin aluminum foil to silicon and silicon nitride surfaces*", Procedia CIRP, vol. 94, pp. 863–868, 2020.
[4] P. Baliozian et al., "*Thermal laser separation of PERC and SHJ solar cells*", IEEE Journal of Photovoltaics, vol. 11, no. 2, 2021.