Lifespan optimization and quantification of bonds on thin-film solar modules

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Introduction, problem statement and objectives

The research group Energy Systems Engineering (ESE), led by prof. dr. ir. Michaël Daenen, is part of imo-imomec, an affiliated lab of imec and located at EnergyVille 2. ESE examines the reliability of photovoltaic (PV) systems. One of focal points of the research group is the research into thin-film solar (TFPV) modules, these are interesting for building-integrated photovoltaics (BIPV). Since the combination of TFPV with BIPV is still in research phase, there are still some reliability problems. One of these reliability problems is the lifespan of the connection between the solar cells and the conductor to the junction box. The main goal of this master's thesis is to find the most efficient and reliable bonding technique to maximize the lifespan of the electrical connections on TFPV modules. Besides, the losses due to contact resistance between TFPV and conductor should be minimized.

Materials

- Two different substrate materials: Mo and $MoSe_2$.
- Bonds made on molybdenum back contact layer serve as reference level.
- Bonds made on $MoSe_2$ is real situation.
- $MoSe_2$-layer grown as result of the deposition of the CIGS absorption layer.
- Disadvantage of the $MoSe_2$-layer is the extra ohmic resistance.
- $MoSe_2$-substrates created via removing CIGS-layer with mechanical tool.

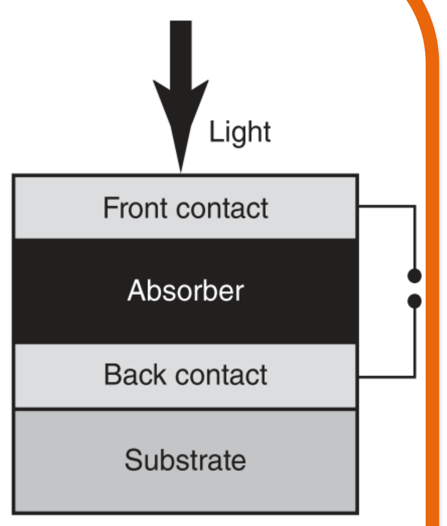

Fig 1.: TFPV Layer sequence [1, p. 20]

Characterization

- Accelerated degradation via thermal cycling and damp heat tests based on the IEC 61646 norm.
- Characterization via determining the contact resistance using the transmission line model (TLM).
- Cross section images with scanning electron microscope for visual inspection.

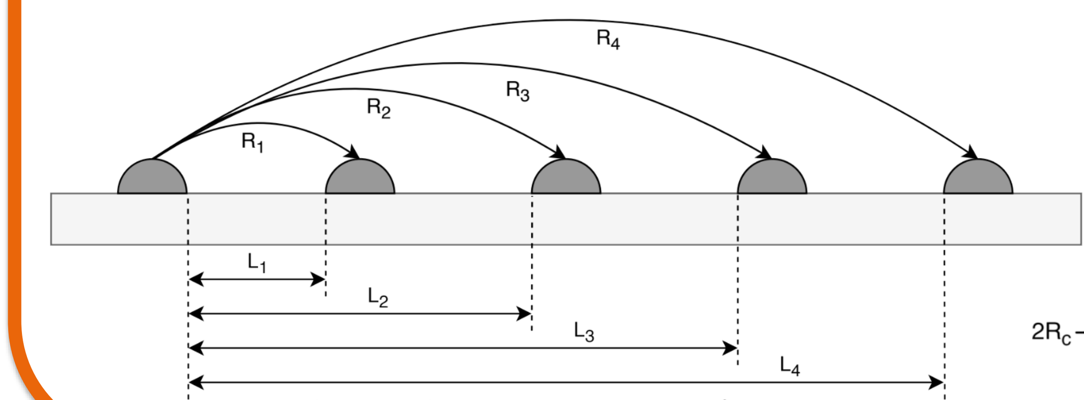

Fig. 2: Resistance measurements for TLM

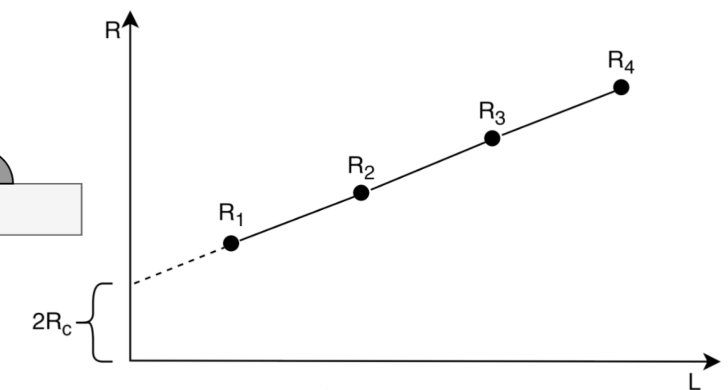

Fig. 3: R_c-determination via TLM

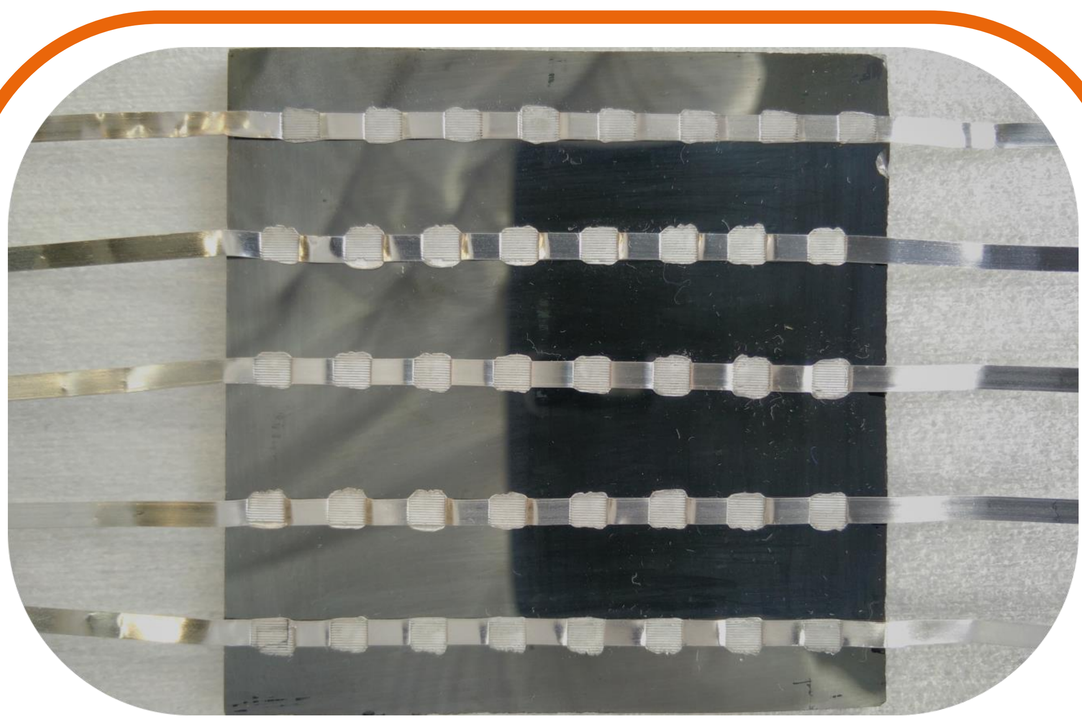

Fig. 4: $MoSe_2$-sample with ultrasonic welds

Ultrasonic welding

Ultrasonic welding (USW) creates bonds by pressing the ribbon and substrate against each other between an anvil and a welding tool. The welding tool transmits ultrasonic vibrations to the bond. The combination of pressure and ultrasonic vibrations results in a weld. Pressure, amplitude and energy can be changed depending on used materials. The ultrasonic frequency is 35 kHz. Each ribbon is welded on 8 spots as shown in Fig. 4.

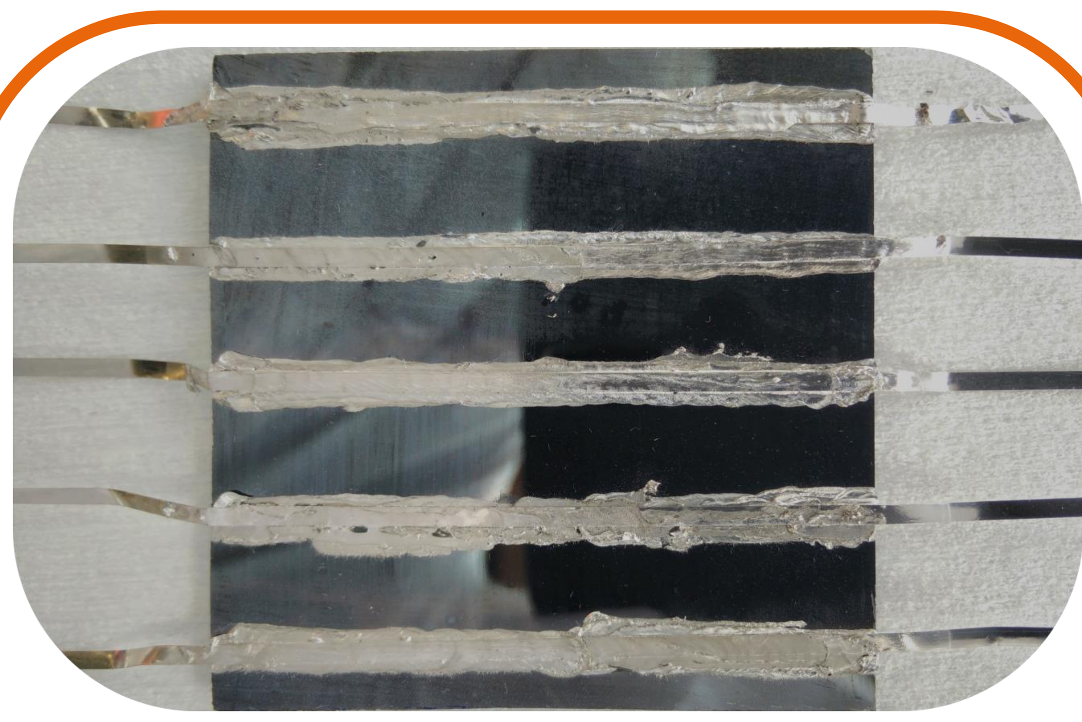

Fig. 5: $MoSe_2$-sample with ultrasonic soldering technique

Ultrasonic soldering

Ultrasonic soldering (USS) uses a flux less solder but uses ultrasonic vibrations instead. The vibrations are transferred via the tool tip to the molten solder and causes cavitation in the solder. The energy from the bursting cavitation bubbles removes the oxide layer from the substrate and forces the solder into crevices and micropores of the substrate [2, 3]. Temperature and ultrasonic energy can be changed to optimize the bonds. Fig. 5 shows a $MoSe_2$ sample with USS.

Fig. 6: $MoSe_2$-samples with 3M 1181 (left) and 3M 1245 (right)

Electrically conductive tapes

3M 1181 uses a conductive adhesive. To create conductivity in the adhesive, there are metal particles in the adhesive to make a connection between the substrate and copper foil.
3M 1245 has a non-conductive adhesive but a groove pattern. The grooves presses through the adhesive to make a metal-to-metal contact to create conductivity between substrate and copper foil. A laminator is used to apply the tapes and create uniform samples.

Results

- Bonds made on $MoSe_2$ have higher contact resistances than Mo
- Contact resistances from both tapes are about thousand times higher than contact resistances from USS and USW
- No significant degradation due to thermal cycling
- Substrate degradation perceived due to damp heat stressing on USS and ECT substrates
- Contact resistivity of USS bonds increased 3,4 times harder than USW bonds after 492 hours damp heat exposure
- Longest TFPV lifespan expected with USW bonds

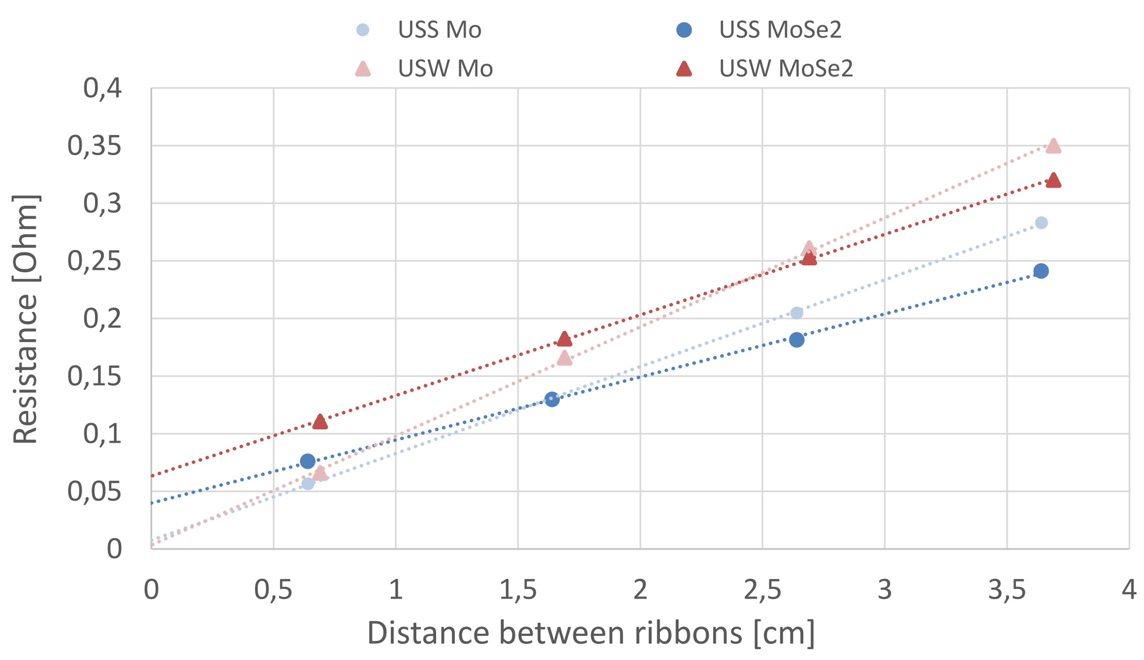

Fig. 7: Initial contact resistance comparison between USS and USW on Mo and $MoSe_2$

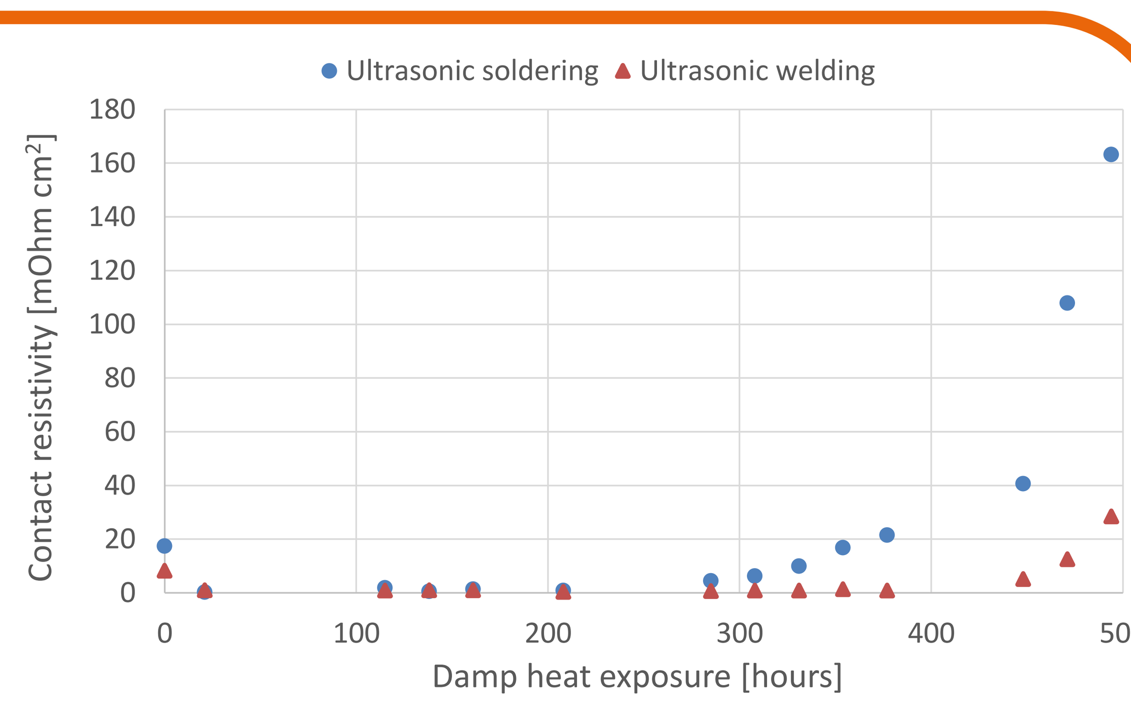

Fig. 8: Contact resistivity evolution $MoSe_2$ samples due to damp heat stress testing

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References

[1] D. Abou-Ras, T. Kirchartz, and U. Rau, Eds., *Advanced Characterization Techniques for Thin Film Solar Cells*, 2nd ed. Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA, 2016.

[2] K. Graff, 'Macrosonics in industry: Ultrasonic soldering', *Ultrasonics*, vol. 15, no. 2, pp. 75–81, Mar. 1977.

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