Investigation of Temperature Homogeneity during Infrared Soldering of Silicon Solar Cells using the Finite Element Method

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Motivation

- In PV industry, automated stringer machines are primarily used for series interconnection of solar cells by an industrial soldering processes utilizing infrared (IR) radiation [1]
- Inhomogeneous heating leads to higher temperatures at solar cell center compared to their edges, resulting in overheating and cell damage at center of solar cell [2]
- Precise temperature control during soldering required for optimized processing of high-efficiency cells, ensuring homogeneous interconnections and high-quality solder joints [3,4]
- **Aim of this work:** Development of finite element method (**FEM**) model to compute **temperature distribution** on industrial silicon solar cells during **IR soldering in an industrial stringer**

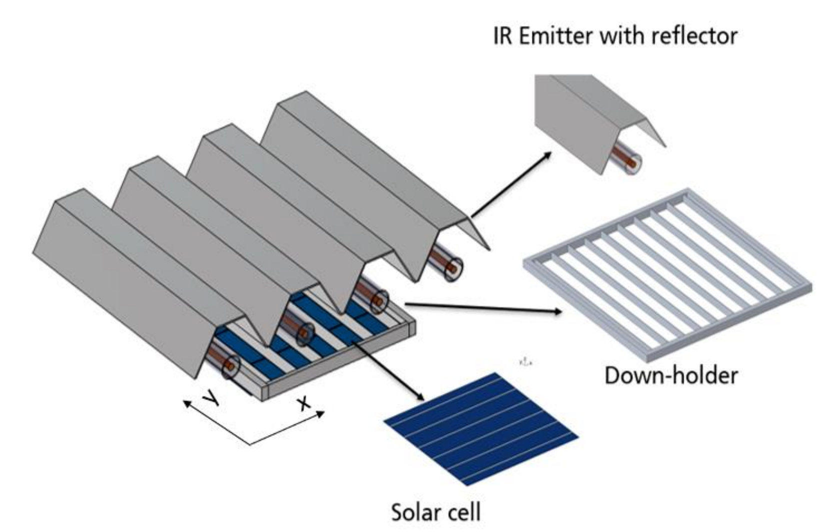

Fig. 1: CAD model of a silicon solar cell and the down-holder under four IR emitters with reflector.

Method

- FEM model with M6 PERC half cell with 6BB & round wire interconnection
- Computation of entire IR soldering process using radiative heat transfer physics between IR emitters and solar cell

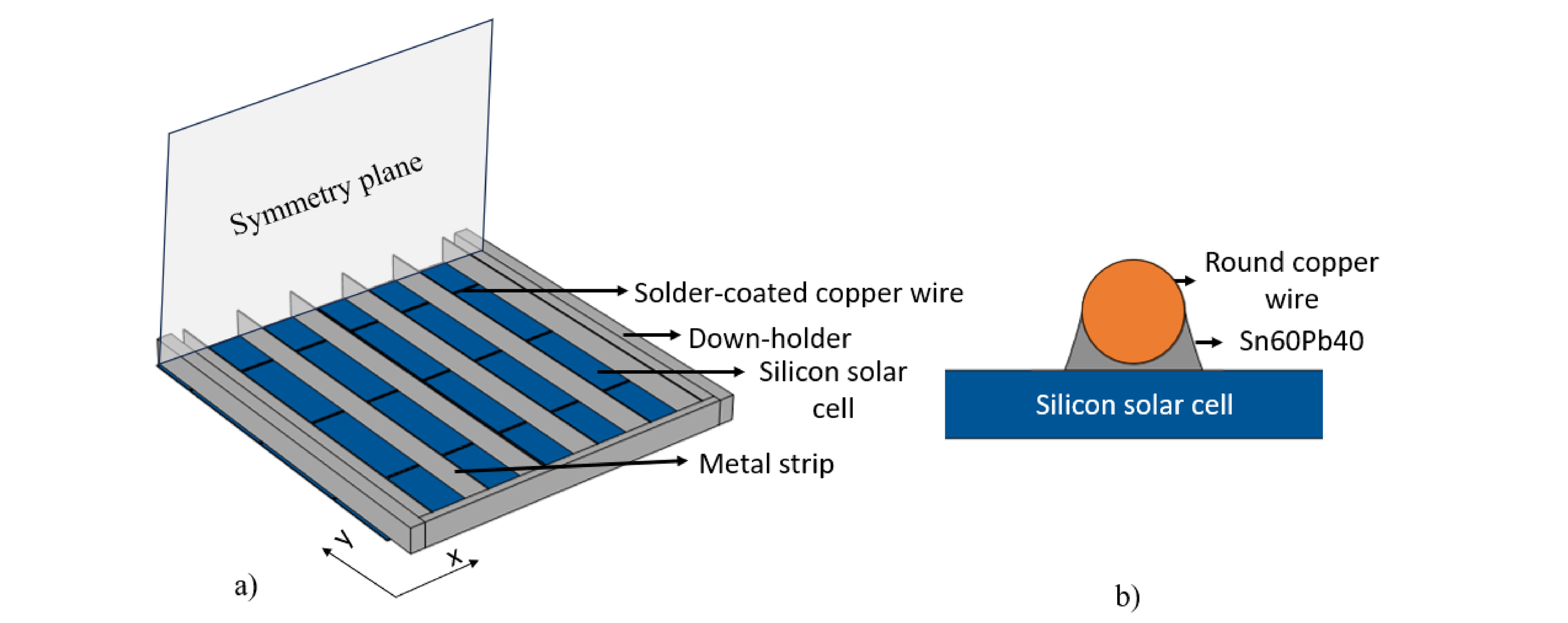

Fig. 2: a) Symmetric geometry of the silicon solar half cell with solder-coated copper wire (ribbon) and the down-holder. b) Geometry of the copper wire, solder alloy and the silicon solar cell.

- Industrial stringer with four IR emitters & hotplates below transport bands
- Two radiation pulses are emitted : Step 1 - Pulse from IR emitter 1 and 2; Step 2 – Pulse from IR emitter 2, 3 and 4
- Power to all four IR emitters P_{IR} = 60 % of 1250 W; duration of each radiation pulse t_{IR} = 1.2 s

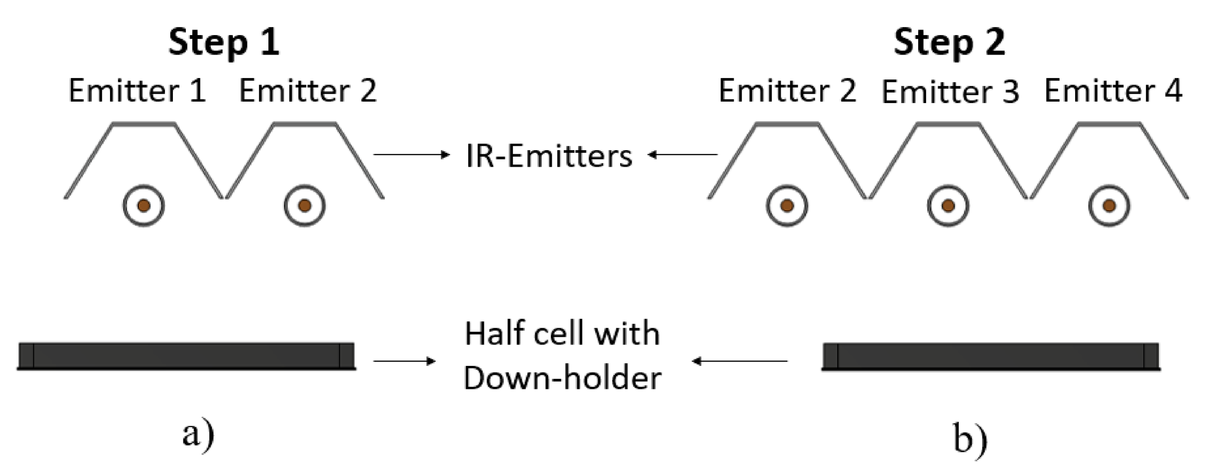

Fig. 3: Geometrical setup of FEM simulation during step 1 (a) and step 2 (b).

Results and Validation

- Si solar cell reach maximum temperature of T_{max} = 234 °C at center and T_{max} = 204 °C at the edges
- FEM model is validated using M6 PERC half cells contacted with three thermocouples attached to down-holder in the stringer
- Maximum temperature difference ΔT_C between measured values and FEM result is ΔT_C **= (8 ± 4) K**
- **Reason for inhomogeneity** : (a) Shading of radiation because of the down-holder; (b) Radial heating in x-direction; (c) Inhomogeneity of IR emitters in y-direction

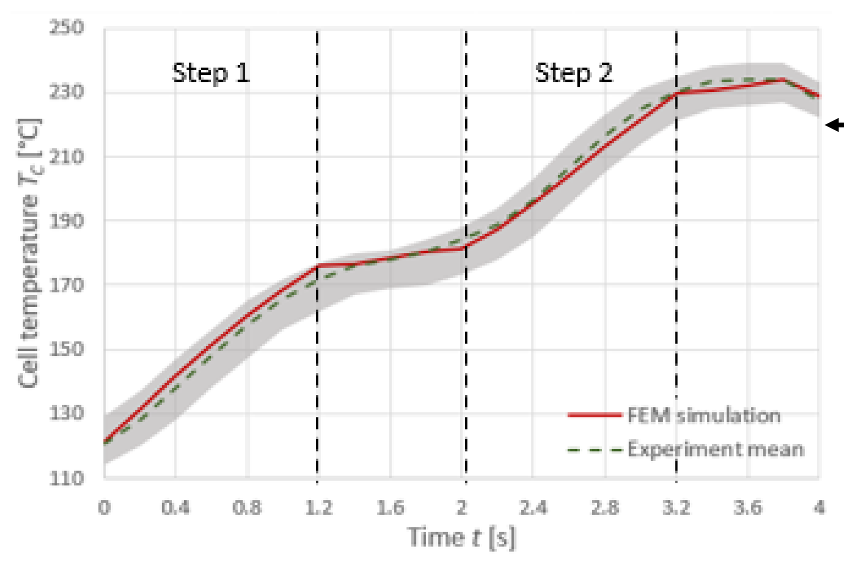

Fig. 4: Comparison of solar cell temperature from simulation (red) and experiment (gray). Gray area: min./max. band of N = 5 repetitions. Dashed lines: mean of measured values.

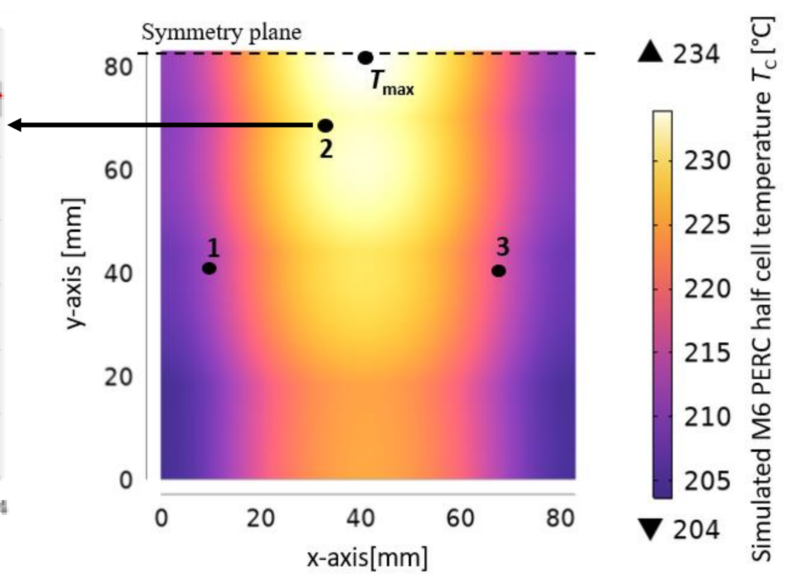

Fig. 5: Simulated temperature distribution on solar cell at t = 3.8 s measured at thermocouple position 1, 2 and 3.

Table 1: Comparison of measured and simulated solar cell temperature at positions x_i / y_i (cf. Fig. 5) for thermocouple i with i = 1, 2, 3.

Thermocouple i	$T_{C,Measured}$ [°C]	$T_{C,FEM}$ [°C]	ΔT_C [K]
1	203	208	5
2	234	232	2
3	218	210	8

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Summary

- FEM model to compute temperature distribution with max. temperature difference of (8 ± 4) K on industrial Si solar cells during IR soldering in industrial stringer
- FEM model is versatile & can be easily adapted to new solar cell technologies, such as TOPCon and SHJ, as well as various solar cell sizes and geometries
- FEM model allows for optimized IR soldering by reduced temperature inhomogeneity, identifying optimal process parameters & improving design of IR emitters in industrial stringers

1. T. Dullweber and L. Tous, Silicon Solar Cell Metallization and Module Technology: Institution of Engineering and Technology, 2021.
2. A. De Rose, C. Rosado Alberdi, A. Kraft, "Influence of IR Soldering Profile on Industrial Silicon Heterojunction Solar Cells", 8th World Conference on Photovoltaics, p. 536-540, 2022, DOI: 10.4229/WCPEC-82022-3CO.4.3
3. A. J. Beinert, P. Romer, M. Heinrich, J. Aktaa, and H. Neuhaus, "Thermomechanical design rules for photovoltaic modules," *Progress in Photovoltaics*, vol. 31, no. 12, pp. 1181–1193, 2023, DOI: 10.1002/pip.3624.
4. M. Hertl, D. Weidmann, and J.-C. Lecomte, *Microelectronics and Packaging Conference, 2009. EMPC 2009. European*, 2009.

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