Optimization of Infrared Soldering Process to Reduce the Temperature Inhomogeneity in Silicon Solar Cells using Finite Element Methods

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Motivation

- Precise heating of solar cells during the industrial infrared (IR) soldering process is critical for new solar cell technologies to prevent overheating and cell damage [1,2,3]
- Experimentally measured temperature inhomogeneity for an industrial IR soldering process exceeds 40 K for Silicon Heterojunction (SHJ) solar cells
- Previous simulation work reduced the temperature inhomogeneity to 27 K for SHJ half-cells using two radiation pulses from the four pre-heating IR emitters in an industrial stringer [4]
- **Aim of this work:** Optimize the infrared soldering process to minimize the temperature distribution inhomogeneity to $T_C < 20$ K on the half solar cell with optimum resources using a finite element method (FEM) model

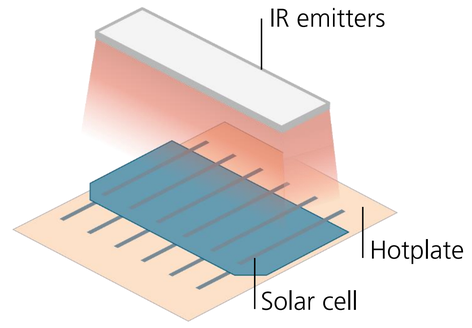

Fig. 1: IR emitters heating the solar cell during the IR soldering process.

Method

- Experimentally validated FEM model adapted from our previous work that computes the radiative heat transfer for entire IR soldering process including the influence of hotplate [4]
- Single radiation pulse from three IR emitters is sufficient to achieve the required temperature on a half-cell
- Radiation pulse duration (t_{IR}) and the power of the IR emitter (P_{IR}) are systematically varied to determine the temperature inhomogeneity
- Two different sizes of Silicon Heterojunction (SHJ) half solar cells are used: M6 with six busbars and M10 with ten busbars

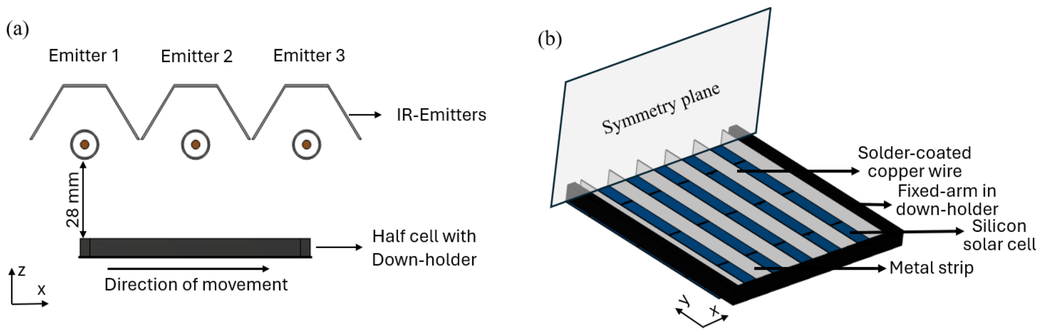

Fig. 2: (a) Half-cell with down-holder positioned centrally beneath the three IR emitters during IR soldering, not to scale. (b) Modelled symmetric geometry used in the FEM simulation [4].

- Industrial IR soldering process heats the solar cells with a radiation pulse duration of 1.2 to 1.3 seconds

Fig. 3: Simulated maximum (red) and minimum (blue) solar cell temperature T_C of SHJ M6 half-cell with the industrial process radiation pulse duration t_{IR} = 1.2 s.

- Temperature slightly increases after the IR radiation pulse as IR emitters continue to emit radiation at threshold power (≈ 30%)
- Inhomogeneity is measured at the peak maximum temperature (t = 2 s), as shown in the figure

Results

- Shorter radiation pulse duration helps in decreasing the inhomogeneity
- Radiation pulse duration t_{IR} = 1 s is determined to be sufficient to heat the solar cells
- Optimized power of the IR emitters 1, 2 and 3 for both M6 and M10 SHJ half-cells to achieve low inhomogeneity:

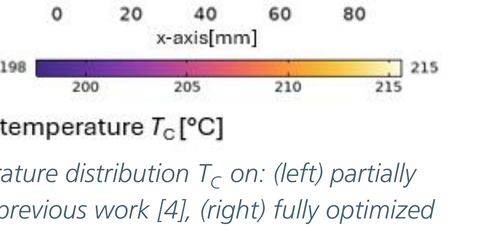

Table 1: Simulated temperature T_C for SHJ half-cell for a radiation pulse duration t_{IR} = 1 s measured at peak T_{C_Max}. (t = 2 s).

Solar cell size	Peak $T_{C\_Max.}$ (°C)	Peak $T_{C\_Min.}$ (°C)	ΔT_C (K)
M6 half-cell	215	198	17
M10 half-cell	214	199	15

Fig. 4: M6 SHJ half-cell simulated temperature distribution T_C on: (left) partially optimized with 27 K inhomogeneity from previous work [4], (right) fully optimized M6 SHJ half-cell with 17 K inhomogeneity.

- **Reasons for inhomogeneity on the edges**: (a) shading of radiation because of the down-holder (b) inhomogeneity of IR emitters in y direction

Summary

- FEM model is precisely developed using the influential process parameters: radiation pulse duration (t_{IR}) and the power of the IR emitter (P_{IR})
- Optimum process parameters have been identified to reduce the inhomogeneity on M6 and M10 SHJ half solar cells
- Inhomogeneity has been reduced from more than 40 K (measured for industrial IR soldering process) to 17 K and 15 K on M6 and M10 SHJ half cells, respectively
- Easy to adapt to new solar cell sizes and technologies

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