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Thermomechanical Stress in Glass-Glass Modules of Half Silicon Solar Cells Interconnected by Conventional Tabbing

Pei-Chieh Hsiao[1], Zhimeng Wang[1], Ning Song[1], Yang Li[1], Zi Ouyang[1], Chen Zhu[2], Jun Lv[1,2,4], Canjun Shen[2], Cheng Chen[2], Guoqing Chen[2], Xueqing Zhang[3], and Alison Lennon[1]

[1] School of Photovoltaics and Renewable Energy Engineering, UNSW, Sydney, Australia, 2033
[2] LONGi Solar Technology Co., Ltd, Xi'an, China, 710018
[3] Hebei Sizhuo Photovoltaic Technology Co., Ltd, Shijiazhuang, Hebei, China, 050051
[4] Electronic Information Engineering College of Sanjiang University, Nanjing, China, 210012
E-mail: p.hsiao@unsw.edu.au

Owing to the mismatch of coefficient of thermal expansion (CTE) between Si and Cu, thermomechanical stress is induced in Si solar cells in thermal processes such as cell interconnection and module lamination. During interconnection over 200 MPa tensile stress in Si [1, 2] predicted by finite element modelling (FEM) may suggest high likelihood of crack formation in the solar cells. On the contrary, compressive stress was generally analysed [3] when using FEM to simulate the lamination process since glass has greater CTE than Si. In this report, the integrated stress evolution in Si was investigated by FEM when Si half cells were interconnected by conventional tabbing and subsequently laminated into glass-glass modules.

The material properties were obtained from the literature. Mono-crystalline Si was modelled as an anisotropic material with a temperature-dependent CTE. Glass was modelled as a linear elastic material. A bilinear elastoplastic model was applied to Cu ribbon, solder and screen-printed Ag. An elastoplastic material yields when the stress is larger than its yield strength. It means that the material undergoes plastic (permanent) deformation and the stress increases slower in the plastic region. The viscoelastic behaviour of encapsulant EVA was modelled using an equivalent static model with modified temperature-dependent Young's modulus.

The model was based on a 2D geometry with three interconnected half cells. The cell gap was 2 mm and the thickness of glass, EVA, Cu ribbon, Si was 2.0, 0.8, 0.2 and 0.18 mm, respectively. The front and ribbons were connected to Si via front busbar and rear Ag pads, whose lengths were different and shorter than the Si length. Therefore, the front and rear bonding endpoints were misaligned.

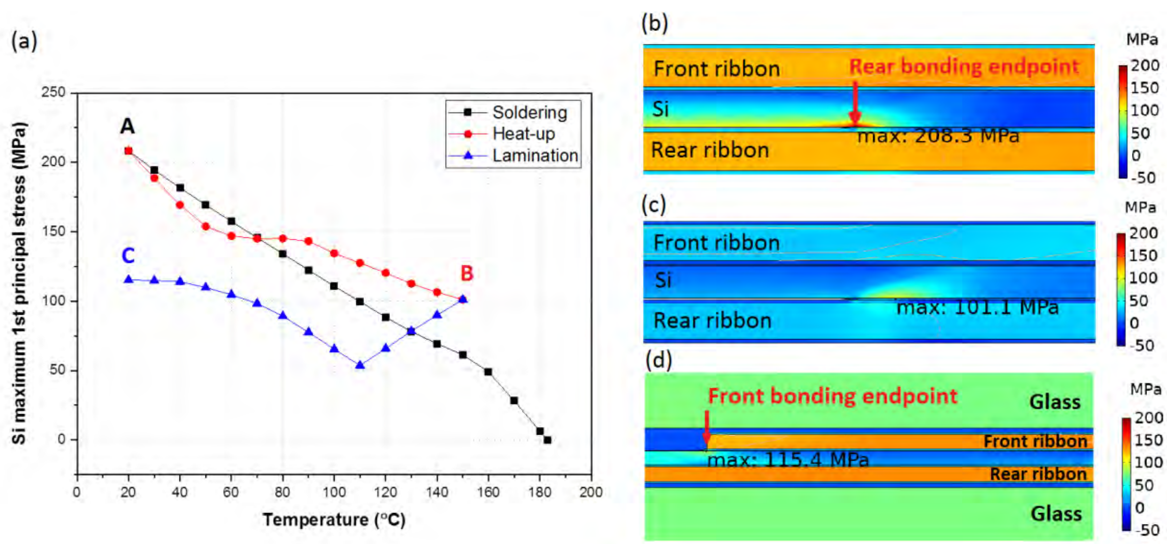


Figure 1(a) shows the evolution of 1st principal (tensile) stress in Si undergone soldering (black curve), laminate heat-up (red curve) and glass-glass module lamination (blue curve). During soldering the Si tensile stress increases approximately linear with decreased temperature. At 20 °C the maximum stress is 208 MPa located at the rear bonding endpoint [see

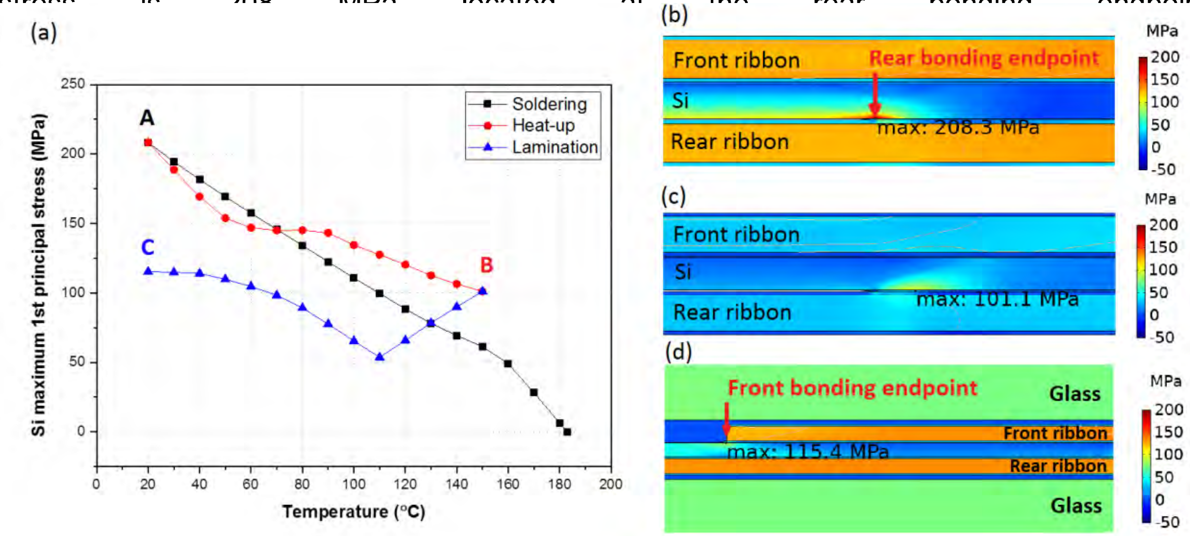


Figure 1(b)]. In the heat-up process, the decrease of Si tensile stress is not linear because the maximum stress point shifts toward the cell centre [see

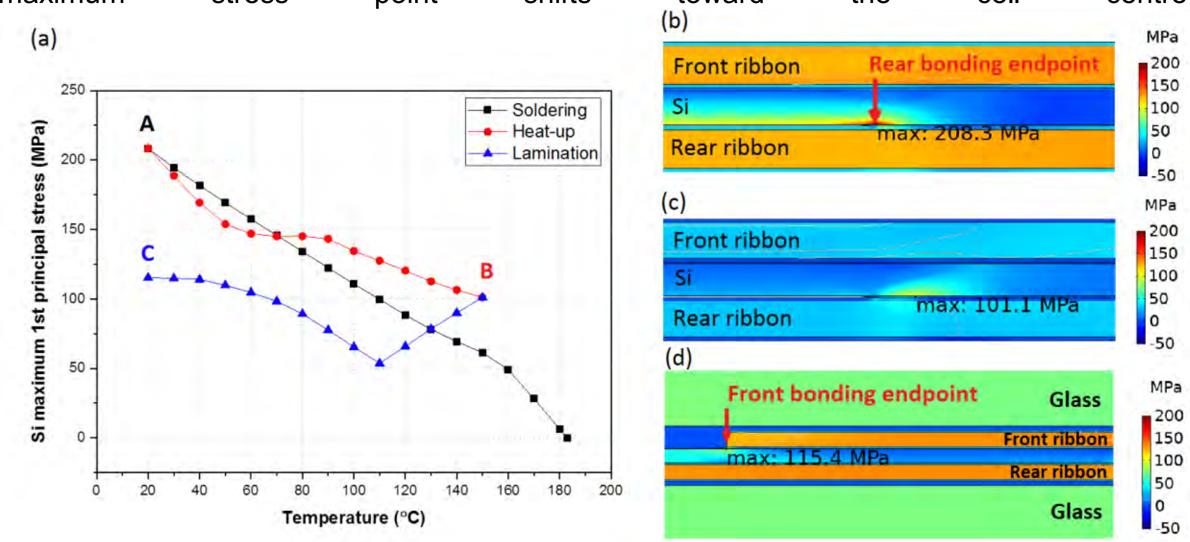
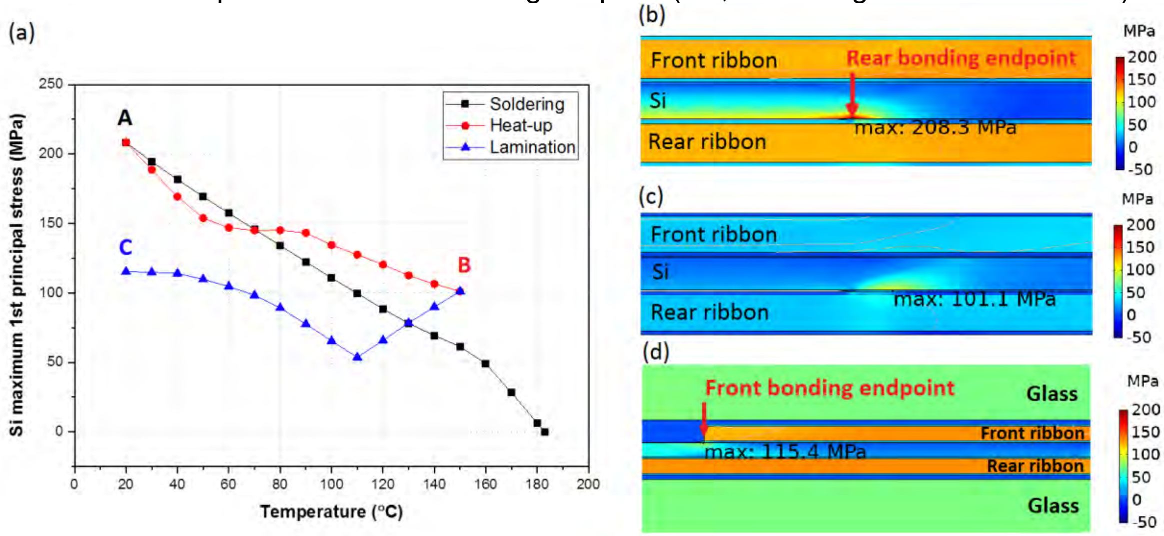


Figure 1(c)]. During the initial lamination cooling from 150 °C to 110 °C, the maximum tensile stress decreases as the glass compression counteracts the solder-induced tensile stress. Within this temperature range, the maximum stress remains at the rear bonding endpoint. With further decrease in temperature, the maximum tensile stress starts to increase, which is attributed to the transition of the maximum stress point to the front bonding endpoint (i.e., at the edge of front Cu ribbon). As shown



in Figure 1(d), Si tensile stress is 115 MPa when module temperature is 20 °C, which is significantly lower than after soldering.

The evolution of von mises stress in Cu ribbons is plotted in Figure 2(a). During the soldering process, Cu ribbons undergo firstly the elastic regions, followed by the plastic regions, resulting in a bilinear stress-temperature response. At 20 °C the maximum von mises stress of 204 MPa occurs in the front ribbon at the front bonding endpoint. When the interconnected cells were heated up, the plastic strain was unchanged. Due to the interaction from EVA and glass in lamination cooling, the maximum von mises stress transits to the cell gap regions, locating at the bended regions near the maximum curvature with a 66 MPa stress increment from after soldering.

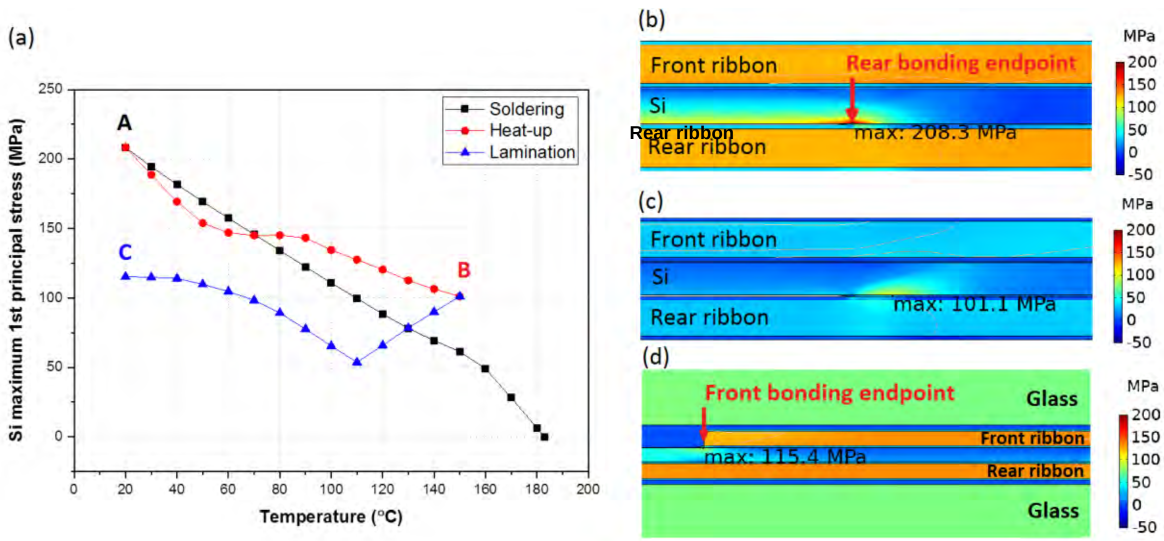


Figure 1. (a) Simulated 1st principal (tensile) stress in Si after soldering (black), heat-up (red) and lamination (blue); (b) stress mapping at 20 °C after soldering (point A on graph(a)); (c) stress mapping at 150 °C after heat-up (point B on graph(a)); and (d) stress mapping at 20 °C after lamination (point C on graph(a)).

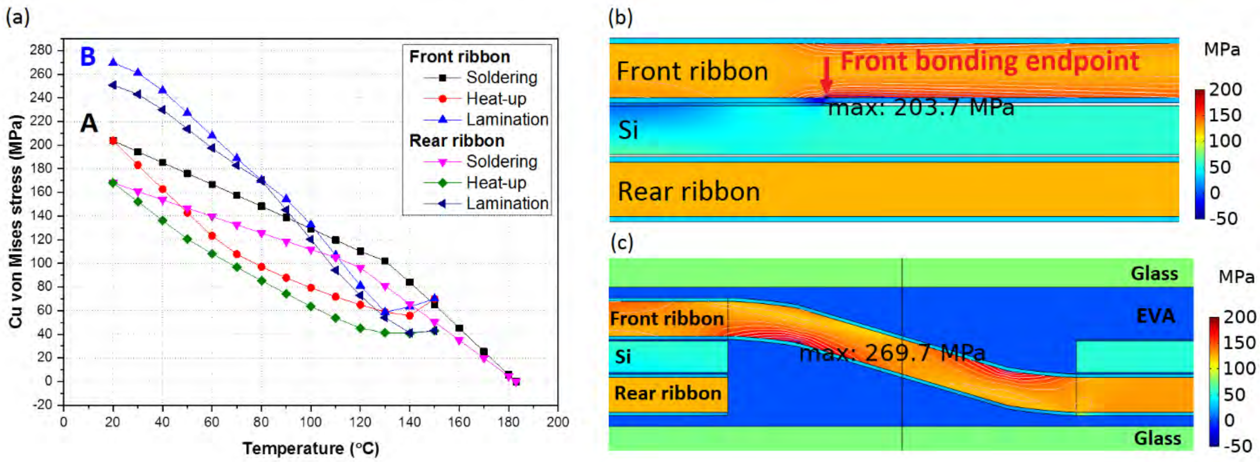


Figure 2. (a) Simulated von mises stress in Cu ribbons after soldering, heat-up and lamination; (b) stress mapping at 20 °C after soldering (point A on graph(a)); and (c) stress mapping at 20 °C after lamination (point B on graph(a)).

References

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