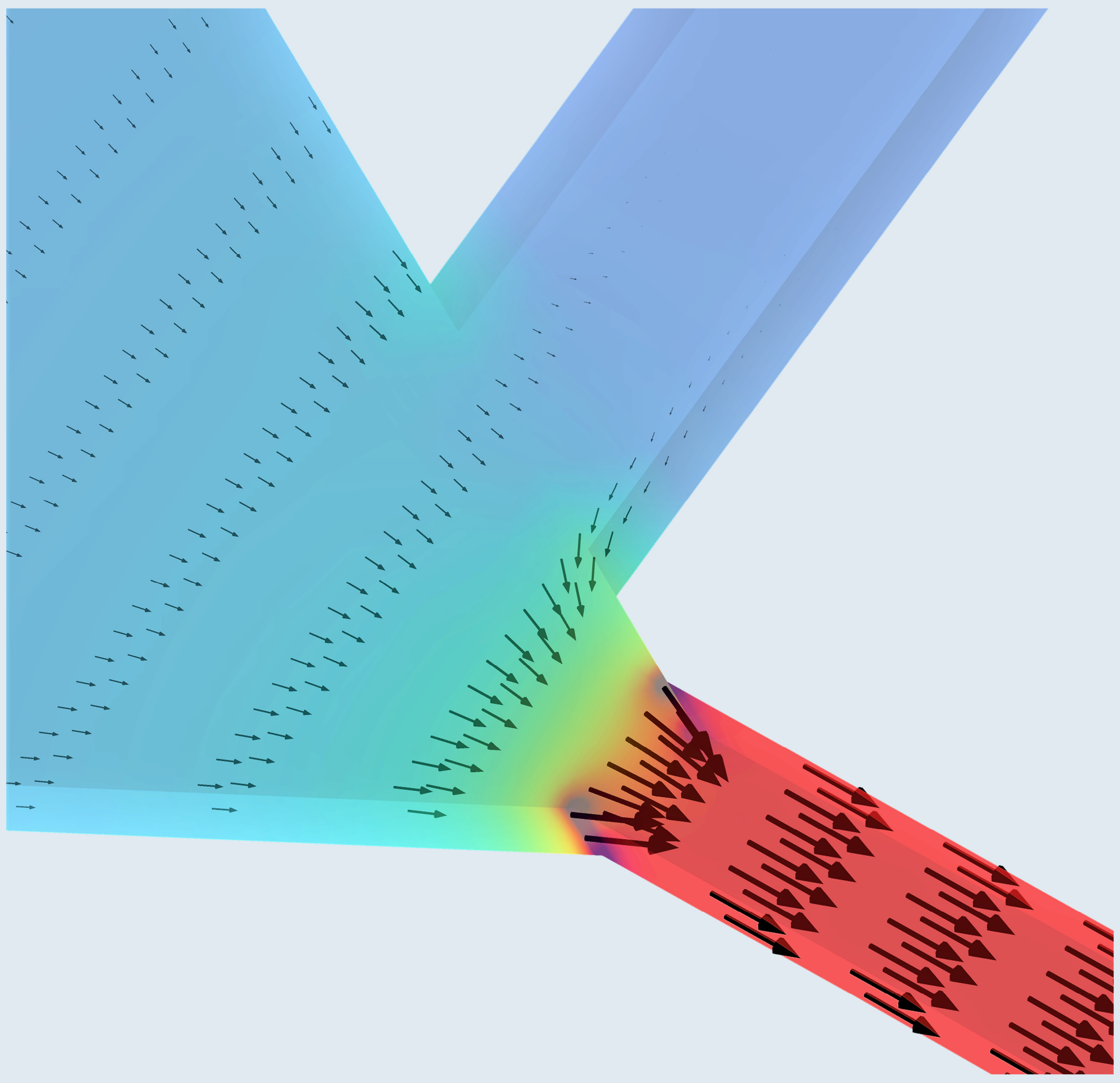

Investigation of Electromigration in Fine-Pitch Copper Interconnects Through Simulation and Analysis

Understanding the primary factors on electromigration lifetime of electrical systems and implementing design optimization strategies for enhancing interconnect reliability and performance.

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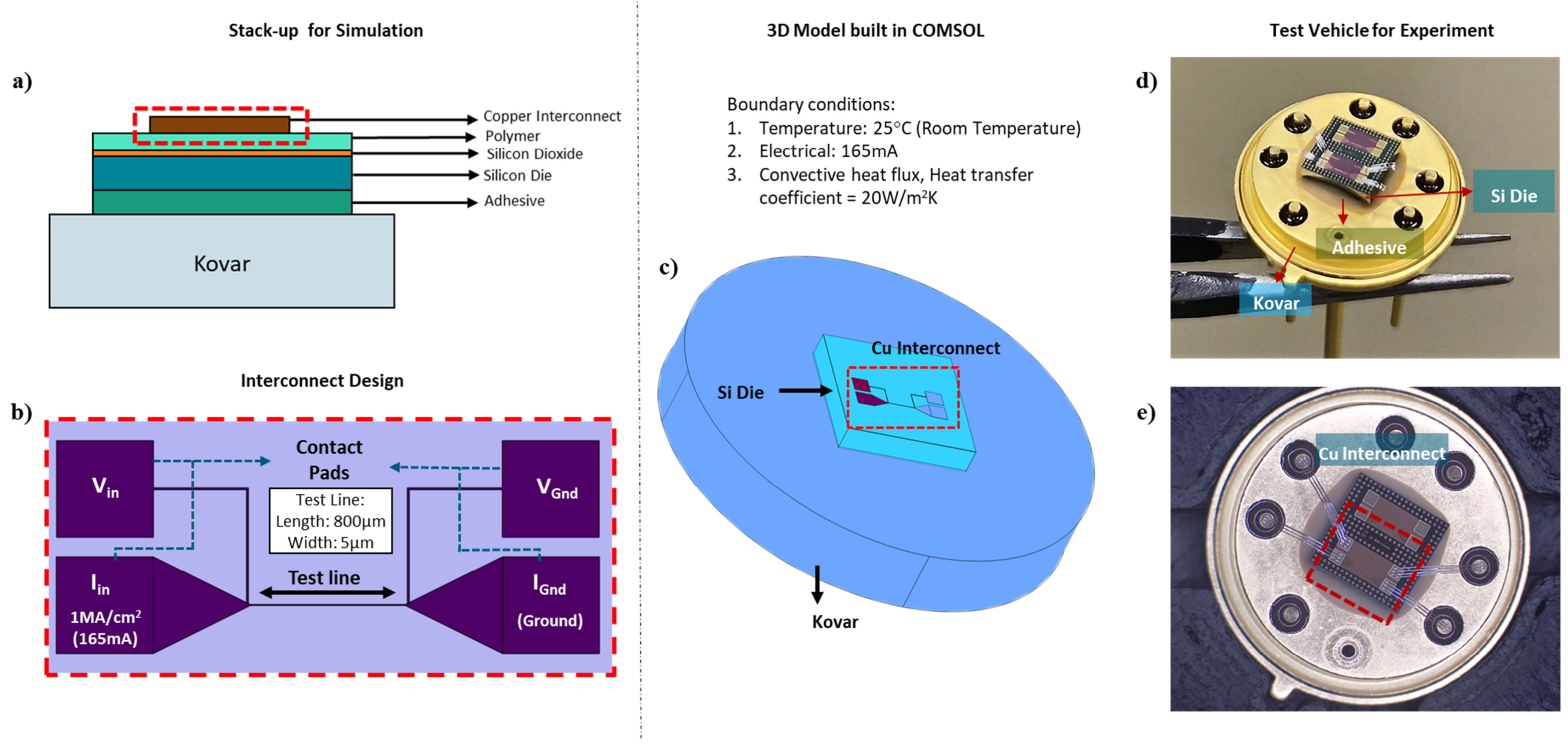
Abstract

In microelectronics, electromigration has been extensively studied in chip design for decades. However, the ongoing trend towards miniaturization has resulted in higher interconnect densities and reduced line/space (L/S) ratios, leading to smaller trace cross-sections. Consequently, it increases current density in the interconnects thereby elevating the risk of electromigration-induced failures. Joule heating and current crowding are the two major factors contributing to this problem.

Joule heating is generated when an electrical current flows through the interconnect, causing it to heat up. Current crowding results from uneven current distribution, leading to localized high current density. By managing these factors through proper design optimization, it is possible to reduce the risk of interconnect failure and improve the overall reliability of the device.(Ref. 1).



Boundary conditions:
1. Temperature: 25°C (Room Temperature)
2. Electrical: 165mA
3. Convective heat flux, Heat transfer coefficient = 20W/m²K

FIGURE 1. a) Stack-up of the test vehicle for simulation, b) Interconnect design, c) 3D model build in COMSOL® with boundary conditions, d) Side view of the test vehicle for experiment, e) Top view of the test vehicle.

Methodology

A three-dimensional (3D) model is constructed, featuring the copper interconnect and its stack-up, representing the test vehicle used in the experiment, as shown in Figure 1. The AC/DC Module is utilized to simulate temperature and current distribution, with selected boundary conditions (Figure 1 b & c). The boundary conditions used in the simulation are designed to correlate with experimental values. The results thus can be compared to the experimental data to determine accuracy and validity.

Simulation is used to investigate how polymer thickness and geometry impacts Joule heating and current crowding on the Cu interconnect.

Results

The result can be seen in Figure 2a, which demonstrates that using a thinner polymer of the same material can lead to reduced thermal resistance, decreased Joule heating, more efficient heat dissipation, and a decreased risk of localized temperature rise that can cause electromigration damage.(Ref. 2)

Additionally, an improved geometry of the test structure (Figure 2b) and incorporation of straight test line and rounded corners in the design (Figure 2c) can result in a more uniform current distribution and reduce the likelihood of hotspots. These factors can contribute to improved reliability and lifetime of the interconnect. (Ref. 3)

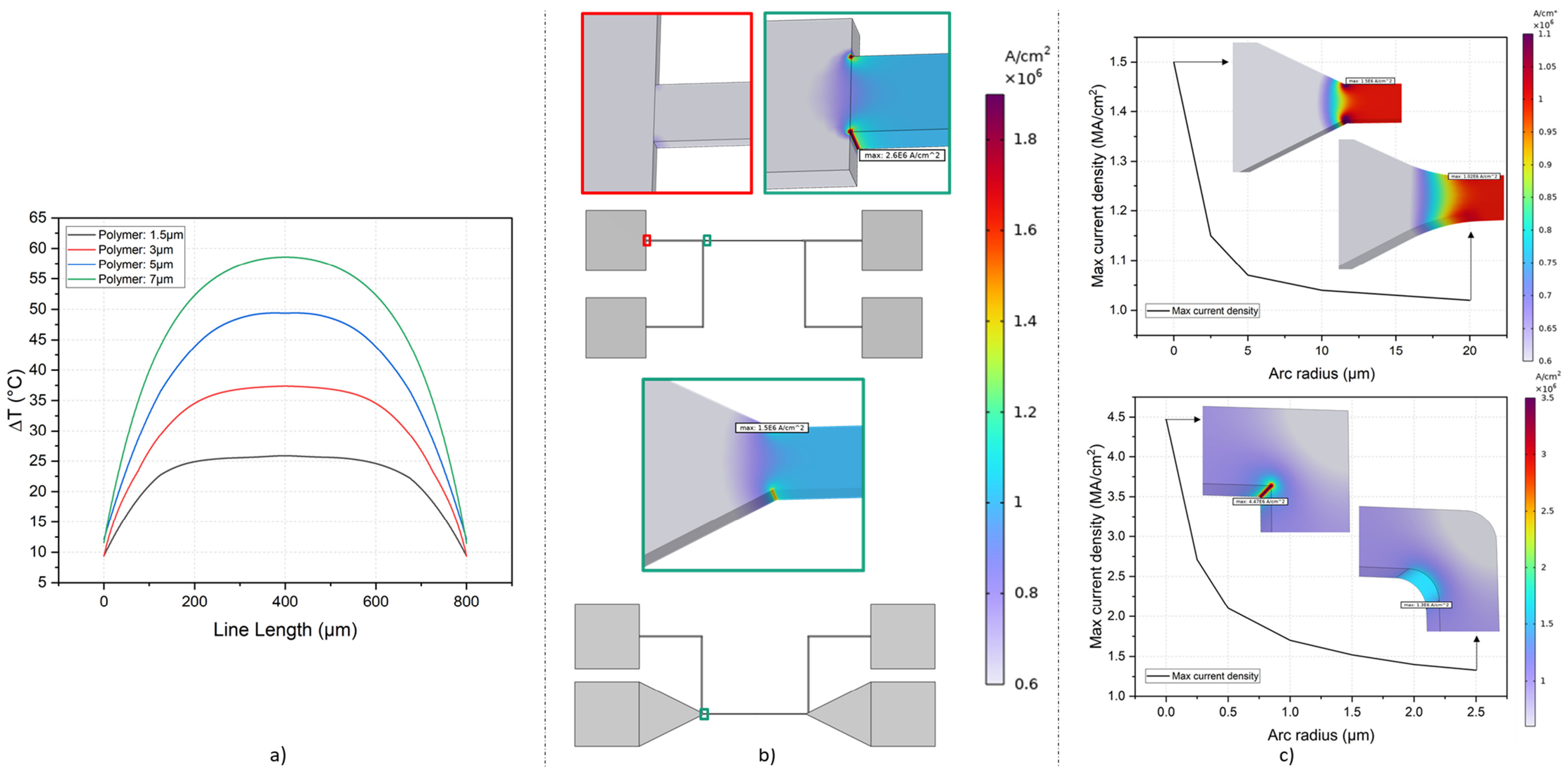


FIGURE 2. a) Influence of polymer thickness on Joule heating (ΔT), b) Comparison of (Top) NIST with (bottom) optimised design on current crowding, c) Influence of arc radius in the (top) transition area and (bottom) 90° angled line, on current density.

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