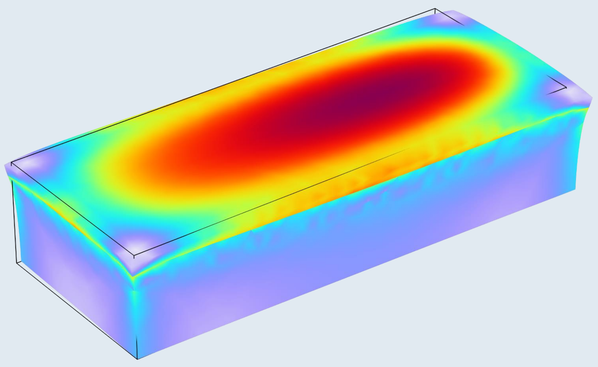


Laser Direct-Write Silver Electrode

This study carries out simulation research focusing on the mechanism of silver-electrode formation via laser-induced sintering and curing of silver paste.

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Abstract

Laser-cured nano-sliver paste represents a low-cost fabrication technique for flexible micro-nano electrodes. Transient localized heating induced by laser irradiation triggers solvent volatilization and sintering-curing of silver particles within the silver paste. In this work, a multi-physics coupling model integrating solid heat transfer, concentrated species transport, and solid mechanics is established using COMSOL. The solid heat transfer module is adopted to solve the temperature-field distribution.Mass-flux boundary conditions are applied in the concentrated-species transport interface to simulate solvent evaporation on the silver-paste surface. The computed mass fractions of silver and solvent are fed back to the thermal-physical properties within the solid heat-transfer module to achieve two-way coupling. The influences of laser power, scanning speed and silver-paste thickness on the curing behavior of silver electrodes are investigated. Meanwhile, the solid mechanics interface is incorporated, in which the temperature field from the heat-transfer module is unidirectionally coupled to solid mechanics for calculating the thermal-stress distribution of the substrate, so as to effectively predict substrate damage.

Introduction

Laser direct writing of silver electrode is an important technique for fabricating flexible conductive electrodes. In this paper, multiphysics coupling of heat transfer in solids, concentrated mass transport and solid mechanics is employed to simulate laser-direct-written silver electrodes. The results show that the silver mass fraction increases significantly, achieving sintering and curing.

Methodology

Laser heating on silver-paste surface produces solvent-evaporation mass flux J_{evap}, which raises silver mass fraction and alters the average density and thermophysical properties of the silver-paste layser. An enginerring equivalent evaporation function $f_{boil}(T)$ is used to describe temperature-dependent evaporation efficiency. A slowly-varying function wpos avoids negative J_{evap} and improves solver convergence. Regions with silver mass fraction over 90% are defined as sintered-cured silver-wire electrodes.

$$J_{\text{evap}} = \mathrm{k_t} \cdot \rho_{\text{mix}} \cdot \omega_{pos} \cdot f_{boil}(T)$$

$$f_{boil}(T) = 0.5 \cdot \left(\frac{\tanh\left(T - T_{\text{solv}}\right)}{10K}\right)$$

$$\frac{1}{\rho_{\text{mix}}} = \frac{\omega_{Ag}}{\rho_{\text{Ag}}} + \frac{\omega_{\text{solv}}}{\rho_{\text{solv}}}$$

Results

Figure 1(a) illustrates that by adjusting the laser power and scanning speed, the maximum temperature at the surface layer of the sintering temperature (500K) for high-temperature silver-paste curing. Figure1 (b) shows the sintered silver-wire electrode formed after solvent evaporation upon laser scanning over the silver-paste surface.

Figure 1(c) and (d) allow analysis of the thickness of the sintered-cured silver electrode, facilitating the investigation of the sheet resistance of silver electrodes. Therefore, the line width and sheet resistance of the sintered-cured silver-wire electrode after scanning can be controlled by tuning various laser parameters.

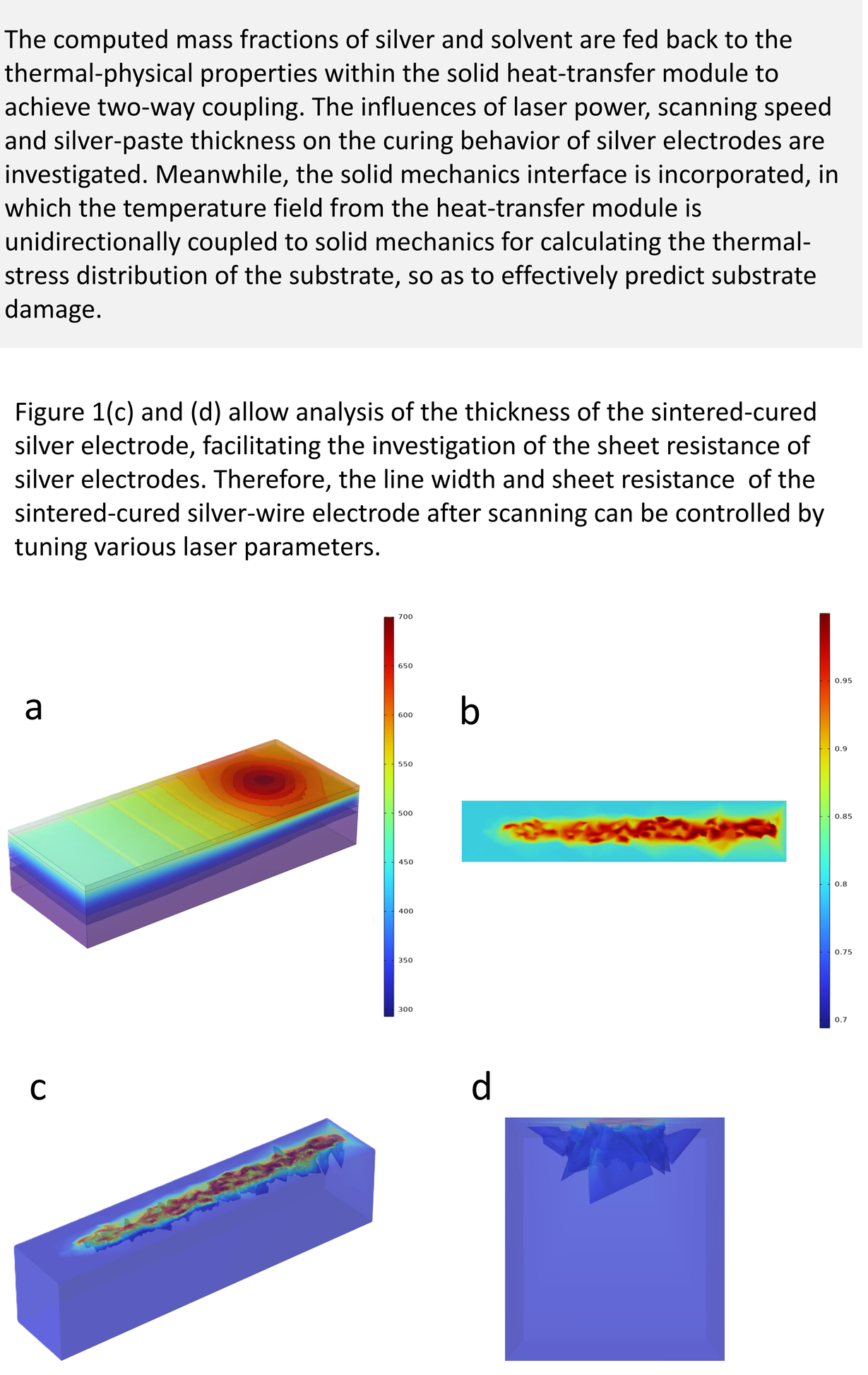


FIGURE 1. (a) Temperature field distribution after laser exposure; (b) Mass fraction of Ag after laser exposure; (c) 3D transparent view of the sintered silver electrode; (d) side view of the sintered silver electrode