Supplementary Materials

Polyethylene glycol-assisted stabilization of low-silver electrically conductive adhesives for solar cell interconnection

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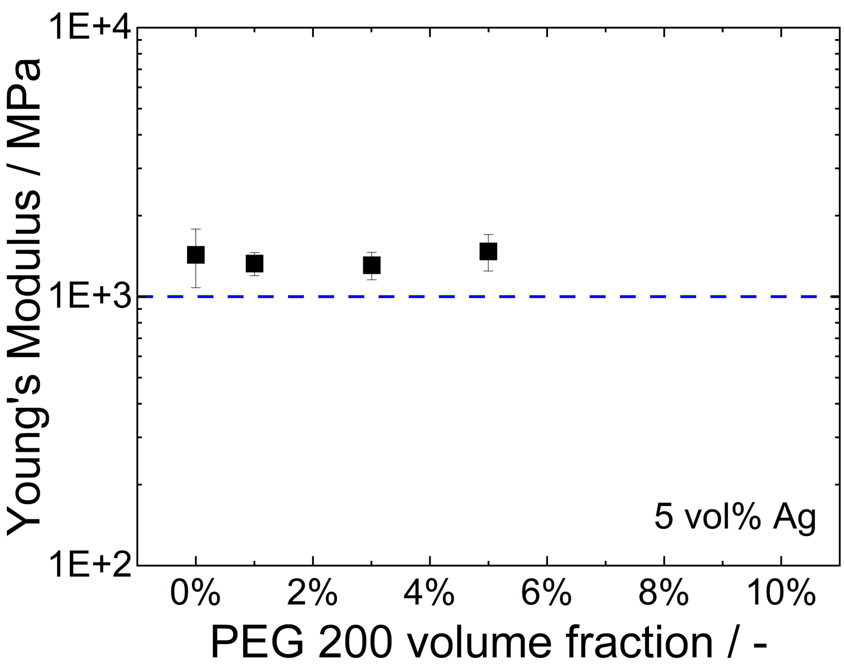

Figure S1. Young's Modulus of ECAs containing 5 vol% silver as a function of PEG 200 volume fraction. The modulus is independent of PEG 200 content and slightly exceeds the maximum value required for solar cell interconnection (indicated by the dotted blue line). The squares indicate the mean value, and the error bars denote the standard deviation obtained from 10 replicate test samples.

Characterization of organic compounds on the particle surface

Thermogravimetric analysis (TGA) was conducted using a TGA 5500 (TA Instruments, Germany) under an air atmosphere. The temperature was increased to 600 °C at a heating rate of 10 K·min^{-1}, and the corresponding mass loss was recorded. Silver flakes were analyzed as received. For the preparation of pre-treated particles, 10 g of silver flakes were dispersed in an ethanol-water mixture (50vol%:1vol%). Then, 0.1 g of PEG 200 was added, and the suspension was stirred for 15 h. Afterwards, the particles were rinsed with the ethanol-water mixture and subjected to five centrifugation cycles. The particles were then dried under vacuum and kept overnight at 89.9 °C. One reference sample without PEG was prepared following the same procedure, denoted as "washed".

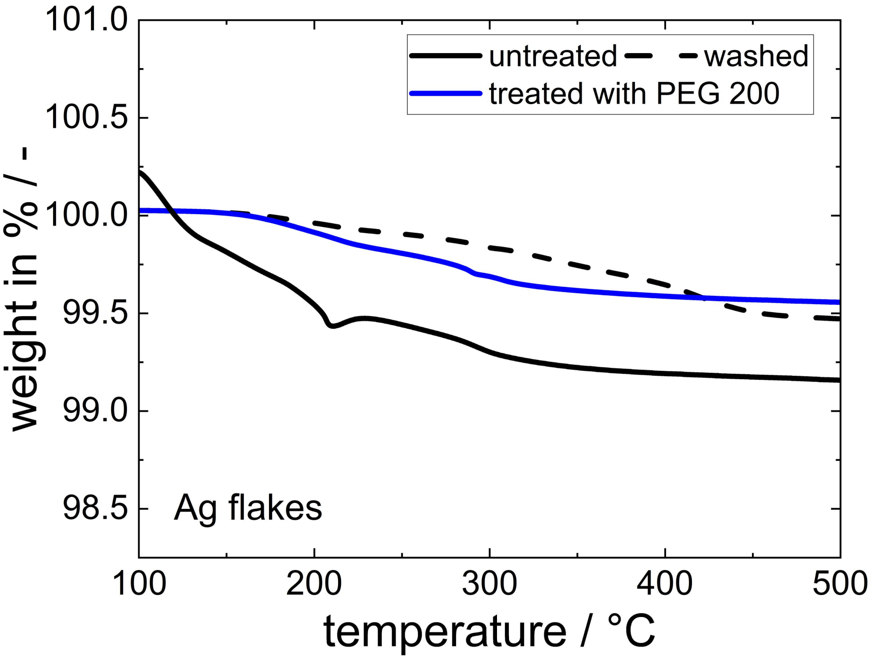

Figure S2. TGA of silver flakes: black: as received (untreated), dotted black: washed with ethanol, blue: pre-treated with PEG 200. The mass loss is the highest for untreated particles (1.06%). Washing with ethanol removes app. half of the organic fatty acid layer on the particles surface reducing mass loss to 0.55%. TGA results for PEG-treated particles indicate partial replacement of the original fatty acids by PEG 200, as the primary mass loss occurs around 285 °C, corresponding to the boiling point of PEG 200. Total mass loss is comparable to the mass loss of the washed particles.

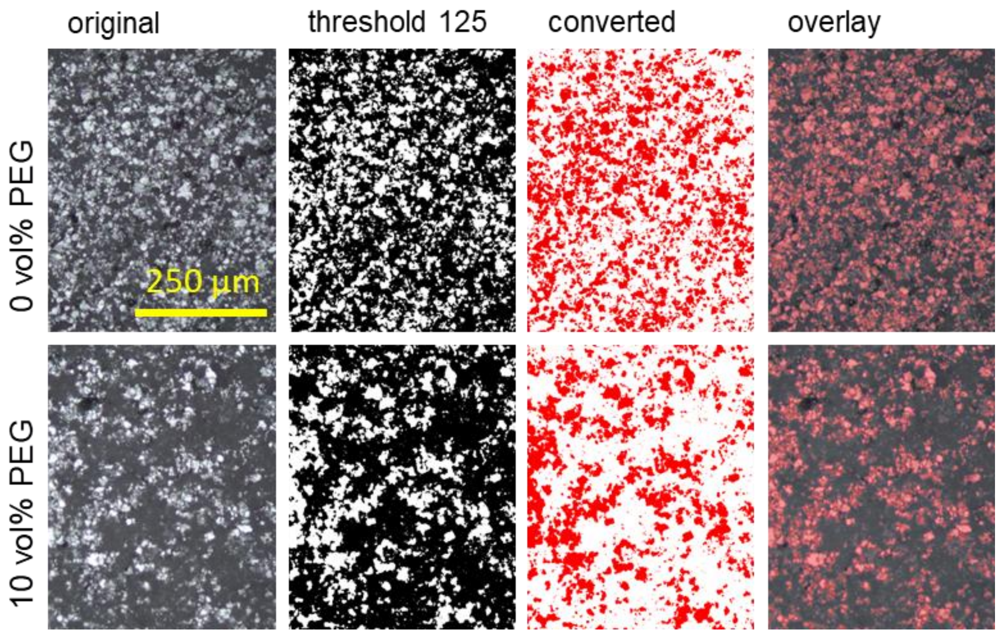

Figure S3. Image processing procedure for microstructural analysis. Original light microscopy images of the ECAs were converted to binary (black-and-white) images using a threshold value of 125 (greyscale range: 0-255). The binary images were subsequently converted to white-and-red representations and overlayed onto the original image to verify the suitability of the threshold value: Red areas accurately cover the light grey to white areas of the original images, which correspond to the silver particles.

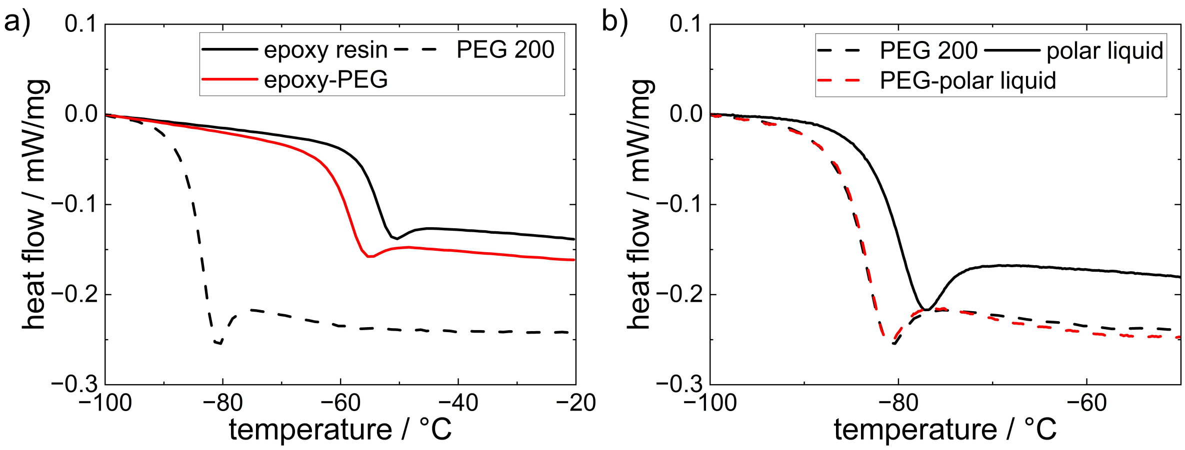

Figure S4. DSC analysis of the individual components included in the ECAs and their mixtures. Heat flow as a function of temperature (heating rate of 10 K·min^{-1}) for a) the epoxy resin, PEG 200, as well as their mixture containing 10 vol% of PEG 200, and b) PEG 200, the polar liquid, and their mixture containing 5 vol% polar liquid.

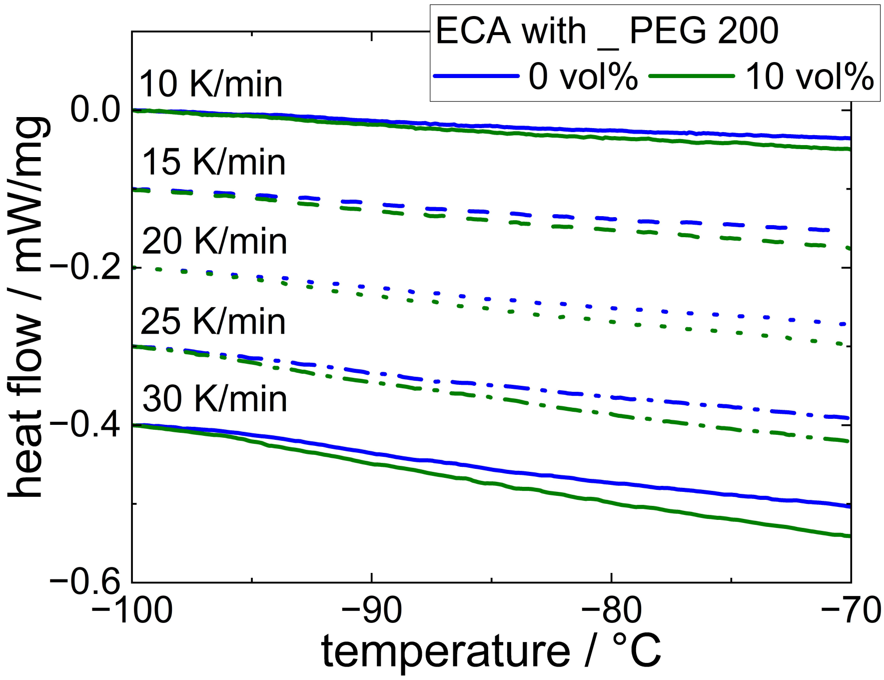

Figure S5. DSC analysis of ECAs containing 5 vol% silver particles and 10 vol% PEG 200. The shoulder associated with the secondary glass transition (compared to the ECA without PEG 200) becomes more pronounced as the heating rate is increased from 10 to 30 K·min^{-1}.

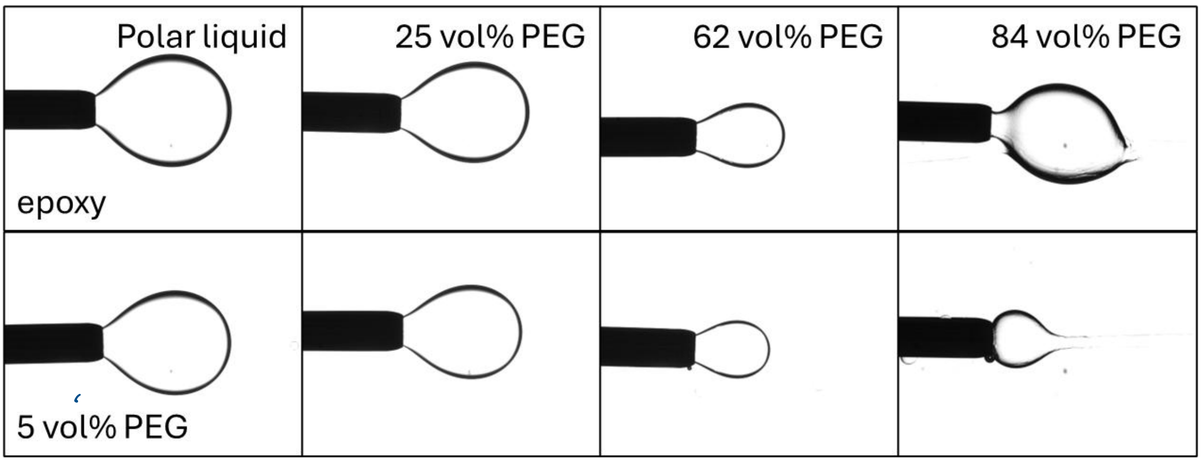

Figure S6. Shadow images of droplets containing polar liquid and different volume fractions of PEG 200, enclosed by epoxy resin containing either 0 vol% PEG 200 (upper row) or 5 vol% PEG 200 (lower row), used for interfacial tension determination. At 84 vol% PEG 200 in the secondary liquid, the droplet pulls threads, gradually dissolving into the epoxy resin, exhibiting no finite interfacial tension.