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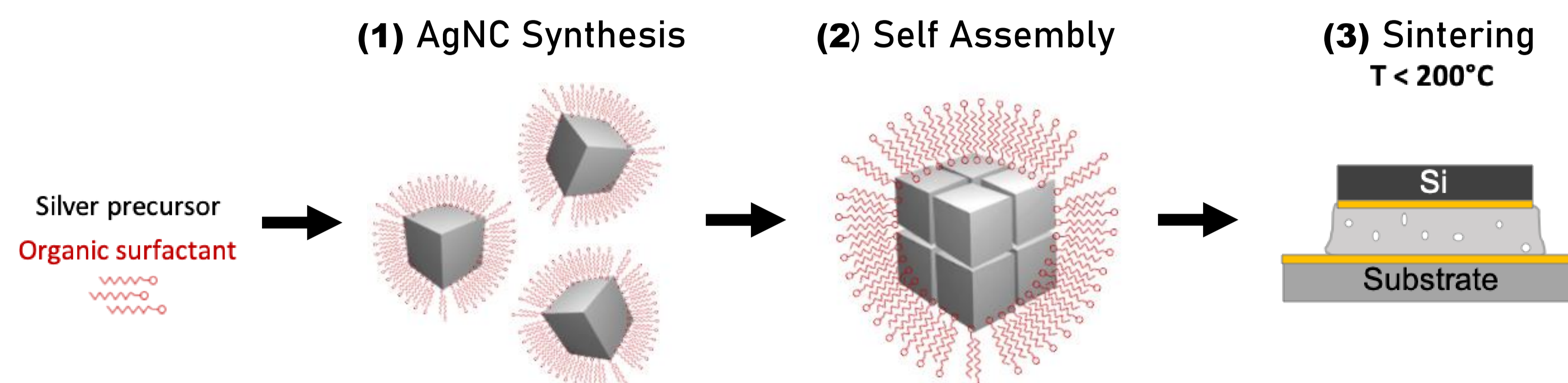
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IMPROVED LOW TEMPERATURE SINTER BONDING USING SILVER NANOCUBE SUPERLATTICES

Maxime Bronchy,^{1,2} Lucien Roach,¹ Laurent Mendizabal,² Céline Feautrier,³ Etienne Durand,¹ Jean-Marc Heintz,¹ Etienne Duguet,¹ Mona Tréguer-Delapierre¹

An open challenge in modern microelectronics is to sinter dense, robust and conductive electrical connections at low T ($< 200^\circ\text{C}$). Such junctions can be produced using metallic nanoparticles, such as Ag nanocubes, which have a high density of low-coordination surface atoms and pack densely in 3D. Monodisperse nanocubes (20 - 60 nm) were self-assembled into close-packed supercrystals by drop-casting. The uniform edge lengths and corner sharpness were confirmed by spectroscopy and electron microscopy. Sintered assemblies produced uniform joints with good thermal stability and high electrical conductivity. These junctions will improve the performance of sintered microelectronics.



(1) Silver Nanocube Synthesis

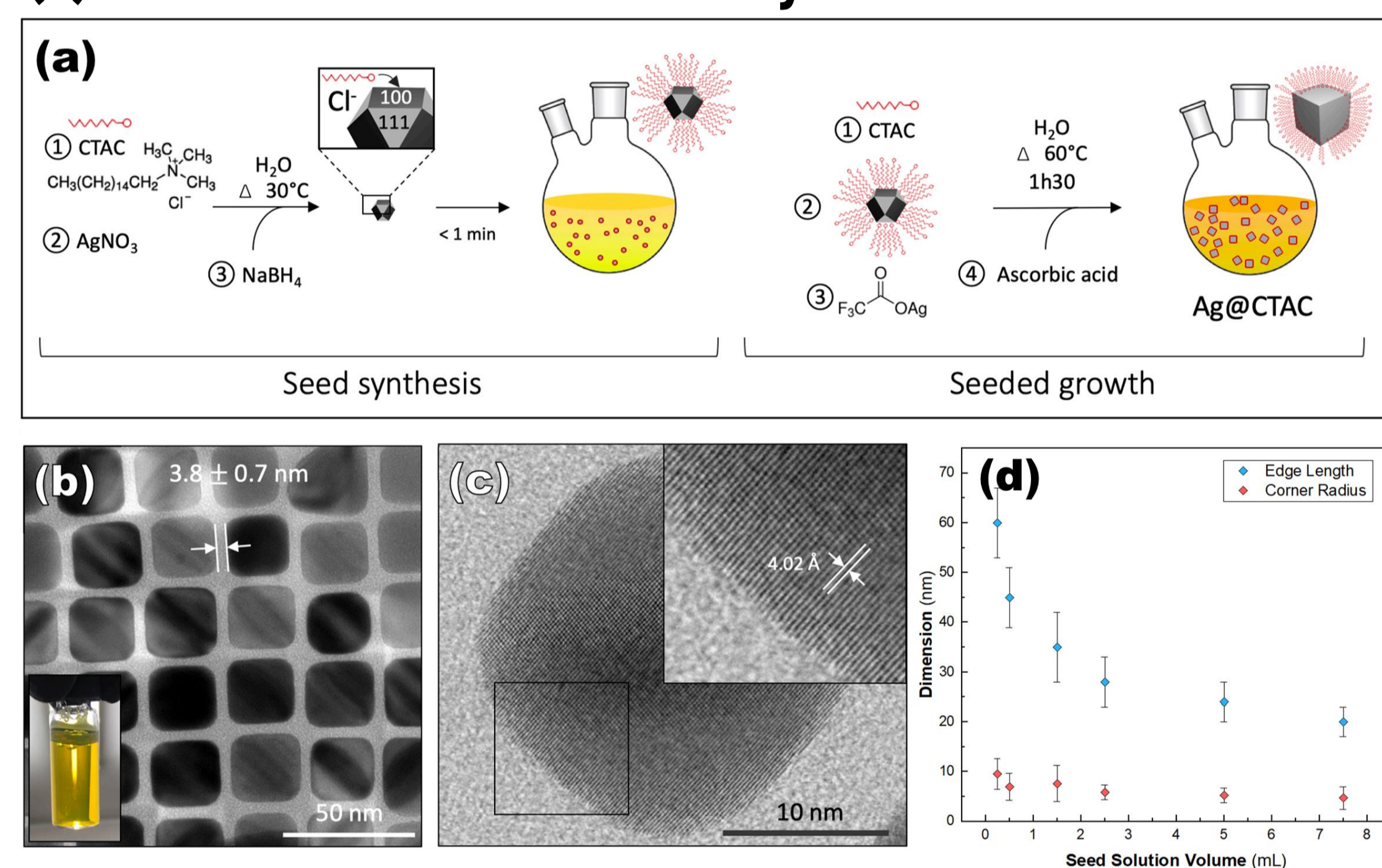


Figure 1. (a) Scheme of the colloidal synthesis (b) TEM image of Ag nanocubes of edge length, $L = (20 \pm 3)$ nm. *inset*: photograph of solution. (c) High-resolution micrograph of an individual Ag nanocube. *inset*: measured lattice spacing of 4.02 Å consistent with a {100} facet in Ag. (d) Change in Ag nanocube edge length and corner radius with seed solution volume.

- Monocrystalline Ag Nanocubes were synthesized using a CTAC-directed seeded synthesis.
- Particles had high monodispersity ($\approx 10\%$) and shape yield ($\approx 85\%$) with tunable size (20 - 60 nm).

(2) Optical Properties

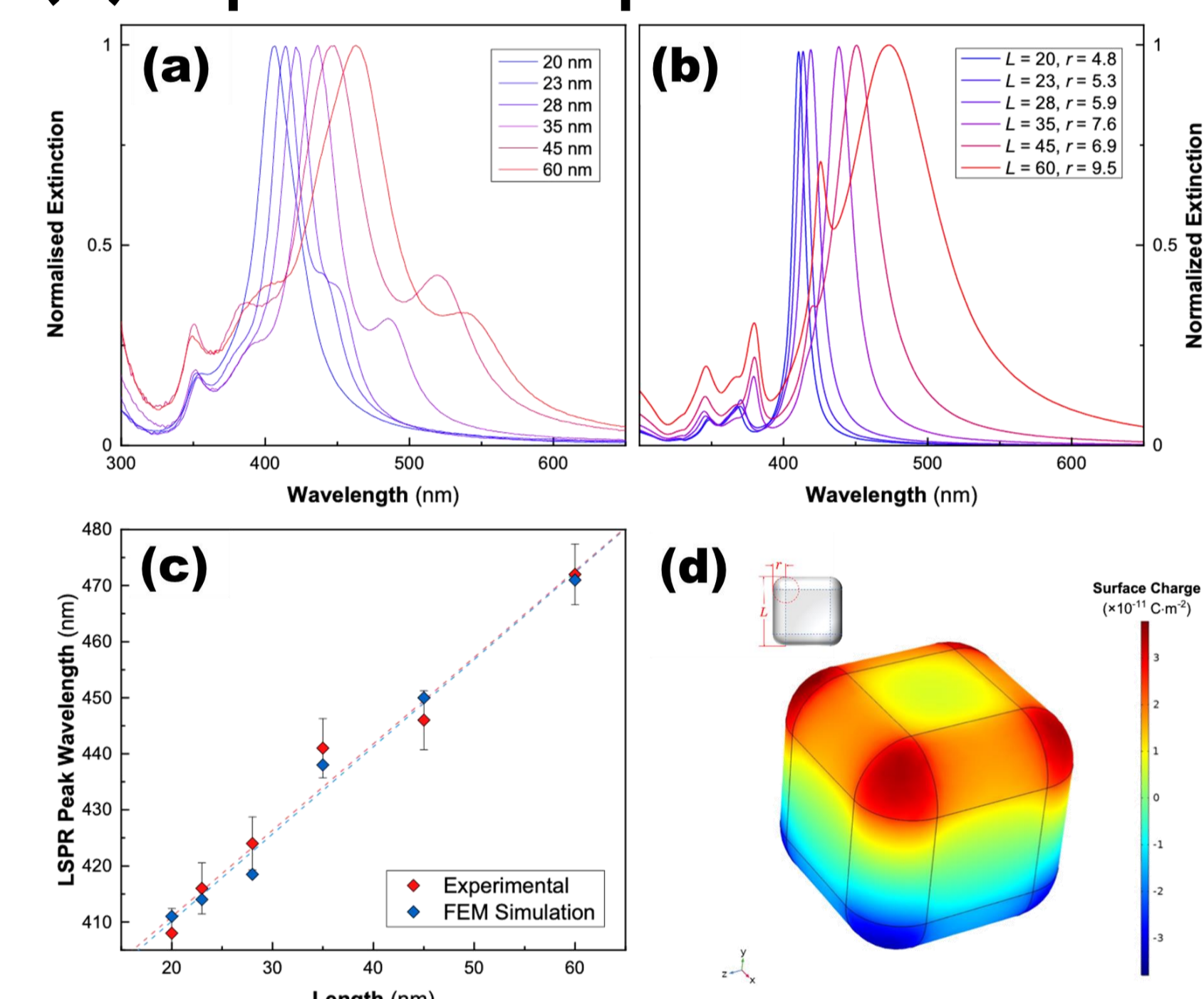


Figure 2. (a) Normalized UV-vis extinction spectra of the synthesized Ag nanocube samples (b) FEM simulated spectra of Ag nanocubes of the same dimensions as (a). (c) comparison of both measured and simulated peak extinction wavelengths. (d) Dipolar excitation for $L = 20$ nm, $r = 4.8$ nm ($|E_0| = 1 \text{ V}\cdot\text{m}^{-1}$).

- Nanocube spectra had narrow distinct peaks.
- Peaks redshift with increasing edge length.
- Closely matched by theoretical predictions indicative of high monodispersity.

(3) Sintered Junctions

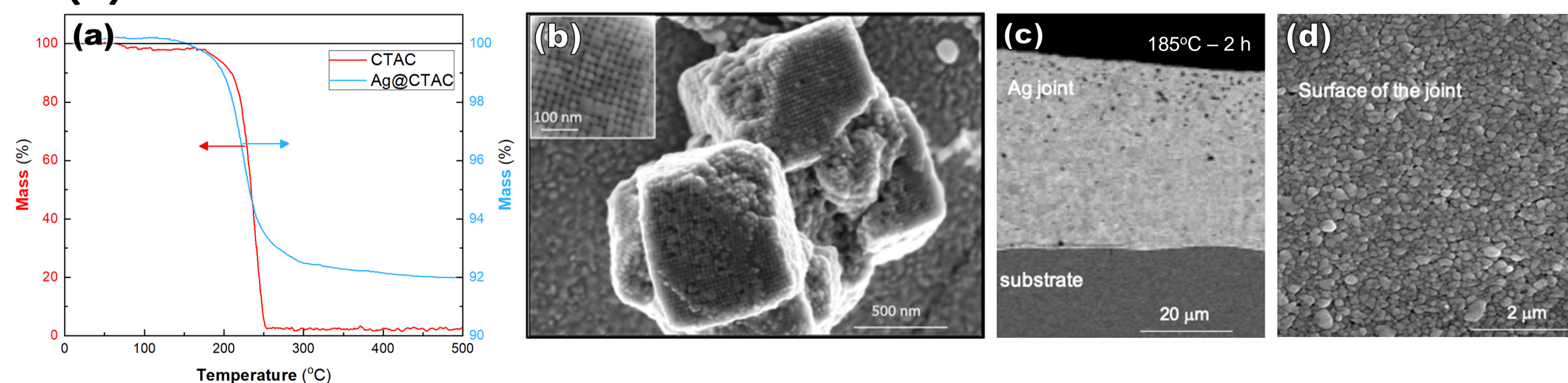


Figure 3. (a) TGA curve of CTAC and CTAC-capped Ag nanocubes under air gas flow. SEM images of densely packed Ag nanocube superstructures ($L = 20$ nm) (b) before and (c,d) after heating. *inset*: top-view SEM image of silver nanocube arrays (c) cross-sectional view of the silver cube joint after uniform heating (d) top-view of the same sample.

- Cubes self assemble into 3D cubic lattices when drop-cast.
- SEM analysis shows that porosity $\approx 6\%$ vol at 185°C , below decomposition temperature of CTAC.
- CTAC initially $\approx 8\%$ wt of sample, suggests migration to exterior of joint during sintering.
- Joints are mostly continuous under SEM and resistivity ($(3.9 \pm 0.1) \mu\Omega\cdot\text{cm}$) is close to that of bulk Ag ($1.6 \mu\Omega\cdot\text{cm}$).