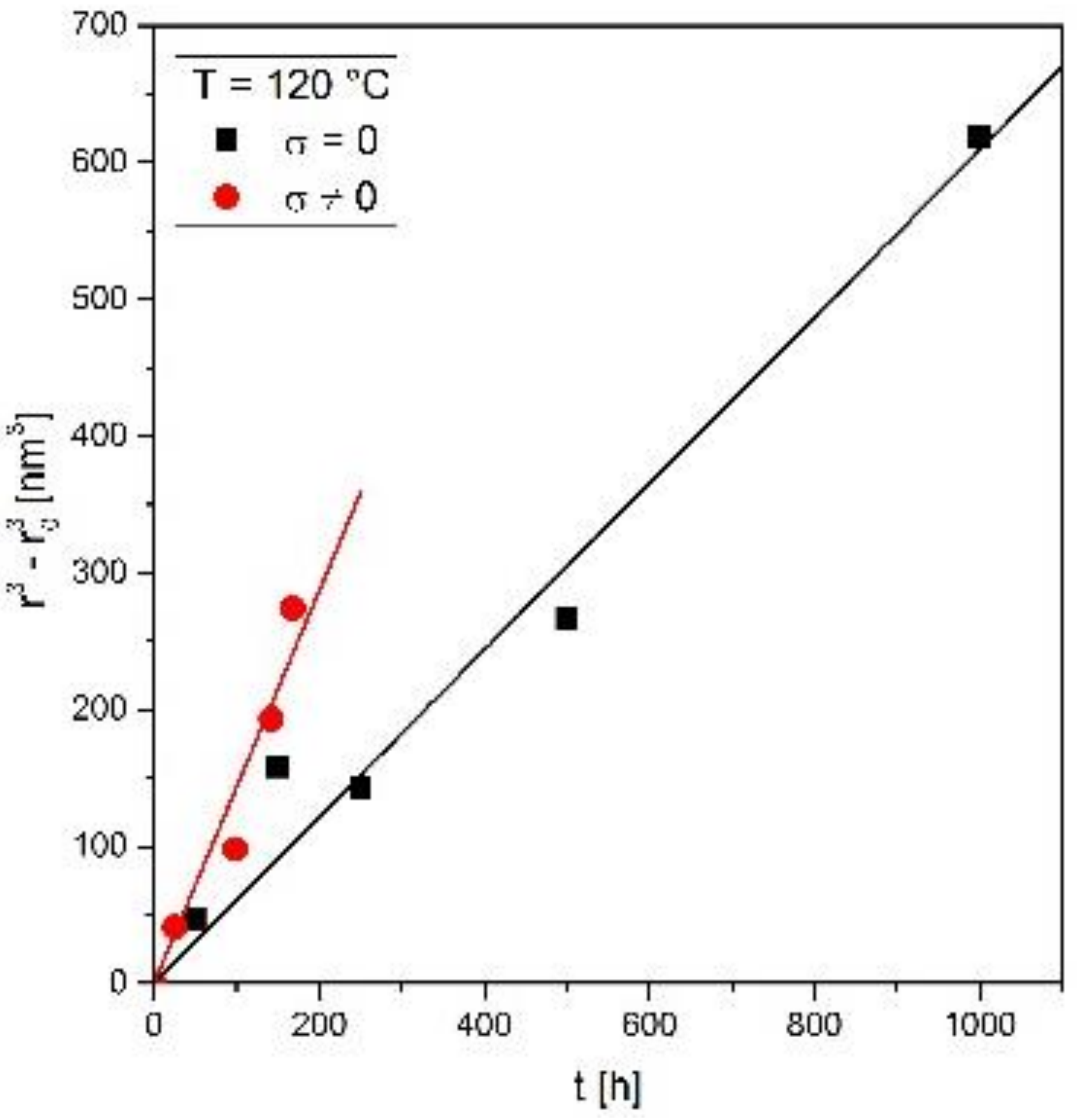
Influence of heat treatment and creep loading on an Al-Cu-Li alloy

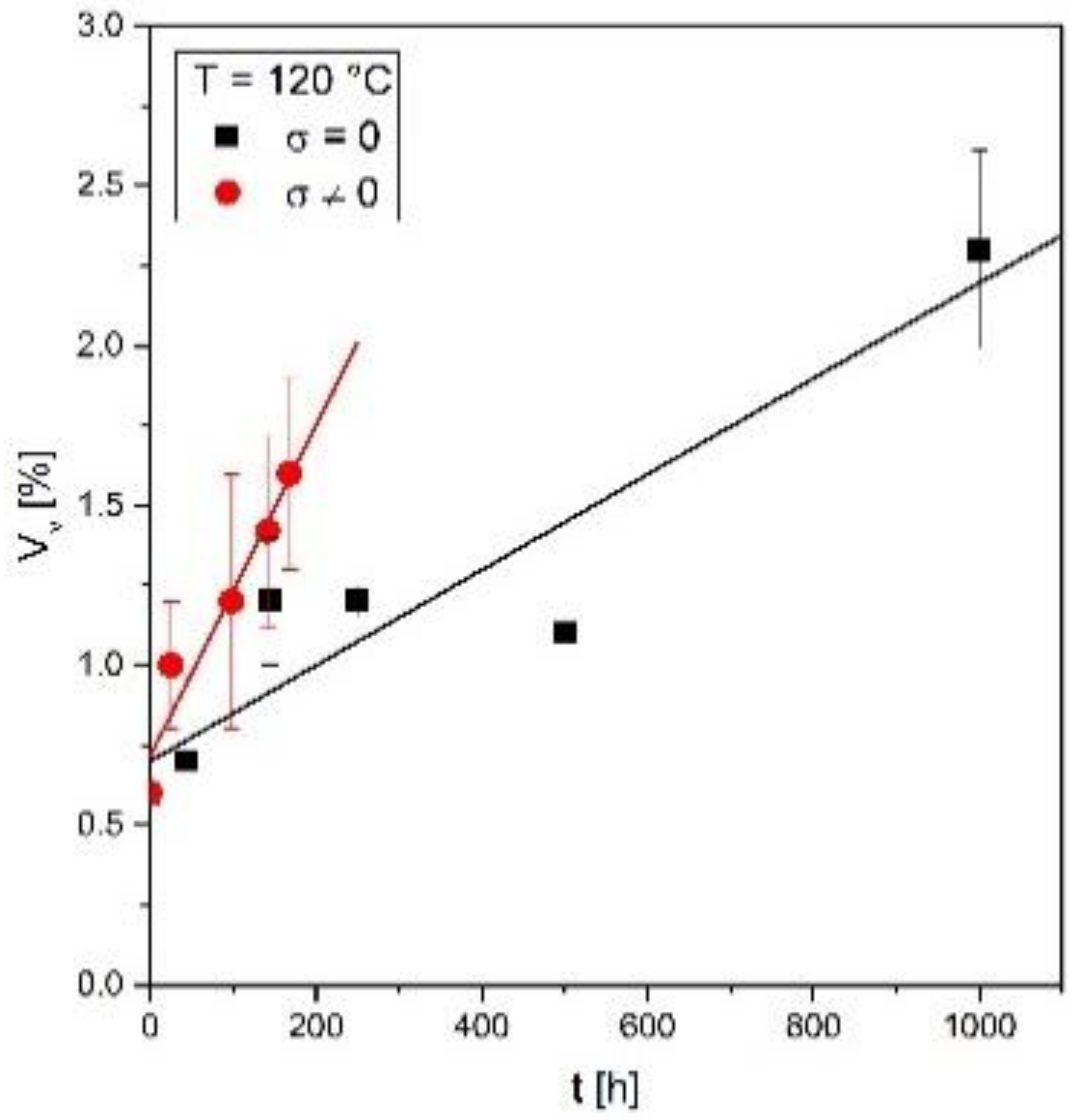
C. Rockenhäuser, I. Häusler, R. D. Kamachali, D. Heidl, B. Skrotzki

Bundesanstalt für Materialforschung und -prüfung

Motivation:

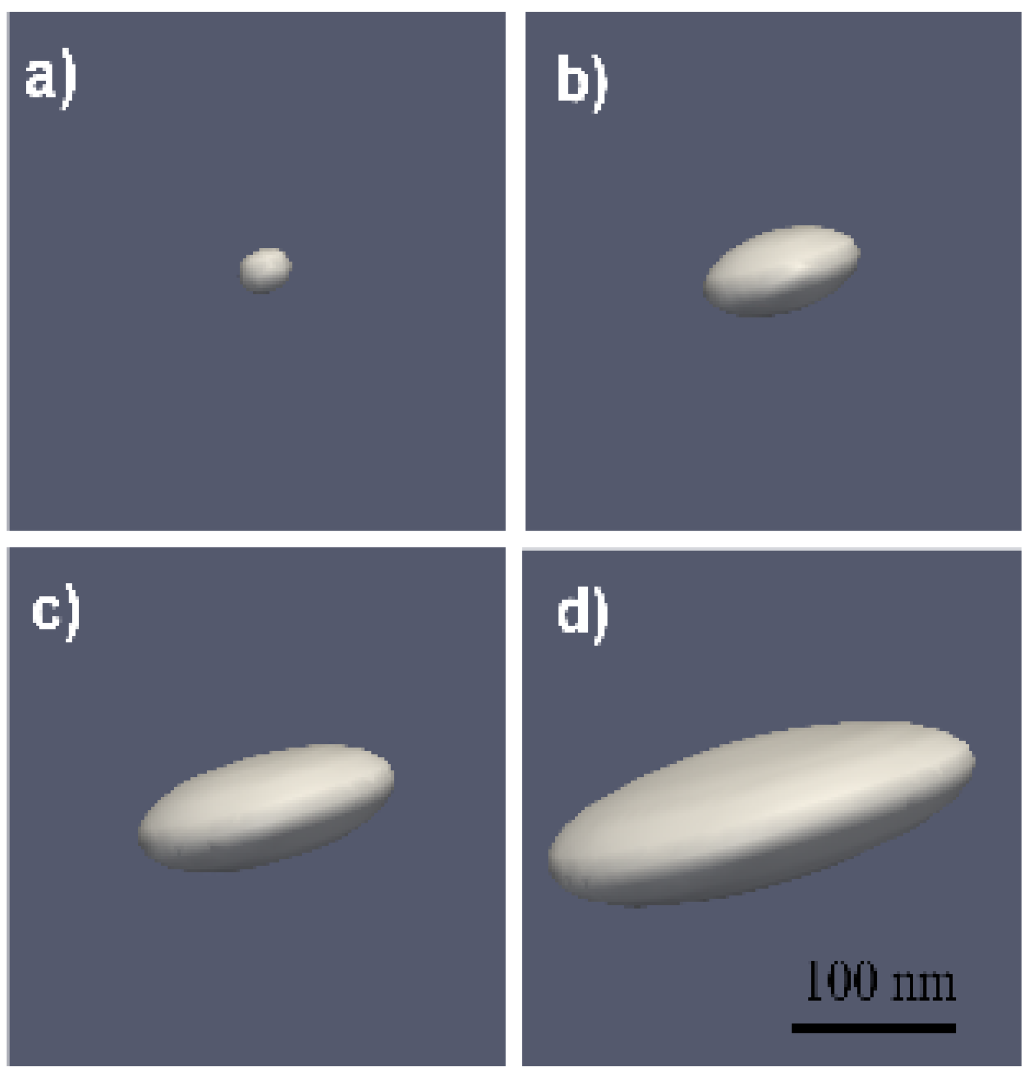
Understanding the influence of mechanical loading on the age hardening of an Al alloy

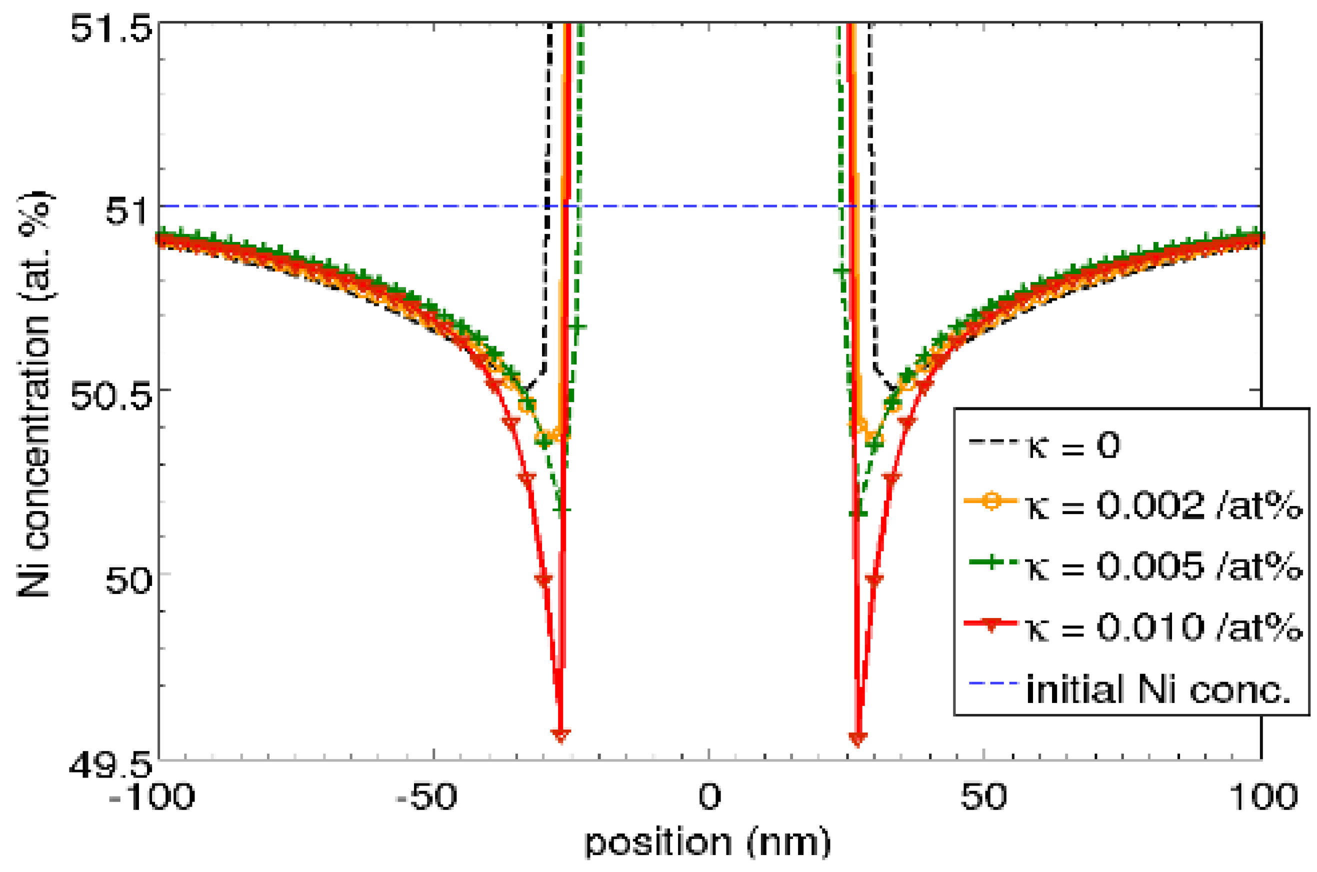




B. Skrotzki, J. Murken, in: Lightweight Alloys for Aerospace Applications, The Minerals, Metals & Materials Society, Warrendale, PA (2001) 51

- Precipitation hardened microstructures are instable if subjected to service conditions close to artificial aging temperature
  - Coarsening
  - Ostwald ripening
- Degradation of mechanical properties may take place
- Service loads may affect coarsening/ripening processes
- Mechanism of precipitate evolution must be understood





R. D. Kamachali, et al., Modelling Simul. Mater. Sci. Eng. **22** (2014) 034003

Mechanical coupling

- Internal stress fields around precipitates due to structural mismatch also affect
  - Diffusion processes
  - Growth
  - Morphology
- Elastic constants are composition dependent and cause mechanical driven fluxes
- New modelling approaches take the coupling between chemistry and mechanics into account

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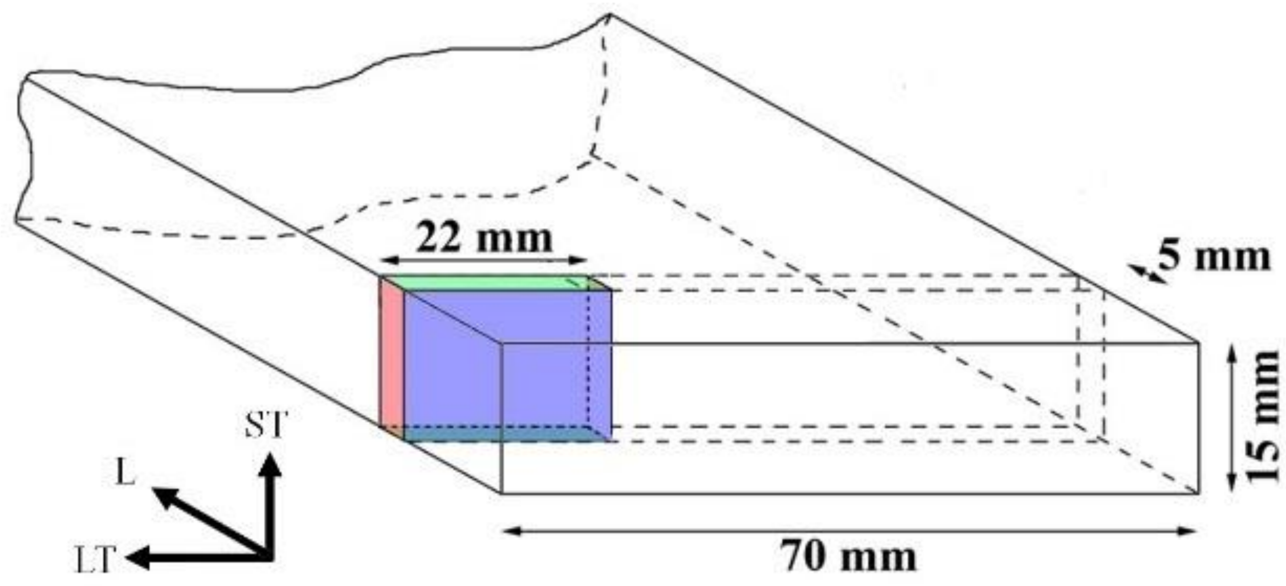
Experimental:

Material and treatment

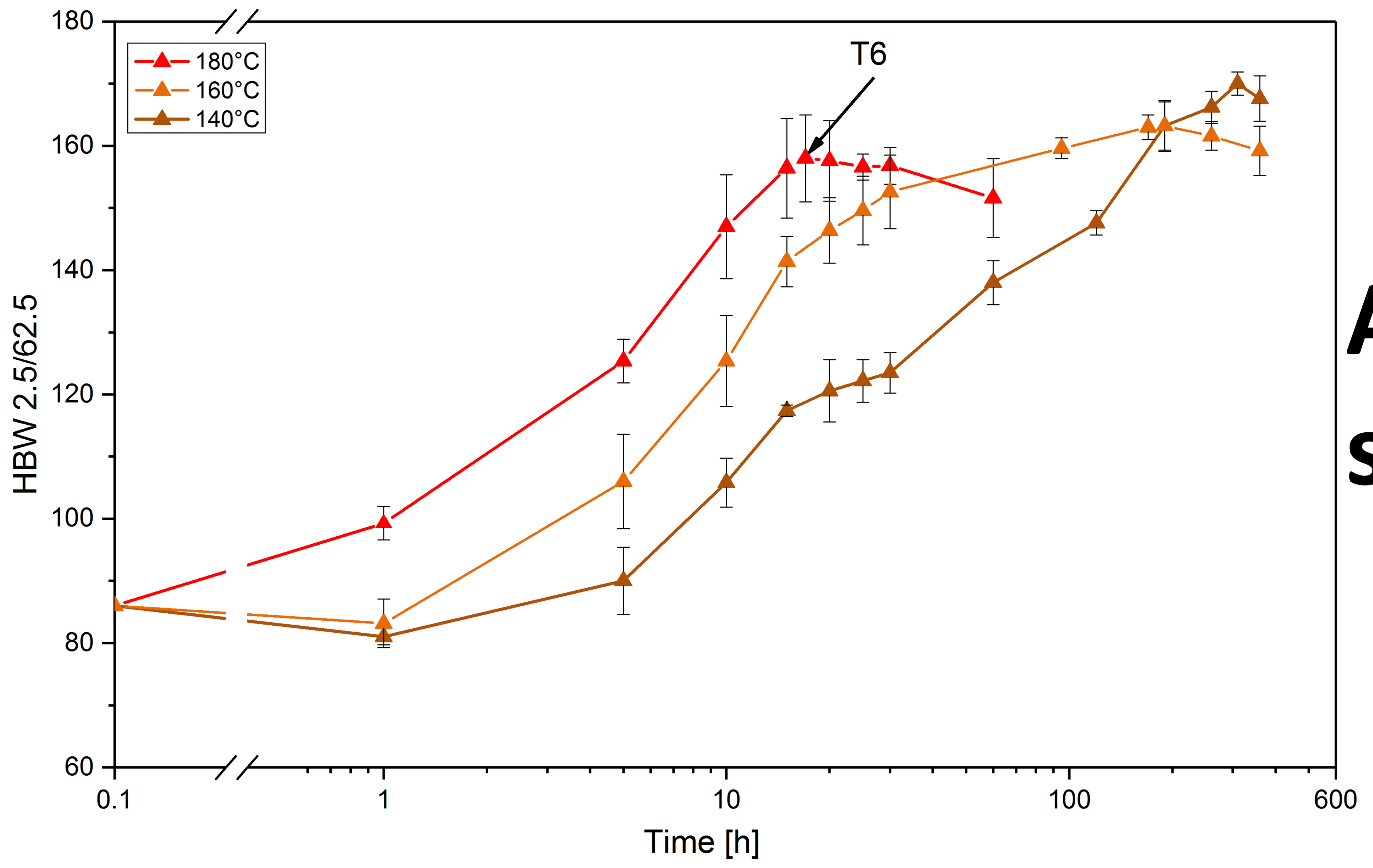
- Al-4Cu-1Li-0.25 Mn (composition close to 2195)
- impurities < 0.06 mass-%
- Homogenization 24 h/525 °C/WQ
- Extrusion @ 420 °C
- SHT 70 min/505 °C/WQ
    - Stretching ca. 3 % (= initial state as received)
    - Resolutionising (reduced dislocation density)
- Artificial aging

Mechanical characterization

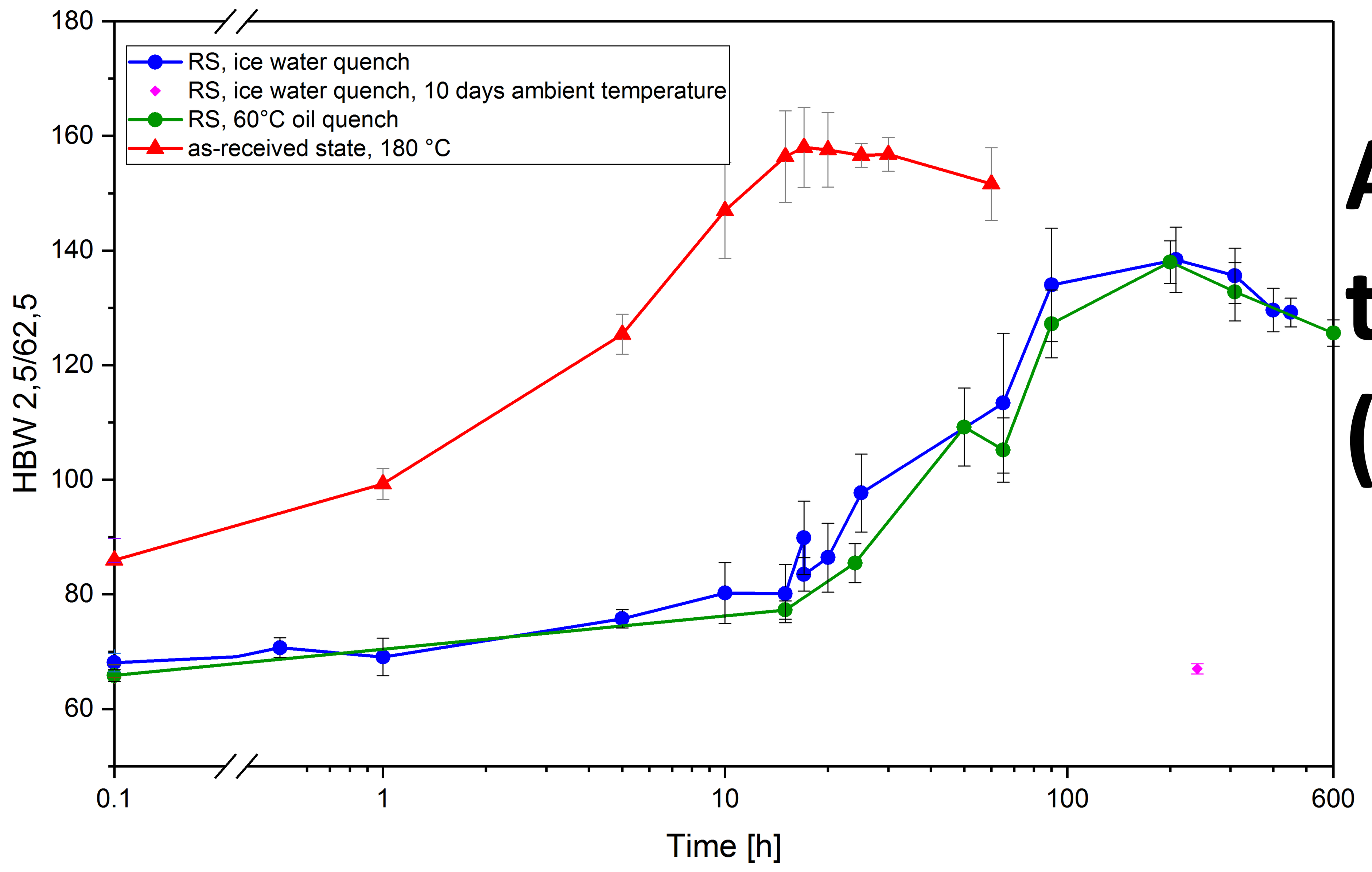
- Brinell hardness
- Microstructural characterization (TEM)
- Conventional specimen preparation
- JEOL 2200FS TEM/STEM
- JEOL ARM 200F HR-STEM
- Imaging in $[110]_{Al}$
- Quantitative image analysis



Hardness:



Ageing of as-received stretched samples



Ageing of resolu-tionised (RS) samples (180 °C)

DFG Deutsche Forschungsgemeinschaft
German Research Foundation
SPP 1713

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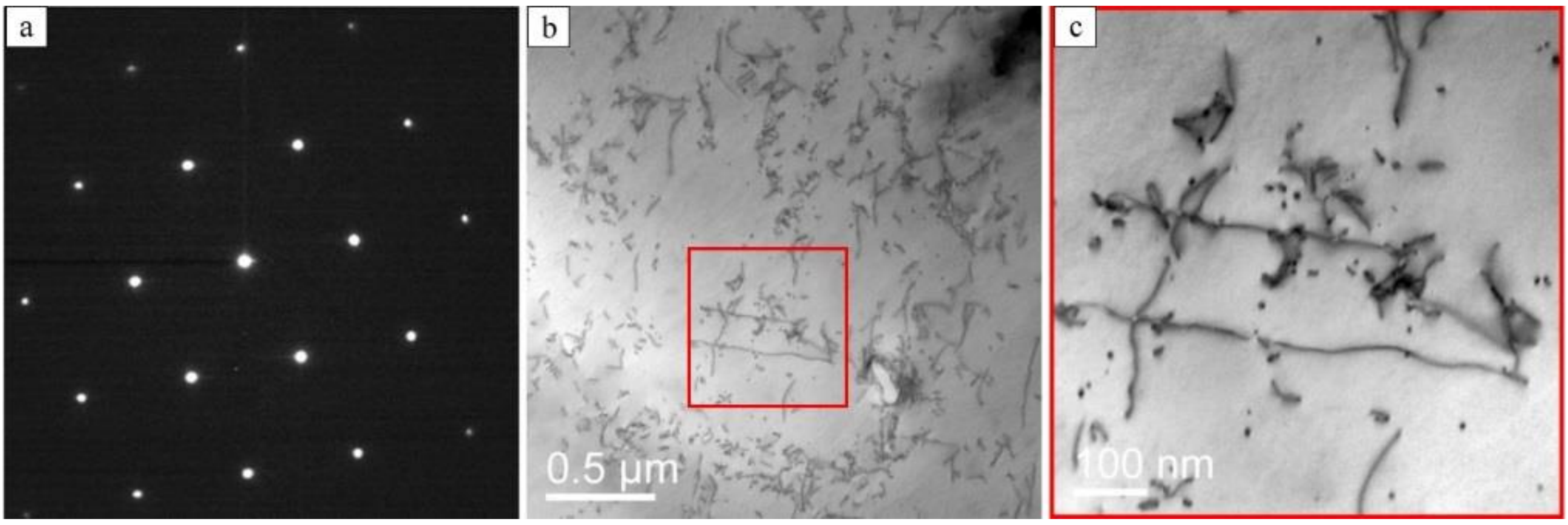
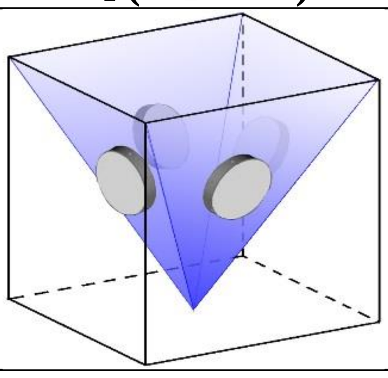
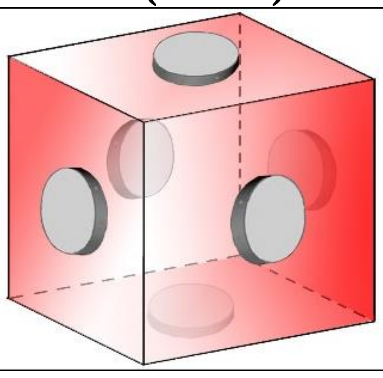
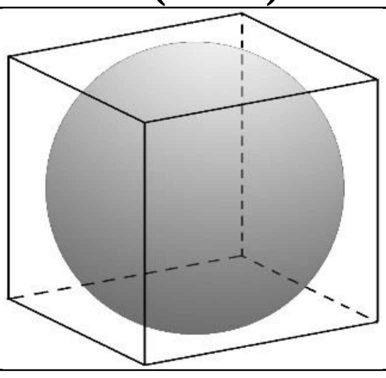
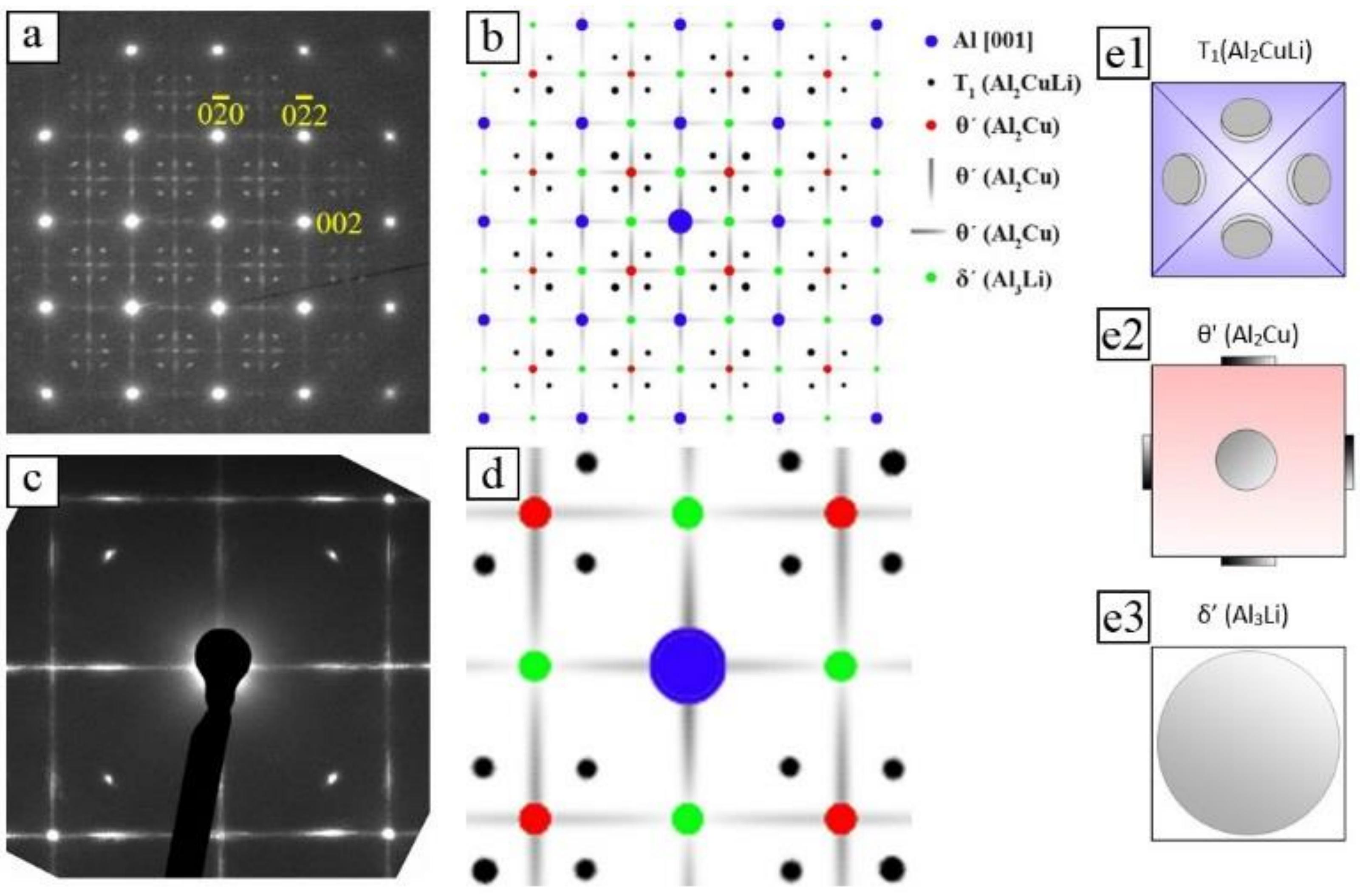
Initial state and precipitate evolution:



[100]$_{Al}$ **Initial state**

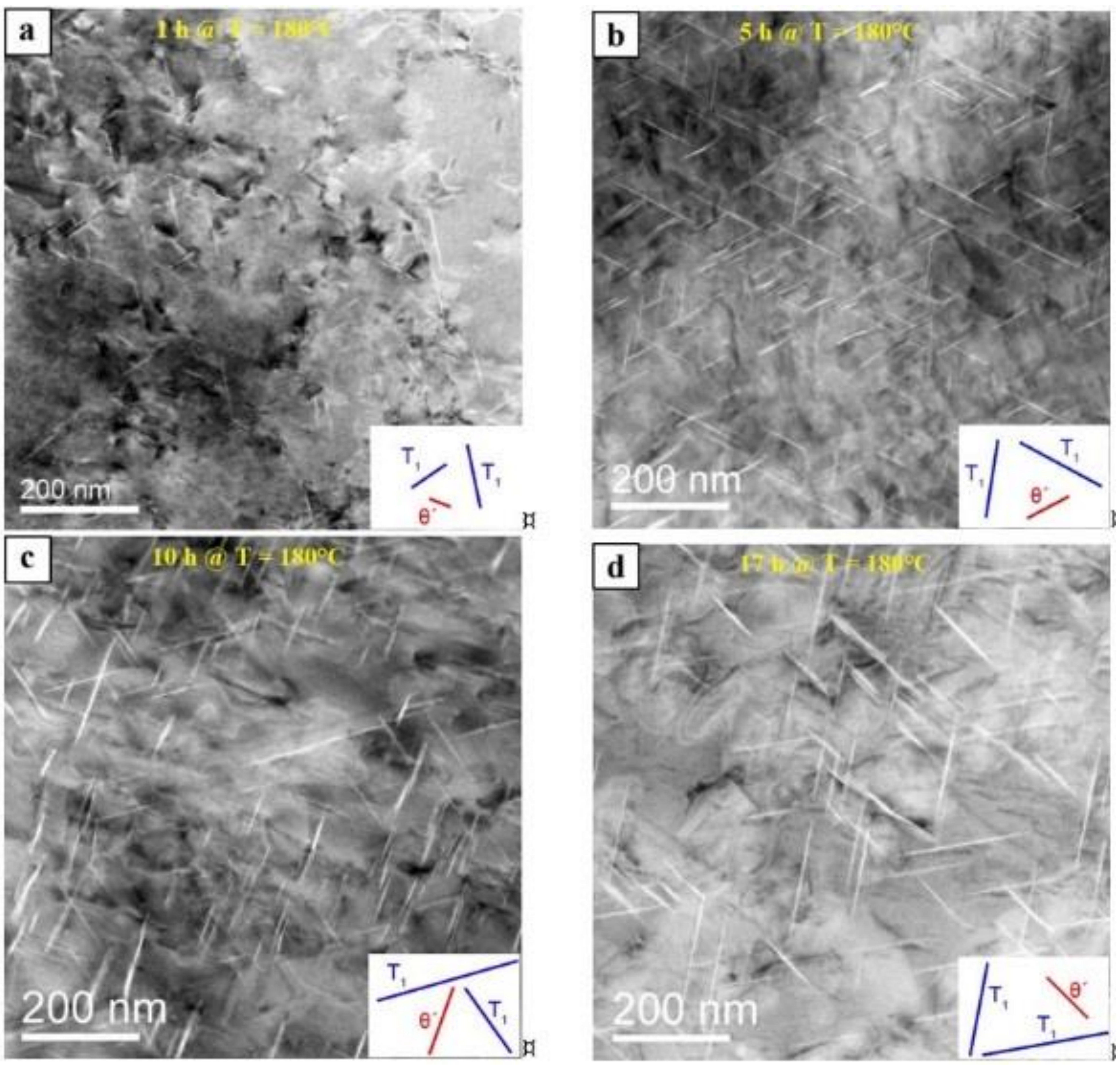
I. Häusler, et al., *Materials* 10 (2017) 117

Phase	T_1 (Al_2CuLi)	θ' (Al_2Cu)	δ' (Al_3Li)
			
Space group	P6/mmm (191) hexagonal a = 0.4954 nm c = 0.9327 nm	I-4m2 (119) tetragonal a = 0.4040 nm c = 0.5800 nm	Pm-3m cubic a = 0.40109 nm
Orientation relationship	$(00.1)_{T1}$ ‖ $\{111\}_{Al}$ $<10.0>_{T1}$ ‖ $<110>_{Al}$	$(100)_{\theta'}$ ‖ $(100)_{Al}$ $[100]_{\theta'}$ ‖ $[100]_{Al}$	$(100)_{\delta'}$ ‖ $(100)_{Al}$ $[100]_{\delta'}$ ‖ $[100]_{Al}$
No. of orientation variants	4	3	1



Aged samples

- Number and size of precipitates change considerably with ageing time
- Length, thickness, number density, volume fraction were quantitatively analyzed



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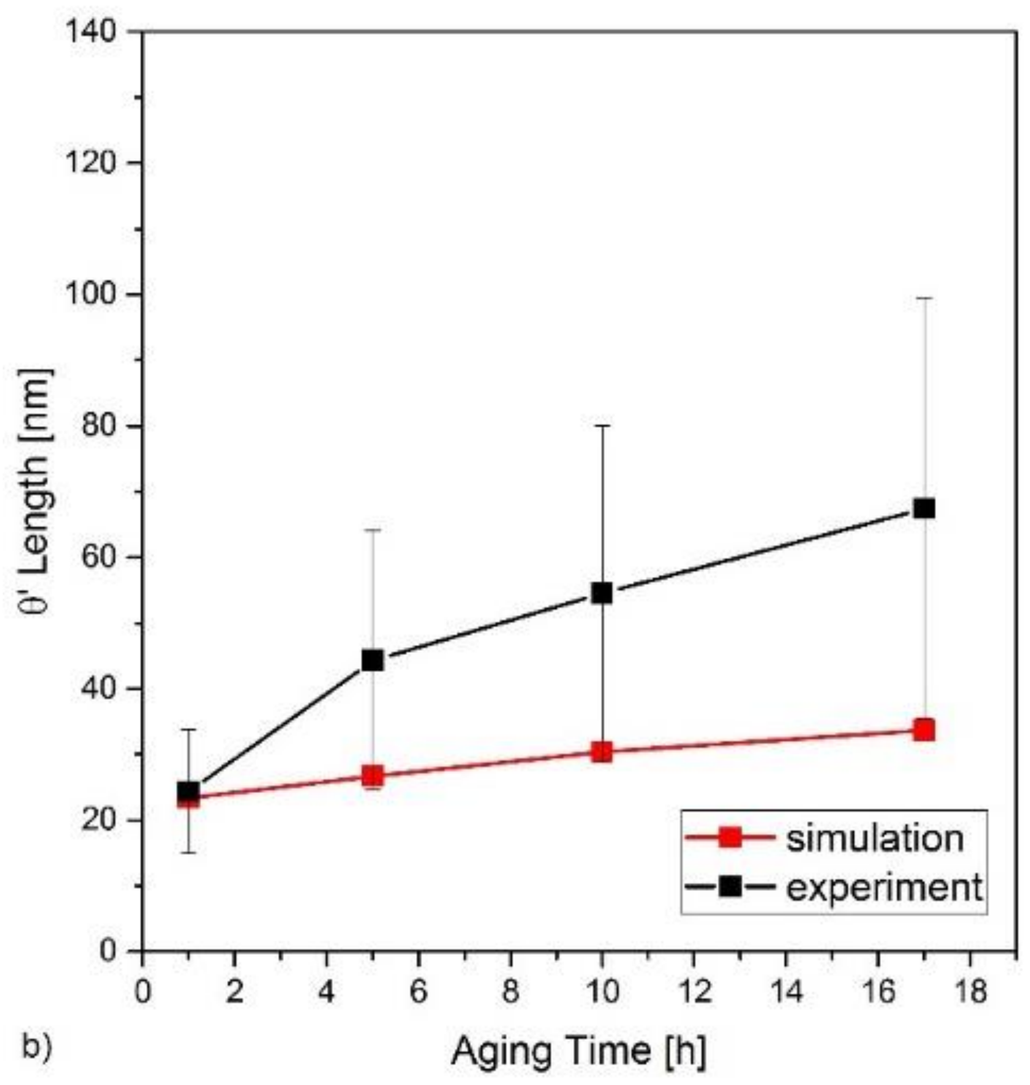
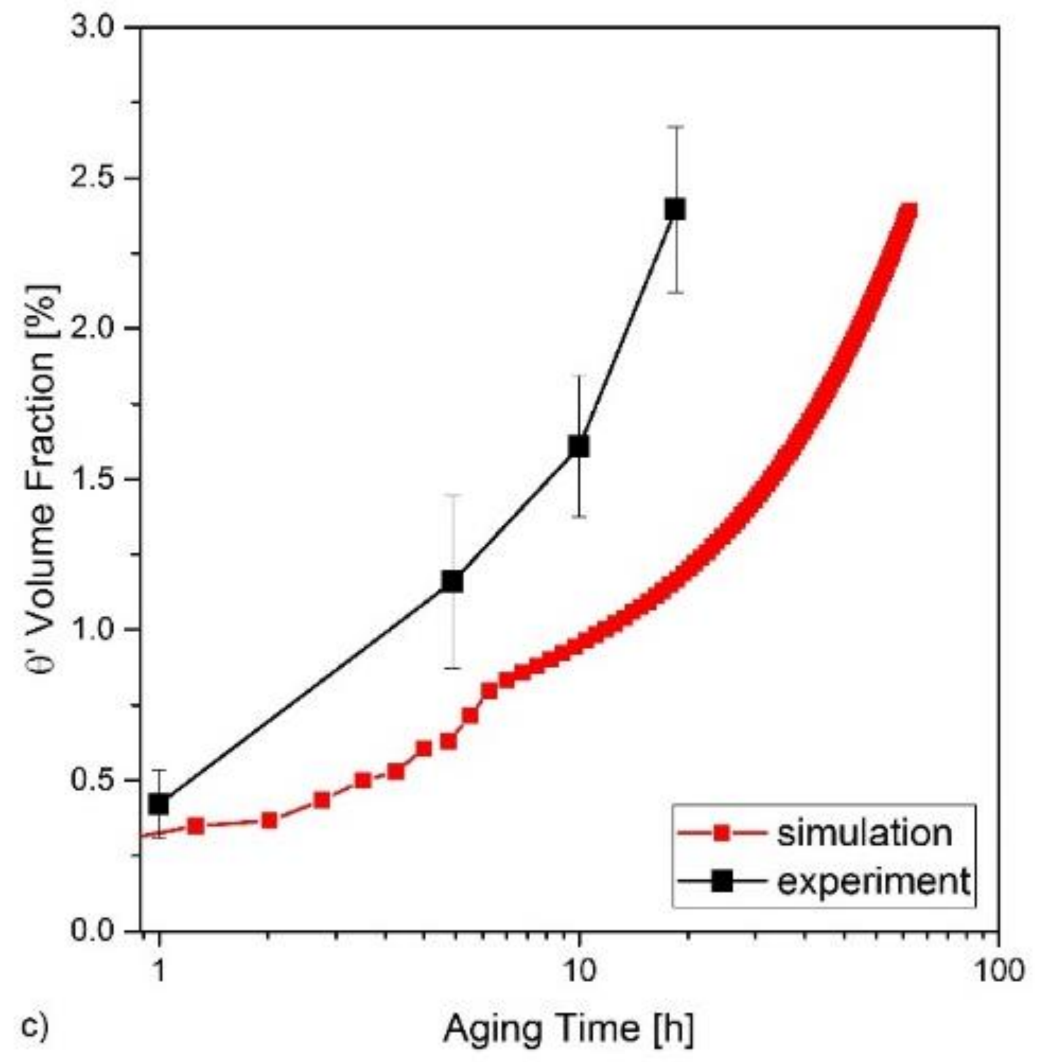
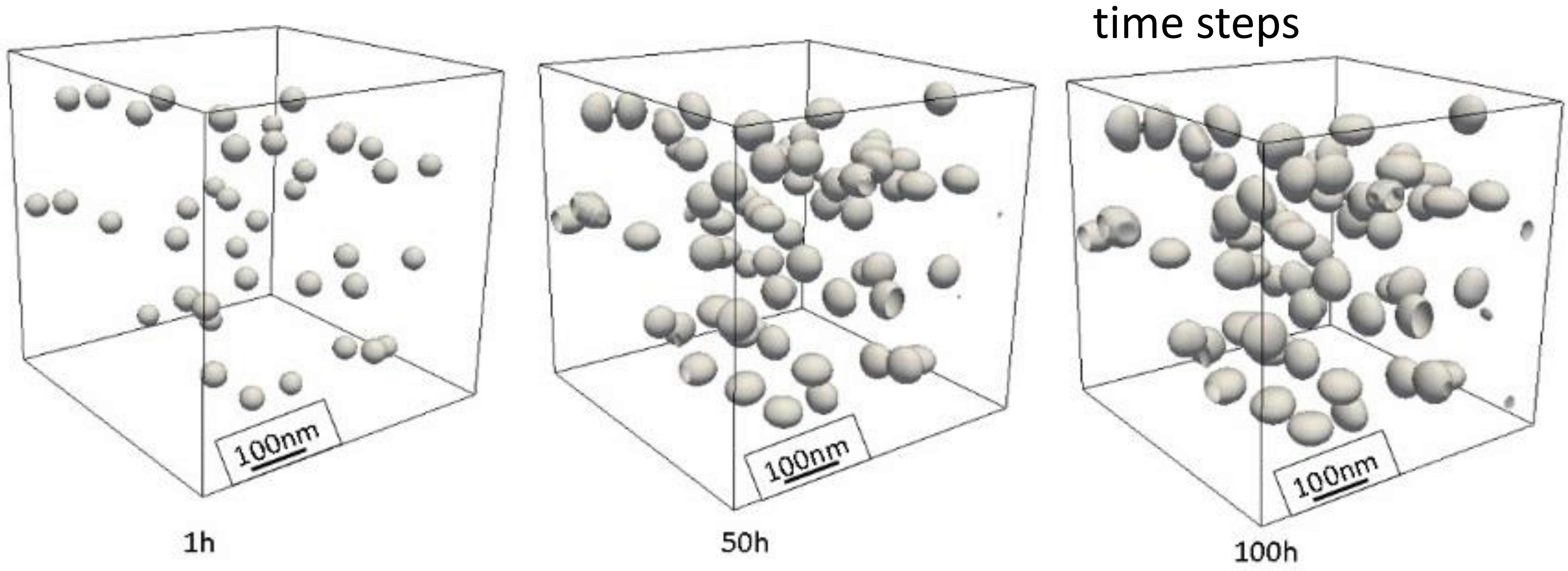
Precipitate evolution and simulation:





3D-Simulation and experimental data of θ‘ Nucleation and growth

Growth and ripening of θ′ precipitates after nucleation in individual variants and their formation as plates for different time steps



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Conclusions:

- Time dependent evolution of precipitates responsible for age hardening was studied in an Al-4Cu-1Li-0.25Mn-alloy by TEM investigations and complementary phase field simulations
- T_1 (Al_2CuLi) and θ′ (Al_2Cu) form during aging at 180 °C
- The length of both precipitates increases with time up to peak hardness
- θ′ is the dominant phase with respect to volume fraction: it increases rapidly with time while that of T_1 grows slowly
- The θ′ precipitates volume fraction does not reach a saturated stage after 17 h at 180 °C (peak hardness)
- The simulation results show similar trends for the evolution of precipitate length and volume fractions
- 3D phase-field simulations of θ′ phase were performed with full consideration of interface, elastic and chemical effects
- Good agreements with the experiments were observed.

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