Applications of Advanced Scanning Transmission Electron Microscopy Techniques in the Study of Light Alloys

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In recent years, the development of advanced imaging and spectroscopy techniques of scanning transmission electron microscopy (STEM) has greatly promoted the fundamental research of light alloys. In this presentation, two different alloys are used to illustrate the application of such techniques.

The first one is in the examination of the θ'/θ'' sandwich structure in an Al-Cu-Au alloy. θ'' and θ' are two important metastable precipitate phases in binary Al-Cu alloys. It was reported that trace additions of Au to the Al-Cu alloys enhance the age hardening response [1]. However, the exact mechanism has not been clearly understood. In this work, the microstructure of aged Al-3.95wt%Cu-0.13wt%Au alloy was studied using atomic-resolution high-angle annular dark-field (HAADF) and energy-dispersive X-ray spectroscopy (EDX) STEM. It was found that θ'' precipitates are often attached to one or both sides of θ', forming sandwich structures (Figure 1). The origin of the θ'/θ'' sandwich structure was investigated using density functional theory (DFT) calculations, and the experimental and theoretical results will be presented in this talk.

The second case is the study of the crystal structure of the equilibrium Φ phase in Mg-Zn-Al casting alloys. Three slightly different models have been proposed previously, based on either electron [2] or X-ray [3] diffraction techniques. However, there is still a lack of direct observation of the atomic structure to support any of these models. In this work, the structure of primary intermetallic particles of Φ phase in the Mg-8wt%Zn-4wt%Al alloy was examined using combined techniques of atomic-resolution HAADF-STEM, EDX-STEM mapping, electron energy-loss spectroscopy (EELS) mapping, and position averaged convergent beam electron diffraction (PACBED). It was found that all three previous models agree reasonably well with the experimental images, except for a few atomic sites. Judged from the experimental and simulation results (Figure 2), the two more recent models (nearly identical to each other) were found to be more accurate than the earliest one.

References:
[1] Y. Chen, et al., The enhanced theta-prime (θ') precipitation in an Al-Cu alloy with trace Au additions, Acta Mater. 125 (2017) 340.
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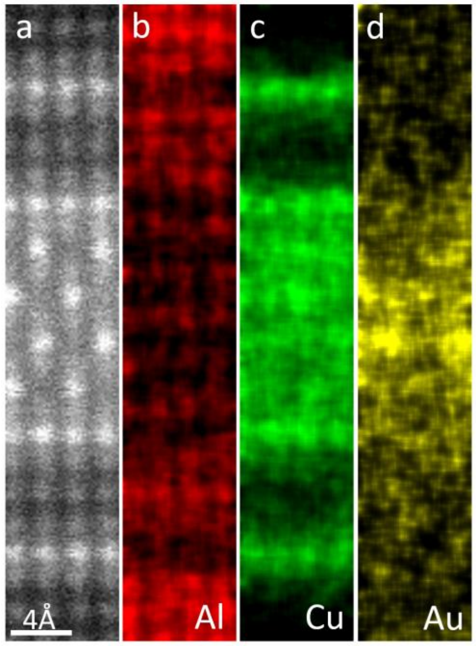

Figure 1. (a) HAADF-STEM image and (b-d) EDX-STEM maps of θ'/θ'' sandwich structure in aged Al-3.95wt%Cu-0.13wt%Au alloy. Au mainly distributes in the central part of θ'.

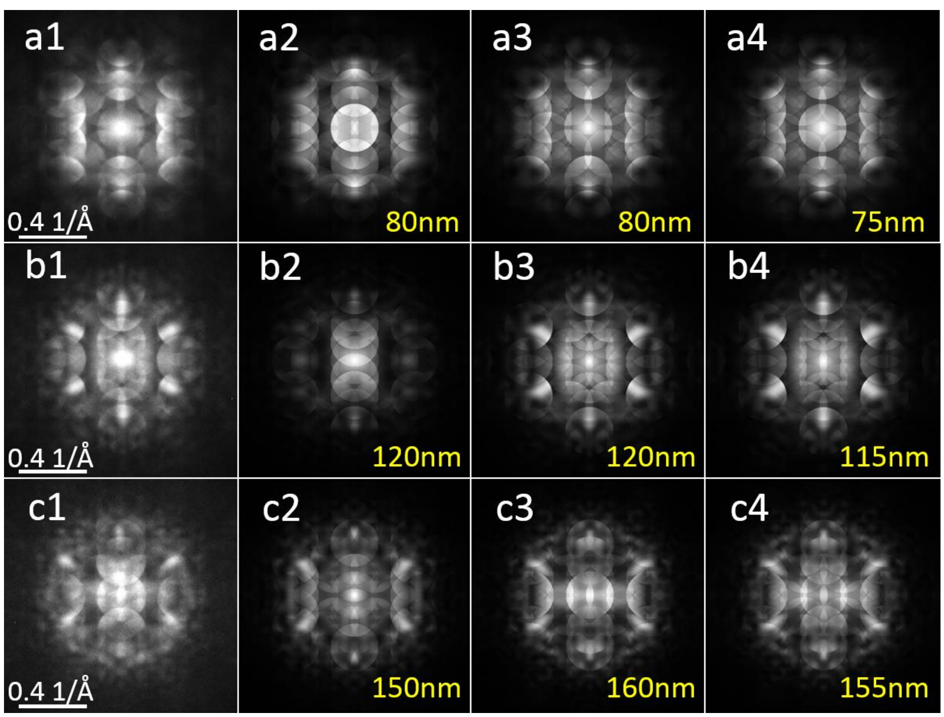

Figure 2. (a1-c1) Experimental PACBED patterns from regions of different thicknesses of Φ phase primary intermetallic particles in Mg-8wt%Zn-4wt%Al alloy, compared with simulated patterns using (a2-c2) Model 1, (a3-c3) Model 2, (a4-c4) Model 3. Models 2 and 3 give better matching than Model 1.