**Interfaces and defects: their role during precipitation in Al-Ag alloys**

Zhang, Z.[1], Bourgeois, L.[1,2], Rosalie, J.M.[3] and Medhekar, N.V.[1]

[1] Department of Materials Science and Engineering, Monash University, Australia, [2] Monash Centre for Electron Microscopy, Monash University, Australia, [3] Erich Schmid Institute of Materials Science, Austria

Physical metallurgy is concerned with the fundamentals and applications of phase transformations, or the process by which atoms arrange themselves from one structure to another. Al-Ag alloys have served as a textbook system for understanding the solid-state phase transformations. Apart from being a model system, Ag has engineering importance as a magic micro-alloying element in high-strength aluminium alloys that can dramatically accelerate or even modify precipitation [1]. Recent studies have shown that in this role, Ag segregates at the interfaces of a wide range of precipitates [2-3]. However, the atomic mechanisms of interfacial segregation during phase transformations are largely unknown.

To understand the common role of Ag in aluminium alloys, we revisited the binary Al-Ag system and characterised the atomic structures of the different precipitate phases and interfaces using high angle angular dark field scanning transmission electron microscopy (HAADF-STEM). Surprisingly, we found a new precipitate phase $\zeta$ (AgAl) as shown Fig.1, which has a bi-layered structure enriched in Al and Ag on alternating close-packed planes [4]. Our in-situ STEM revealed the time-resolved phase transformation from the face-centred cubic (FCC) GP zone $\varepsilon$ phase to the hexagonal close-packed (HCP) $\gamma'$ phase via the intermediate z phase, Fig.2. Our first-principles calculations showed that $\zeta$ phase is a local energy minimum state formed during Ag clustering in aluminium. This study demonstrates the manipulation of phase transformation pathways via processing. Also, the layered structure of $\zeta$ that is analogous to the well-known Ag segregation in various aluminium alloys.

The FCC/HCP interface of $\gamma'$ ($Ag_2Al$) precipitate is another classical topic in metallurgy. It is well accepted that the growth of $\gamma'$ precipitate involves the movement of Shockley partial dislocations at the interfaces. By locating the atomic positions on HAADF-STEM images and applying periodicities in the viewing direction, we built experimentally-informed 3D models of the precipitate-matrix interface and identified dislocation structures. Sessile dislocations were found at the precipitate-precipitate junctions, Fig.3. Depending on the contacting angle, two Shockley partial dislocations react to form a Lomer-Cottrell dislocation or a Hirth dislocation. Interestingly, each type of dislocation is associated with a unique chemical distribution at the dislocation core. Our bulk and in-situ heat treatments showed that the growth behaviours of $\gamma'$ precipitate phase can be totally changed with different types of interfacial dislocations. This study points a direction of controlling precipitation via engineering the defect structures at interfaces.

1. Polmear, I. J., *Nature* 186.4721 (1960): 303-304.
2. Rosalie, J. M., and Bourgeois, L., *Acta Materialia* 60 (2012): 6033-6041.
3. Kang, S. J., Kim, Y. W., Kim, M., & Zuo, J. M., *Acta Materialia* 81 (2014): 501-511.
4. Zhang, Z, Bourgeois. L., Rosalie, J. M. and Medhekar, N. V., *Acta Materialia* 132 (2017): 525-537.

The authors acknowledge funding from the Australian Research Council (LE0454166, LE110100223), the Victorian State Government and Monash University for instrumentation, and use of the facilities within the Monash Centre for Electron Microscopy. Authors also gratefully acknowledge the computational support from Monash Sun Grid cluster, the National Computing Infrastructure and Pawsey Supercomputing Centre. LB and NM acknowledge the financial support of the Australian Research Council (DP150100558). ZZ is thankful to Monash University for a Monash Graduate Scholarship, a Monash International Postgraduate Research Scholarship and a Monash Centre for Electron Microscopy Postgraduate Scholarship.

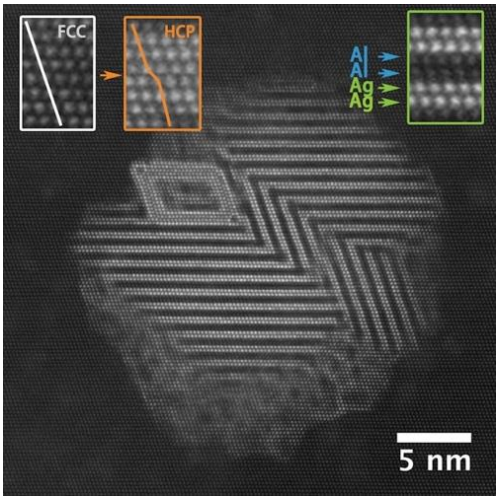


Fig.1. Atomic resolution HAADF-STEM image showing the bi-layered ζ phase is different from the known FCC and HCP structures [4].

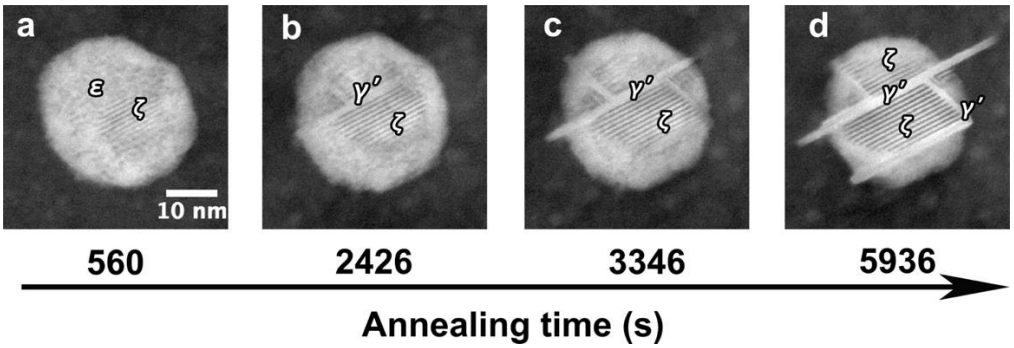


Fig.2. In situ HAADF-STEM images showing the time-resolved ε-ζ-γ' phase transformation while annealing the Al-1.7at.%Ag sample at 150°C [4].

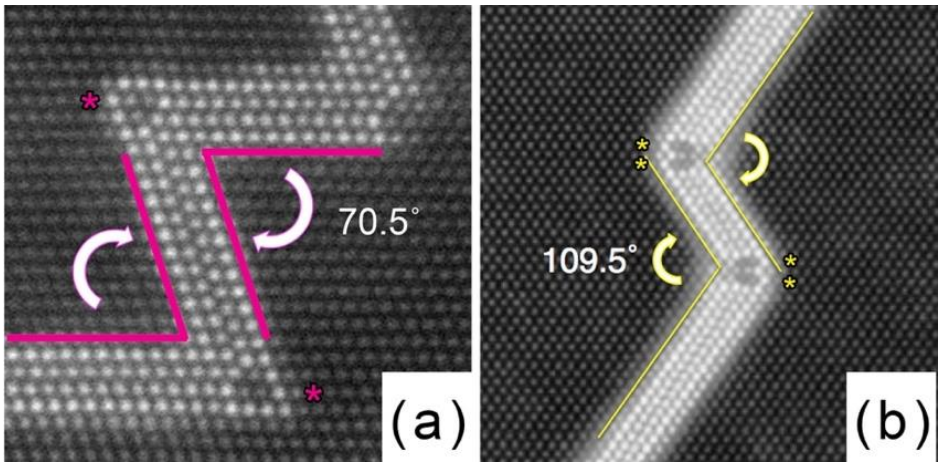


Fig.3. γ' precipitate assemblies with (a) Lomer-Cottrell dislocations and (b) Hirth dislocations at the precipitate-precipitate junctions.