



# Local decomposition induced by dislocation motions inside precipitates in an Al-alloy

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Dislocations in crystals are linear crystallographic defects, which move in lattice when crystals are plastically deformed. Motion of a partial dislocation may remove or create stacking fault characterized with a partial of a lattice translation vector. Here we report that motion of partial dislocations inside an intermetallic compound result in a local composition deviation from its stoichiometric ratio, which cannot be depicted with any vectors of the primary crystal. Along dislocation slip bands inside the deformed  $\text{Al}_2\text{Cu}$  particles, redistribution of Cu and Al atoms leads to a local decomposition and collapse of the original crystal structure. This finding demonstrates that dislocation slip may induce destabilization in complex compounds, which is fundamentally different from that in monometallic crystals. This phenomenon of chemical unmixing of initially homogeneous multicomponent solids induced by dislocation motion might also have important implications for understanding the geologic evolution of deep-focus peridotites in the Earth.

Precipitate hardening and dispersion strengthening have been widely applied in many engineering materials, in which small particles of second phase (usually with complex crystal structure) play critical role in resisting dislocation motion in the matrix. In case of precipitate hardening, the hardness or yield strength of an alloy, which was experienced a higher temperature solution treatment, increases with the presence of small-sized precipitation and these precipitates usually have coherent or semi-coherent interface with the matrix. In contrast, in dispersion strengthening alloys, dispersed second phases usually do not have coherent interface with the matrix, such as  $\text{Al}_2\text{O}_3$ -reinforced Al composites. Quantity, morphology, and distribution of these small particles are of critical importance in tuning mechanical properties of the materials. However, in the past decades, more and more experimental observations indicate that the small-sized second phase can be decomposed during plastic deformation, leading to degradation of material properties. For instance, when Al-Cu alloys with  $\theta'$  precipitate is plastically deformed at ambient temperature, dissolution or decomposition of the precipitates was detected<sup>1,2</sup>. Such a phase dissolution induced by plastic deformation has been observed in various Al-alloys in which precipitates play a crucial role in mechanical performance of the alloys, such as  $\text{Al}_{13}\text{Fe}_4$  particle in Al-Fe<sup>3</sup>,  $\beta'$ -phase in Al-Mg-Si<sup>4</sup>,  $\gamma'$ -phase in Al-Ag<sup>5</sup>,  $\eta'$ -phase in Al-Zn-Mg<sup>6</sup> and  $\delta'$ -phase in Al-Li alloy<sup>7,8</sup>. In addition, steels provide another example where deformation-induced phase dissolution has been recognized for decades. When a pearlitic steel (consisting of cementite ( $\text{Fe}_3\text{C}$ ) and ferrite) is plastically deformed at ambient temperature,  $\text{Fe}_3\text{C}$  particles are found to refine and dissolve<sup>9–12</sup>, typically in heavily cold drawing of pearlitic steels for producing extraordinarily strong wires<sup>13</sup>.

The dissolution of the strengthening particles in engineering alloys under mechanical loading unavoidably leads to a detrimental consequence in the designed microstructure and performance of the materials. Stability control of the strengthening particles relies on a thorough understanding of the mechanism of dissolution, in which the behavior of dislocations is believed to be the central issue. Interactions between dislocations and small particles have been extensively studied and several mechanisms have been proposed, such as Orowan mechanism<sup>14–16</sup> and cutting mechanism<sup>17,18</sup>. In addition, particular attention has been paid to the interface between second phase and matrix<sup>9–11,19–22</sup>. Although it is known that motion of partial dislocation in ordered structures may remove or create anti-phase boundaries, dislocation behaviors inside the precipitates with complex structures like those in Al-alloys are not well understood. Dislocation structure at atomistic scale (particularly at the core of a dislocation) is crystal structure-dependent. Hence, dislocation dynamics in complex structures may differ fundamentally from that in monometallic lattices.