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Dislocation processes accompanying the Portevin-Le Chatelier effect in Al–Mg alloys

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ABSTRACT

Aluminum alloys have great potential to replace steels in automotive structures and closure applications. However, formability limitations continue to remain an obstacle in their widespread usage. Solute strengthening in AA5000 Al–Mg alloys can be exploited to increase ductility and strength simultaneously, but dynamic strain ageing and negative strain rate sensitivity in these alloys lead to Portevin-Le Chatelier (PLC) instability and cause premature failure. PLC instability is associated with the diffusion of Mg atoms to dislocations and dislocations moving away from diffusing Mg atoms, resulting in plastic strain occurring in bursts. Macroscopically, the PLC effect has been well characterized. The underlying dislocation structures and atomistic mechanisms responsible for dynamic strain ageing have not been well understood and is the subject of this study. In this investigation, AA5754 sheets have been strained in situ in the scanning electron microscope and the transmission electron microscope (TEM). Combined electron backscatter diffraction and electron dispersive X-ray spectroscopy analyses show high local Mg concentration regions to correlate well with high dislocation densities. In situ TEM straining data show that glissile dislocations contribute to both nucleation and dissolution of small Mg clusters and precipitates. Electron tomography data show the dynamic nature of the dislocation network of glissile and sessile dislocations. The implications of these observations on the mechanism governing the PLC effect in Al–Mg alloys and the current theories of dynamic strain ageing in Al–Mg alloys will be discussed.