A novel design of hot rolled Al-Cu alloy through ordered $L1_2$ precipitates by minor addition of Nb and Zr

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High strength Al alloys are becoming increasingly important due to their application in aerospace and automotive industries. Dense and uniform precipitation of nanoparticles has been recognized as one of the most effective methods to increase the strength of the alloy as they impede dislocation motion [1]. However, coarsening of the precipitates reduces their high temperature applicability. Our recent efforts aim at overcoming this and improve the elevated temperature strength of Al alloy through sequential precipitation of an ordered precipitate during at high temperature followed by the precipitation of strengthening phase through heterogeneous nucleation. The remarkable coarsening resistance of these alloys lead to relatively good mechanical properties at temperatures beyond 150ºC to 250°C.

Our initial microstructural studies on cast Al-Cu-Nb-Zr alloys using both Transmission electron microscope and 3DAPT show that heterogeneous nucleation of θ″ or θ′ precipitates during aging on Al_3Zr that has formed previously at high temperatures on direct aging of the casting can lead to an impactful increase in room temperature as well as high temperature strength [2,3]. However, efficacy of such microstructural design for rolled product has not been investigated. In order to explore, we have taken composition similar to our previous studies and cast in a water cooled copper mould in the form of 3 mm thick strips using suction casting technique. The 3mm cast strips are hot rolled at 450℃ followed by water quenching. A 40% reduction is given in a single pass. Subsequent heat treatment process involves a solution treatment at 535°C for 30 min and ageing treatment at 190 °C.

Hot rolling of the cast alloy leads to the direct formation of $L1_2$ precipitates in the matrix. A representative STEM image is shown in Fig. 1. Nano-meter sized coherent precipitates in the matrix help to increase the hardness value by about 450 MPa as compared to as-cast condition. The short solution treatment at 535℃ does not dissolve the ordered precipitates. However, Cu concentration increases in the Al matrix during the treatment. At the time of ageing at 190℃, metastable θ″ and θ′ start precipitating and microstructure become stable after certain time. These precipitates nucleates on pre-existing $L1_2$ precipitates as shown in Fig. 2. Composition and phase mapping by transmission electron microscopy have been used to characterize the morphologies of these precipitates that indicate heterogeneous nucleation of the θ"/θ"" precipitates on the ordered nanometric Al_3Zr particles. This complex microstructure slows the coarsening kinetics. The possible reduction of interfacial strain energy based on the synergistic effect of θ′/θ″ and $L1_2$ precipitates and segregation of Zr may lead to enhanced strength and thermal stability of this class of alloys alloys.

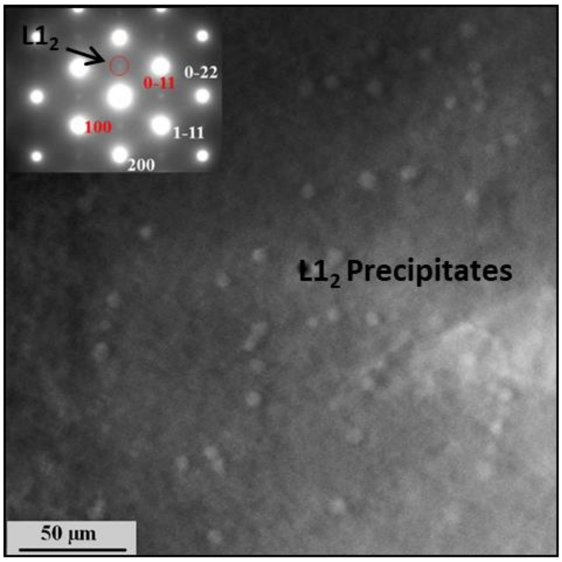

Fig. 1: A representative HAADF dark-field image showing $L1_2$ precipitates and SAD pattern along the [011] zone axis in the inset.

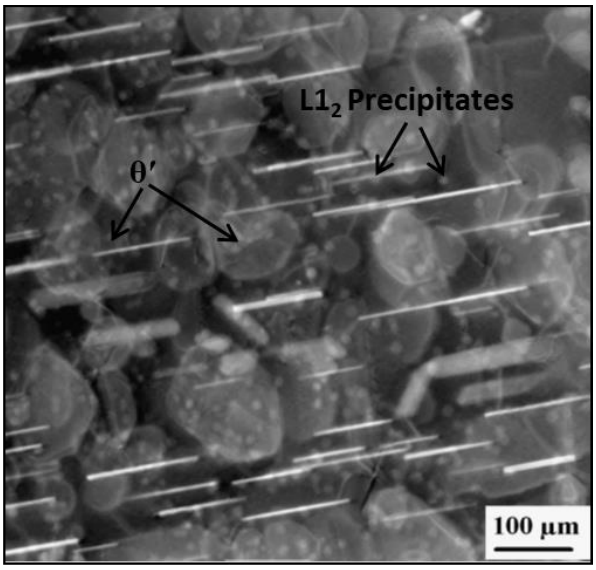

Fig. 2: A representative HAADF image showing heterogeneous precipitation of θ″ and θ′ precipitates on Al_3Zr.

References

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