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Designing and characterizing a complex concentrated gamma/gamma prime 'superalloy'

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Complex concentrated alloys (CCAs), a more general class of high entropy alloys (HEAs) are often near equi-atomic alloys with at-least five different principal components [1,2]. The recently exploding interest in HEAs/CCAs has led to various complex alloy compositions being prepared, characterized using different techniques, and mechanically tested. Though HEAs were initially proposed to have only a single random solid solution phase, in many cases these were found to have ordered intermetallic phases that could in fact be potentially useful for high temperature applications of these complex systems [3]. Hence the motivation of this study is to design HEAs/CCAs containing strengthening ordered $L1_2$ precipitates in an fcc matrix (the architecture of nickel or cobalt base super-alloys) [4]. This study focuses on a detailed atom probe tomography (APT) using Imago LEAP 3000X HR Atom Probe Microscope, coupled with high resolution transmission electron microscopy (FEI Tecnai G2 F20 HRTEM) investigation of fcc/$L1_2$ HEA systems. Two systems will be discussed, $Al_{0.3}CoCrFeNi$ and $Al_{0.3}CuCrFeNi_2$. These alloys have been melt-processed and subsequently heat-treated to develop an appropriate gamma + gamma prime (fcc+$L1_2$) microstructure [4].

The temperature/time evolution of the chemistry, structure, and morphology of the gamma prime precipitates has been studied. The experimental observations suggest that the main elements responsible for gamma prime formation in the $Al_{0.3}CuCrFeNi_2$ alloy are Ni, Al and Cu. Elemental partitioning observed in the APT suggest that the stoichiometry of the precipitate is $(Ni,Cu)_3Al$ as can be seen in Figure 1 (d).

A very fine precipitation of L_{12} ranging from 5 to10 nm diameter was observed after aging at 550 ^{o} C for 150 h in Al0.3CuCrFeNi alloy as shown Figure 2 by TEM and APT. Precipitation of this semi-coherent phase resulted in increase of tensile strength by 1.4 times compared to the unaged condition.

A systematic and detailed analysis coupling Scanning electron microscopy (SEM), site specific lift out by using Focus Ion Beam (FIB), FEI and APT and thereafter a comparison of mechanical properties will be will be presented.

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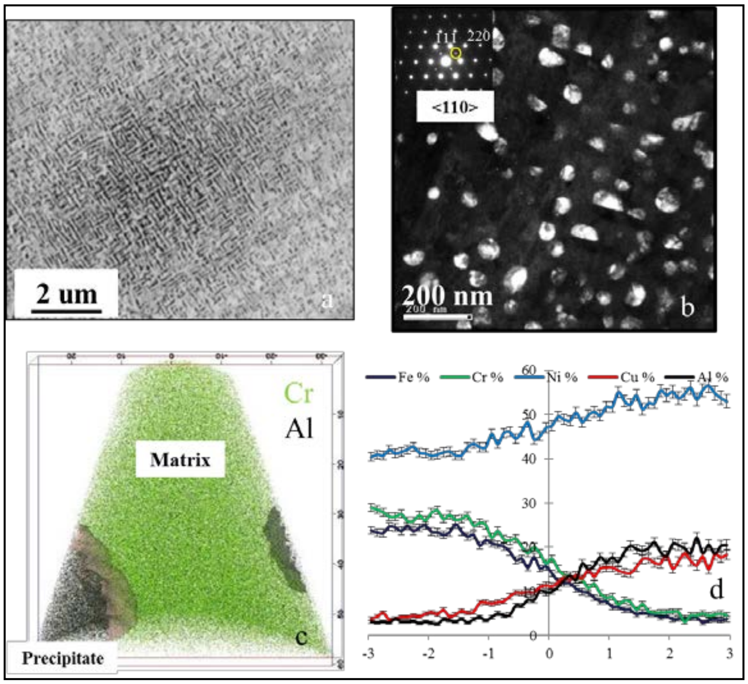

Figure 1. $Al_{0.3}CuCrFeNi_2$ alloy aged at 700 °C for 48 h (a) SEM BSED image showing gamma-gamma prime microstructure (b) TEM Centered DF image obtained by choosing the ½<220> superlattice spot from the [110]ZA SAED pattern shown in the inset (c) APT ions map showing the matrix and precipitate and (d) proximity histogram showing the partitioning across a 10% Al interface.

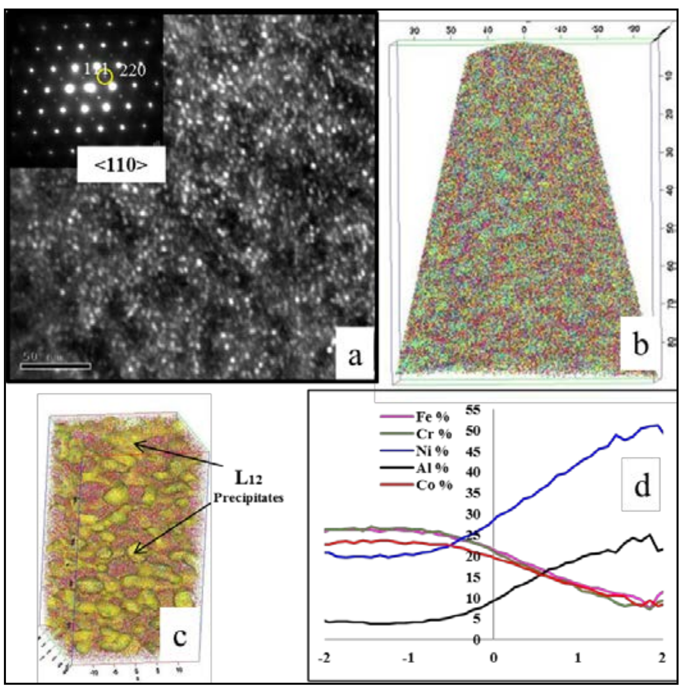

Figure 2. $Al_{0.3}CoCrFeNi$ alloy aged at 550 °C for 150 h (a) (a) TEM Centered DF image obtained by choosing the super-lattice from the SAED pattern shown in the inset (b) A 60nm by 30nm by 30 nm slice APT ions map showing the matrix and precipitate and (c) proximity histogram showing the partitioning across a 9% Al interface.

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