doi:10.1017/S1431927614006667
Microsc. Microanal. 20 (Suppl 3), 2014

Multi-Scale Characterization of Different Generations of Gamma Prime Precipitates in Nickel-based Superalloys Using Correlative Microscopy Techniques

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Nickel-based superalloys have been widely used for elevated temperature applications such as turbine disc of jet engines due to their excellent mechanical properties. The typical microstructure of these alloys primarily consists of dispersed precipitates of the ordered γ' phase with $L1_2$ structure within a disordered face-centered cubic γ matrix. The γ -γ' microstructure in these alloys can be controlled via a combination of composition and cooling rate from the high temperature single γ phase field during processing. Typically during continuous cooling from γ'supersolvus temperature, various size scales of γ' precipitates are formed, primarily due to multiple nucleation events occurring at various temperatures in the γ -γ' regime [1,2]. The complex interplay between thermodynamic and kinetic factors lead to the formation of a complex microstructure consisting of a multimodal size distribution of γ' precipitates (often consisting of three different distinct size distributions ranging from microns to nanometers) and γ' precipitate-free zones, within the γ matrix. The precipitates not only differ in their size and morphology but also in nucleation density and compositions. The resulting morphology, volume fraction, size distribution of these γ' precipitates determine the mechanical properties of these alloys [3,4].

In this study, a unique coupling of three independent characterization techniques, scanning electron microscopy (SEM), energy-filtered transmission electron microscopy (EFTEM), and atom probe tomography (APT), has been employed to determine the multimodal size distribution of γ' precipitates during continuous cooling of nickel-based superalloys. All three techniques have been applied to the same alloy. Thus while the larger primary γ' precipitates have been characterized by SEM, the EFTEM technique was employed to characterize and quantify the secondary γ' precipitates. Furthermore, the APT technique was used to find out the 3D morphology and compositional variations within the most refined nano-scale tertiary γ' precipitates. Particle size distributions of all three types of these γ' precipitates, i.e. primary, secondary, and tertiary have been plotted as a function of diameter. Results showed that different generations of γ' precipitates exhibit different morphological and compositional characteristics.

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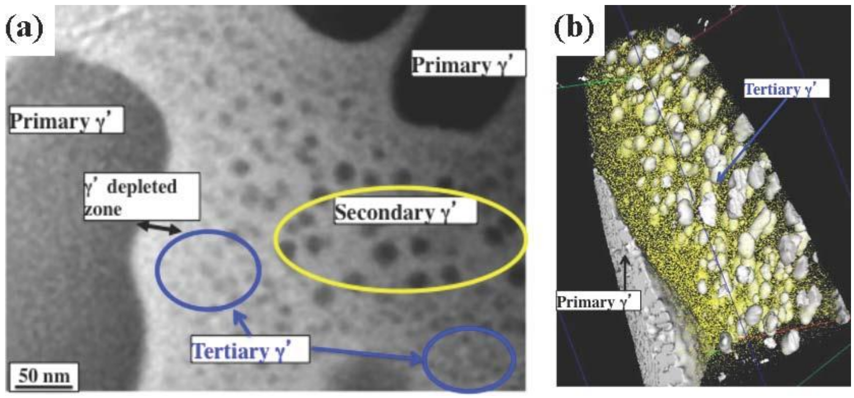

Figure 1. (a) Energy-filtered TEM image (using Cr M-edge), and (b) APT reconstruction showing three distinct γ' generations present in the γ matrix of a commercial Nickel base superalloy, Rene88DT.

https://doi.org/10.1017/S1431927614006667 Published online by Cambridge University Press