

## HRTEM and electron holography studies of strengthening particles in Inconel 718 superalloy

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The aim of this work was visualisation and quantitative analysis of  $\gamma'$  and  $\gamma''$  strengthening precipitates in a commercial nickel-base superalloy Inconel 718 (Ni-19Fe-18Cr-5Nb-3Mo-1Ti-0.5Al-0.04C, wt %) using HRTEM and electron holography imaging.

The microstructure of the IN718 superalloy consists of  $\gamma'$  and  $\gamma''$  coherent nanoparticles homogeneously distributed in the  $\gamma$  matrix. The main problem of particle size measurements in the case of coherent nanoparticles is the use of appropriate imaging conditions. For  $\gamma'$  and  $\gamma''$  particles in Fe-Ni superalloys, the additional problem is the identification of both phases. Because  $\gamma'$  and  $\gamma''$  precipitate as particles lying on the  $\{1\ 0\ 0\}$  planes of the  $\gamma$  matrix, the selected area diffraction patterns of  $\gamma$ ,  $\gamma'$  and  $\gamma''$  are very complicated. In the previous work of the authors [1], the electron diffraction and TEM dark-field imaging conditions, which should be used for visualization of  $\gamma'$  and  $\gamma''$  particles, were described. The same diffraction conditions were also applied for identification of  $\gamma'$  and  $\gamma''$  particles using HRTEM images taken for  $[001]\gamma$  zone axis. The inverse FFT of  $\gamma''$  reflections (single reflection reconstruction) showed  $\gamma''$  particles, while the same procedure for superposed  $\gamma''$  and  $\gamma'$  reflections showed the precipitates of both phases. The  $\gamma''$  particles exhibit a disc shape, while  $\gamma'$  phase precipitates are spherical. The mean diameter of  $\gamma''$  and  $\gamma'$  particles was  $\bar{D} = 12$  nm and  $\bar{D} = 4$  nm, respectively.

The another method used for visualization of  $\gamma'$  and  $\gamma''$  particles was electron holography. On reconstructed phase images particles are visible due to the differences of mean inner potential of  $\gamma'$ ,  $\gamma''$  and  $\gamma$  phases. Unfortunately, using a microscope equipped with Lorentz lens for holography experiments, it was not possible to use the similar diffraction conditions, as those applied for conventional TEM and HTREM imaging, and in consequence to distinguish  $\gamma'$  and  $\gamma''$  particles on phase images. Further studies are in progress.

### References

1. E. Stepniowska, D. Geiger, G. Cempura, B. Dubiel, A. Czyrska-Filemowicz –“Quantification and 3D visualisation of strengthening particles in INCONEL 718 superalloy”, Proc. XIII Int. Conference on Electron Microscopy EM'2008, Zakopane, Poland, 8–11 June 2008, Akapit, Krakow 2008, p.159

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