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Imaging and Characterization of the Microstructure and a Deformation Mechanism of Commercial Nickel Based Superalloys γ' in a Nickel-Based Superalloy using Energy Filtered Transmission Electron Microscopy

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The improvements of creep strength of nickel-based superalloys are becoming increasingly important particularly with regards to disk alloys because of the advances in their fatigue properties; preponderating the service-life limiting property towards creep. In this instance it is the microstructure and operative deformation mechanism that determine the creep strength of the nickel-based superalloys and, as such, realistic physically-based computer models are validated and calibrated based on experimental data from this microstructural information.

There are a number of complex creep deformation modes that can affect the creep strength of these disk alloys and the dominant operative mode depends not only on stress and temperature but also on microstructure. This has been evidenced particularly with regards to a recent study, which had shown that dramatic improvements in creep strength for a given stress and temperature regime can be achieved by changing the operative deformation mechanism simply by altering the microstructure. Work by Viswanathan et al. [1] has shown compelling evidence using ‘g dot b’ analysis that the creep mechanism is that postulated by Kolbe [2]. Therefore, the effectiveness of the physically-based creep model relies on two important concerns: the accuracy of the experimentally determined microstructural information and the precise characterization of the deformation mode.

Recent work [3] has shown that microstructures consisting of multi-modal size distributions of γ (Ni_3Al) precipitates in a γ (FCC) matrix provide the best combination of tensile and creep strength.
The size distributions and volume fractions of secondary and tertiary γ are usually determined directly from either cross-sectional 2D images, usually from secondary electron micrographs of slightly etched surfaces taken on the SEM, or from projected areal fractions of the microstructure from the 3D volume in a TEM foil. Previous work has shown that secondary γ (average size > 30nm) can be imaged accurately and easily using SEM but precise imaging of the smaller tertiary γ using TEM has so far proved both difficult and time consuming. The purpose of this study was to select an imaging technique which best enables rapid and extensive acquisition of microstructural datasets of small γ precipitates from “real” multi-component engineering alloys.

In order to determine the creep deformation mode it was critical to identify the magnitude of the burgers vector of the partial dislocations that form the microtwins that are the dominant creep deformation mechanism. By comparing the superlattice image contrast from HRTEM images and HRES image simulations of the stacking faults viewed from different [110] directions relative to the burgers direction it was possible to conclusively identify that the stacking fault was a Complex Stacking Fault (CSF) and therefore that the partial dislocation that created it was a 1/6[112] type Shockley type (see Figure: 2). This confirmed and supported the compelling evidence from Viswanathan et al that the deformation mechanism was that postulated by Kolbe [2].

In summary, this study involved the use of two Transmission Electron Microscopy (TEM) techniques to satisfy both the issues of the creep model’s calibration and validation requirements; in the first instance an alternative imaging technique, namely, Energy Filtered Transmission Electron Microscopy (EFTEM) was used (see Figure 1) to enable faster and more accurate acquisition of experimentally determined microstructural data than had previously been achieved using conventional imaging techniques [4]; in the second instance, High Resolution Electron Microscopy (HRTEM) in conjunction with HRTEM image simulations was, for the first time used to support the work by Viswanathan et al. [1] in conclusively identifying a recently observed creep deformation mode posited by Kolbe [2] utilizing superlattice image contrast .

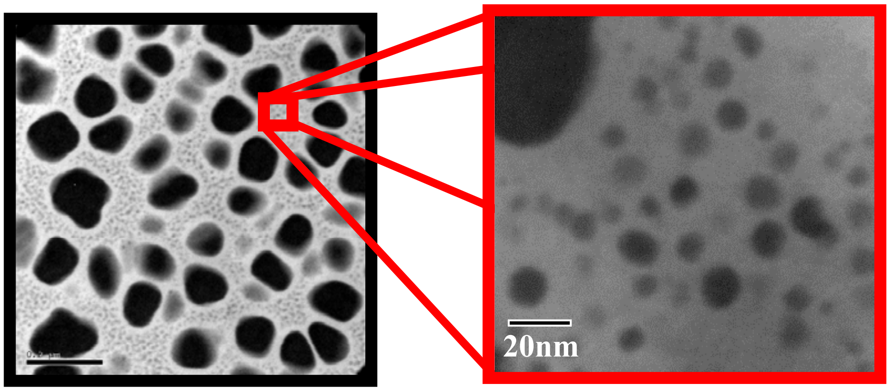

Figure 1: EFTEM elemental using the Cr L-edge showing the bi-modal distribution of γ’ precipitates and the sharply imaged fine tertiary γ’.

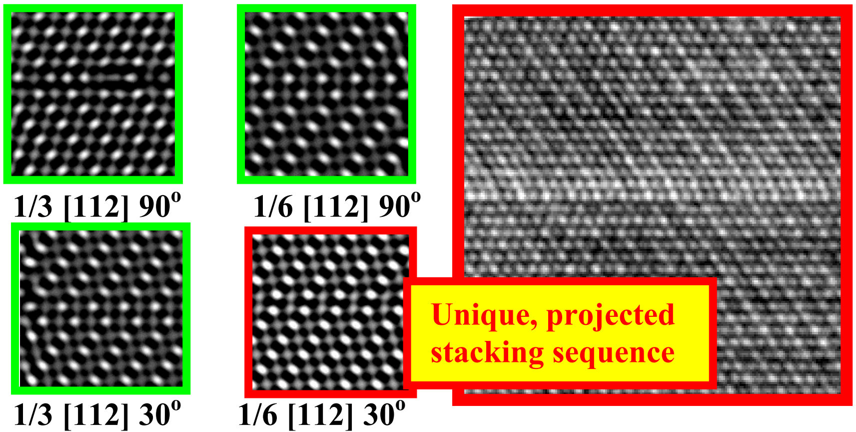

Figure 2: HRTEM image simulations (left) showing the superlattice image contrast of a superlattice intrinsic stacking fault (SISF) formed by a 1/3[112] type super Shockley and a Complex Stacking Fault formed by a 1/6[112] type Shockley partial dislocation viewed at 30^{o} and 90^{o} to the burgers vector.

References
[1] G.B. Visanathan, P.Sarosi, D. Demania and M.J. Mills, *Acta Met.* (2005), In Press
[2] M. Kolbe, *Mat. Sci. En.g A* (2001) 319
[3] S.T. Wlodeck, M. Kelly and D.A. Aiden, *Superalloys* 1996, R.D. Kissinger et al editors, TMS-AIME , Warrendale PA, (1996) 129
[4] P.M. Sarosi, G.B. Viswanathan, D. Demania, and M.J. Mills, *Ultramicroscopy* (2005), In Press