DOI: 10.1017/S1431927605508511
Microsc Microanal 11(Suppl 2), 2005

Characterization of γ–γ' Interfaces in Ni Base Superalloys Subject to Creep Deformation by Conventional TEM and HREM

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Single crystal nickel-based superalloys are widely used as turbine blades and vane materials in aircraft engines due to their outstanding strength and low deformation rate during high temperature creep. These alloys are made of a disordered f.c.c. γ matrix, strengthened by a high volume fraction (up to 70%) of $L1_2$ γ' precipitates. The main microstructural evolution experienced by the rotating blades during service at temperatures higher than 950°C, is the directional coarsening of the γ' precipitates, which leads up to a γ-γ' rafted microstructure. It is a stress-aided diffusion-controlled process that depends on the magnitude, direction and sign of the applied stress, and in a first approximation on the value and sign of the γ-γ' misfit parameter. It is known that the level of the internal coherency stresses created near the γ/γ' interfaces are of the order of magnitude of the applied stress at high temperature creep. In order to relax these coherency stresses, dislocation networks are created at the γ/γ' interfaces after prolonged aging or during high temperature creep deformation. Several questions still remain unanswered, in particular, whether or not these networks act as traps for moving dislocations, thus contributing to strengthening of the material; or on the contrary they act as dislocation sources, therefore contributing to its softening. Here, a detailed analysis of the dislocation networks is performed. Particular attention is paid to the local characterisation of interfaces orientation and its impact on the high temperature creep of the material.
High resolution and conventional electron microscopy is used to investigate rafted microstructures as a function of creep deformation at 1050 °C and under a stress of 150 MPa. Fig. 1 shows the microstructural development as a function of creep time. The cuboidal morphology of γ' particles evolves into elongated rafts perpendicular to the tension axis. Fig. 2 shows a bright field image of the dislocation networks formed during high temperature deformation. Such dislocation tangles are investigated to determine dislocation mechanisms of deformation. Fig. 3 shows a typical high resolution image of the particle matrix interface along a [001] zone axis and the corresponding inverse Fourier transform image after selecting a (001) superlattice reflection. The character of the dislocations as well as the phase where they are situated can be determined from such images. In addition the HREM images have been used (after a procedure based on electron exit wave reconstruction) to determine the strain fields at the interface and around dislocations. EDS analysis is used to determine elemental migration and variation of strain fields as a function of creep deformation.

Acknowledgements
This work was supported by several ONERA contracts and an ECOS program. HAC acknowledges support from IPN (COFAA and CGPI). NCEM-LBNL is gratefully acknowledged for the use of microscopes

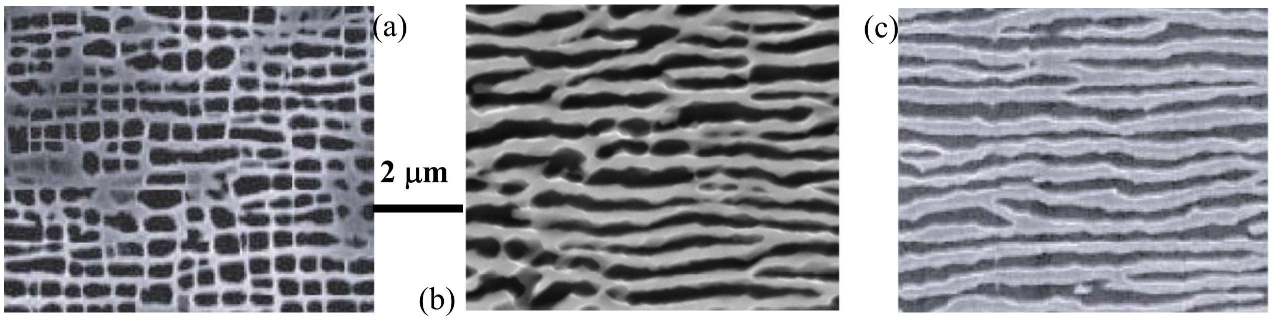
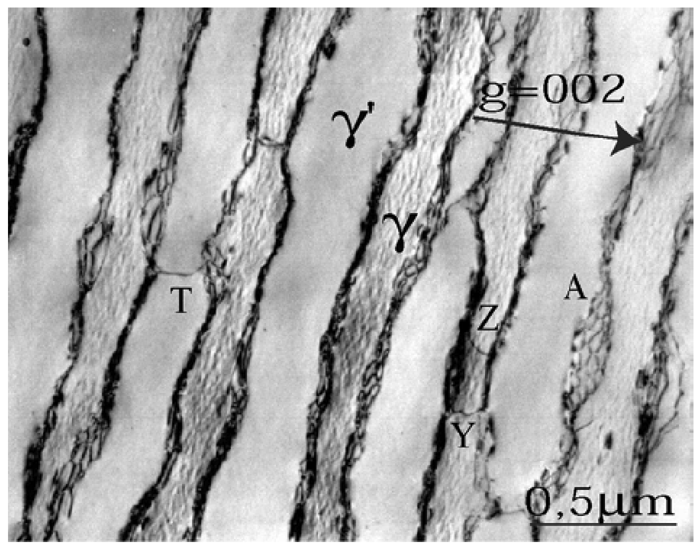


Fig. 1. MC2 Ni base superalloy after creep deformation at 1050 °C and 150 Mpa. (a) 0 h, (b) 20 h and (c) 120 h under stress.

Figure 2. Rafted microstructure in MC2 alloy crept at 1050 °C and 150 MPa (stress axis parallel to [001]) after 20h of creep



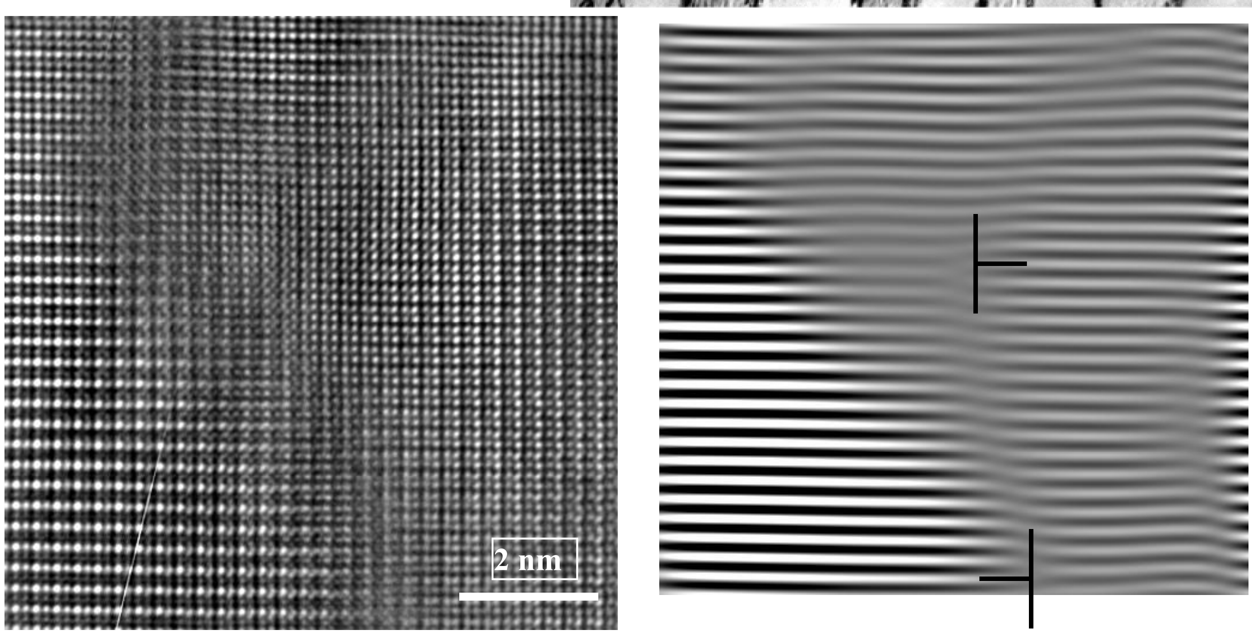


Figure 3. (a) High resolution electron microscopy image of γ–γ' interface in MC2 alloy after 20 h of creep deformation at 1050 C. (b) Dislocations ([001] type) are made readily visible in inverse Fourier transform image.

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