Alloys and Intermetallics

LBP.MS.P15
TEM analysis of localized, planar deformation events which govern creep of single crystalline CoNi-superalloys with γ/γ´-microstructures

Y. Eggeler[1], J. Müller[1], M.S. Titus[2], A. Suzuki[3], T.M. Pollock[2], E. Spiecker[1]

[1]Universität Erlangen-Nürnberg, Center for Nanoanalysis and Electron Microscopy (CENEM), Department for Material Science, Erlangen, Germany
[2]University of California Santa Barbara, Department for Material Sience, Santa Barbara, United States
[3]GE Global Research Center, One Research Circle, Niskayuna, NY 12309, United States

yolita.eggeler@ww.stud.uni-erlangen.de
Keywords: CoNi-Superalloys, Anti phase boundaries, Conventional Transmission Electron Microscopy,

In the present study we use transmission electron microscopy (TEM) to study the effect of creep on the microstructures of novel Co-based single crystal superalloys with γ (fcc) - γ´ ($L1_2$) microstructures [1]. The alloys investigated contain 30-39 at.% Ni [2], which was added to the Co-Al-W ternary system to expand the γ-γ´ phase field and to increase the γ'-solvus temperature [3]. Tensile creep experiments were performed along [001] at stresses of about 300 MPa, at 900°C to small strains (0.5 - 2%).

While crept Ni-base superalloys often exhibit superdislocation in the γ´-phase consisting of two closely dissociated superpartial dislocations connected by an antiphase boundary (APB) [4], the CoNi-alloys show large APBs produced by shearing of single superpartial dislocations. Different two beam conditions were performed using fundamental reflections and superlattice reflections for fault characterization by applying the invisibility criterion. In TEM samples with foil normal parallel to the tensile axis dislocations of type a/2 [011] and a/2 [01-1] are visible which cut the γ´ phase and create APBs (figure 1). Samples with foil normal perpendicular to the tensile axis reveal the presence of macroscopic planar faults extending over several precipitates on octahedral planes (see figure 2). Using higher magnifications one can observe, that these planar defects consist of APBs attached to stacking faults (SFs). By comparing bright-field (BF) micrographs showing only weak residual APB contrast with central dark-field (CDF) images taken with superlattice reflections, which provide good APB contrast, one can clearly locate the APBs, as demonstrated by figure 2 where for one precipitate the APBs are marked with continuous black arrows on both sides of the SF marked with a long dotted black arrow. Partial dislocations define the APB/SF-contact lines. A thicker part of a [110] oriented sample exhibit dislocation loops surrounding an inclined SF with a weak residual APB contrast (not shown). Based on the results mentioned above a first deformation mechanism is proposed where a single dislocation is cutting the γ'-precipitate. However, to further characterize the cutting process samples with [111] foil normal orientation will be prepared and analyzed by e. g. STEM and LACBED. Scanning transmission electron microscopy (STEM) permits analysis of extended TEM foil regions.

The present study contributes to a better understanding of these cutting events, which have not been frequently observed before and is discussed with reference to previous work published in the literature.

1. J. Sato et al," Science (2006), vol.312, p. 90
2. M. S. Titus et al, Scripta Materialia (2012), vol.66, p. 574
3. K. Shinagawa et al, Materials Transactions (2008), vol.49, p. 1474
4. A. Kostka et al, Journal of Materials Science (2007), vol.42, p. 3951
5. The authors gratefully acknowledge GE, NSF, and the DFG priority program SFB-TR 103 for financal support.

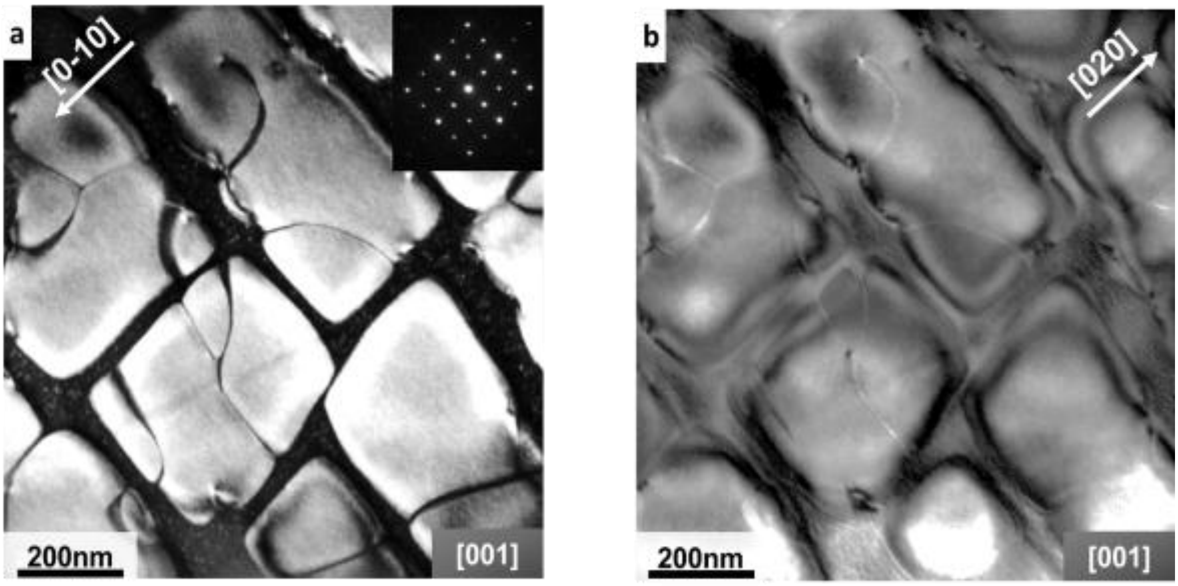

Figure 1. TEM micrographs of CoNi-A crept 0.5% under an applied stress of 310 MPa at 900°C (stress axis out of plane). a) Centered dark field image in two beam condition using superlattice reflection g=(0-10) presenting good APB contrast. b) Bright field image in two beam condition using fundamental reflection g=(020) showing dislocation contrast and weak residual APB contrast. Both micrographs were taken near Zone axis [001].

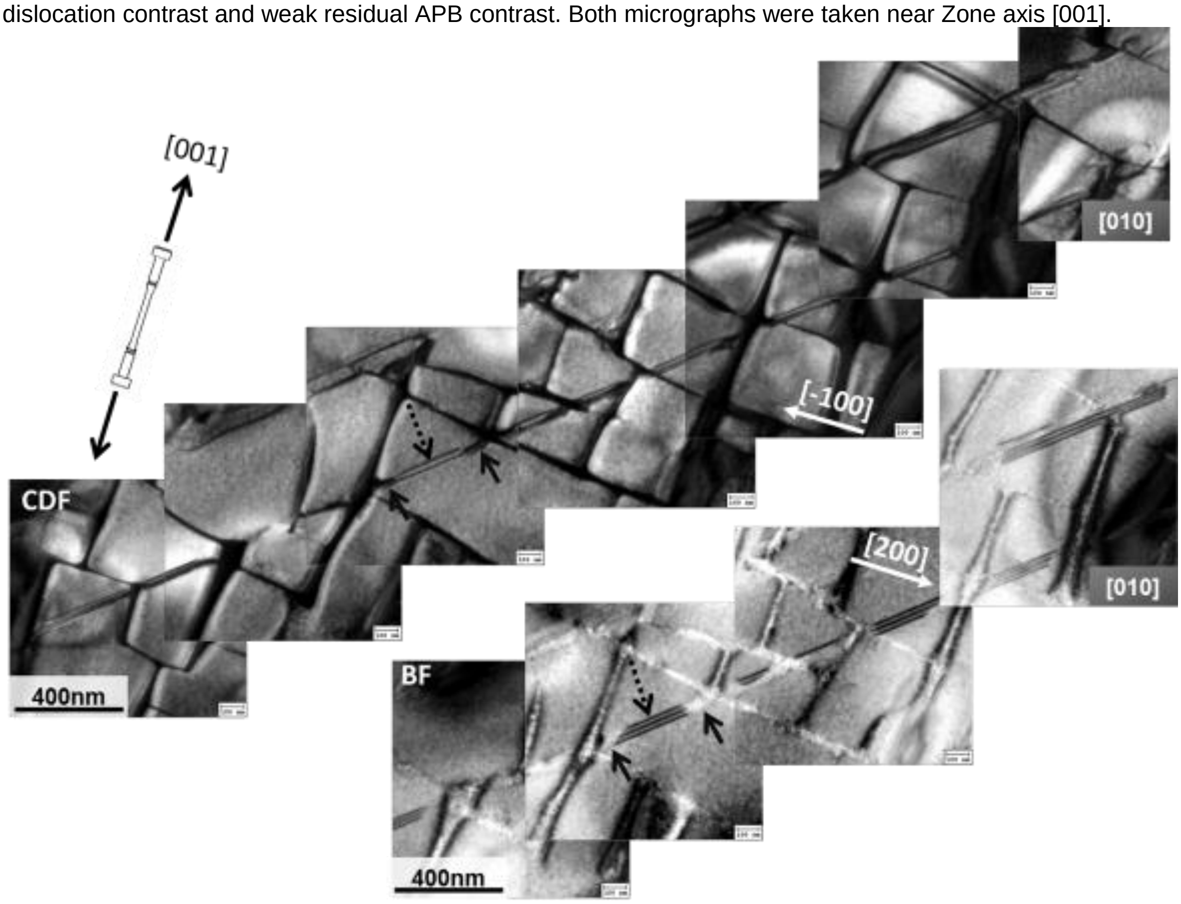

Figure 2. Montage of TEM micrographs shows macroscopic planar faults extended over several precipitates. The upper row of monatage was taken with [-100] superlattice reflection in CDF mode. The lower row of montages shows the corresponding BF contrast taken with the fundamental reflection g=(200). The long dotted arrow marks marks the SF contrast and the two continuous black arrows mark where the APBs are located for the same precipitate in CDF and BF mode. The tensile axis lies in the plane of the micrographs and is schematically drawn in the top left corner. Both modes were taken close to the [010] Zone axis.