Microsc. Microanal. 8 (Suppl. 2), 2002
DOI 10.1017.S1431927602103564

INFLUENCE OF W ON THE TEMPORAL EVOLUTION OF THE MICROSTRUCTURE OF A Ni-Al-Cr SUPERALLOY ON A NANOSCALE

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Due to the properties of native oxides of Cr and Al, Ni-Al-Cr base alloys have inherently good oxidation and corrosion resistance, and are among the most popular Ni-based superalloys. Their excellent mechanical properties are a direct consequence of the presence of $L1_2$-ordered precipitates of Ni_3Al (γ') in a Cr-rich Ni-Al solid-solution (γ). Employing three-dimensional atom-probe (3DAP) microscopy and kinetic Monte Carlo simulations, Schmuck *et al*. investigated the temporal evolution of γ'-precipitates in a Ni-Al-Cr alloy, with a low supersaturation of Al [1]. In this article, we report on the alloys Ni-10 Al-8.5 Cr (at. %) and Ni-10 Al-8.5 Cr-2 W (at. %), which have a high Al supersaturation, using 3DAP microscopy. Cast ingots are homogenized at 1300°C for 20 h and for 0.5 h about 50°C above the solvus temperature. We present results for: (a) water-quenched; (b) 0.25 h at 800°C; and (c) 264 h at 800°C aging states. From 3D atom-by-atom reconstructions, the elemental partitioning ratios and spatially resolved concentration gradients across γ' precipitates are obtained.

Spheriodal γ' precipitates 5-20 nm in size form during quenching in both Ni-10 Al-8.5 Cr and Ni-10 Al-8.5 Cr-2W (Fig. 1) and have a high number density (~10^{23} m^{-3}). After 0.25 h aging, the precipitates remain spheriodal in contrast to the 264 h aging state, which contain cuboidal precipitates. A decrease from 228 nm to 154 nm in average cube length results from the W addition indicating a reduction in the coarsening rate. In Fig. 1, the elemental distributions demonstrate that Al and W partition to γ', and Cr to γ. Elemental partitioning is quantified by the ratio of the precipitate concentration to the matrix concentration. The significant decrease resulting from the W addition in chromium's ratio for all aging states (Fig. 2) indicates that the W causes a stronger partitioning of Cr to γ, and may be a driving force for this result. However, W has only a small effect on the partitioning of Al and Ni. Partitioning of W increases with aging, and evolves more slowly than Al, which has the largest diffusivity in this alloy. Proxigram concentration profiles [2] obtained from the 3DAP analyses (Figs. 3 and 4) present, on a nanoscale, spatially resolved concentration gradients across the γ/γ' interface. For the as-quenched state of Ni-10 Al- 8.5 Cr, the proxigram in Fig. 3a shows a gradual decrease of Cr across the γ/γ' interface. In contrast to the aged states, whose Cr profiles are characterized by a sharp rise at the γ/γ' interface (Figs. 3b, 3c), clear partitioning of Cr occurs. Unlike the ternary alloy, clear Cr partitioning to γ is already present in the as-quenched state of Ni-10 Al-8.5 Cr-2W (Fig 4a). In the as-quenched and 0.25 h aging states, a concentration gradient of W exists within γ' (note arrowheads in Fig. 4). The influence of W on the chemistry of evolving γ' precipitates for Ni-10 Al-8.5 Cr is presented [3].

[1] C. Schmuck, P. Caron, A. Hauet, and D. Blavette, Phil. Mag. A **76**, 527-542 (1997).
[2] O. C. Hellman, J. A. Vandenbroucke, J. Rüsing, D. Isheim, and D. N. Seidman, Microsc. Microanal. **6**, 437-444 (2000).
[3] This research is supported by National Science Foundation DMR-972896 (CKS, DI & DNS) and NASA Glenn HOTPC (RDN).

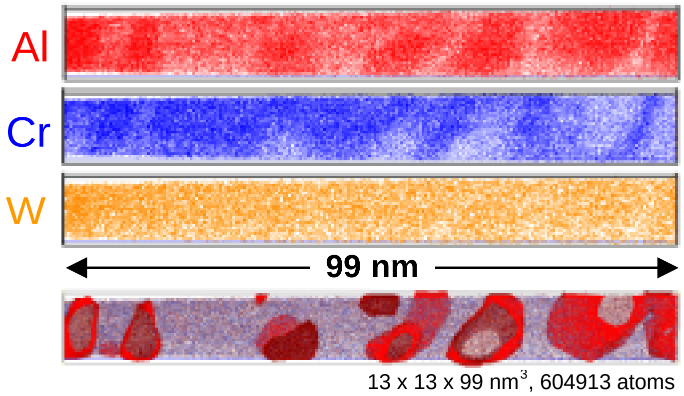

FIG. 1 - Three-dimensional distributions of Al, Cr and W atoms for as-quenched Ni-10 Al-8.5 Cr-2 W (at. %) showing elemental partitioning behavior to γ or γ'. 12 at.% Al isoconcentration surface in red reveals γ' precipitates with sizes 5-20 nm (*bottom*).

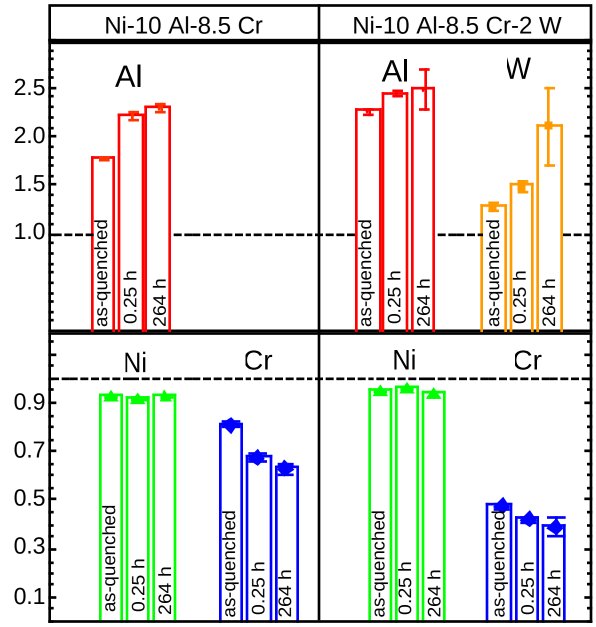

FIG. 2 - Partitioning ratios measured by 3DAP microscopy analyses of Ni-10 Al-8.5 Cr (*left*) and Ni-10 Al-8.5 Cr-2W (*right*) as a function of aging time– as-quenched, 0.25 h and 264 h at 800°C.

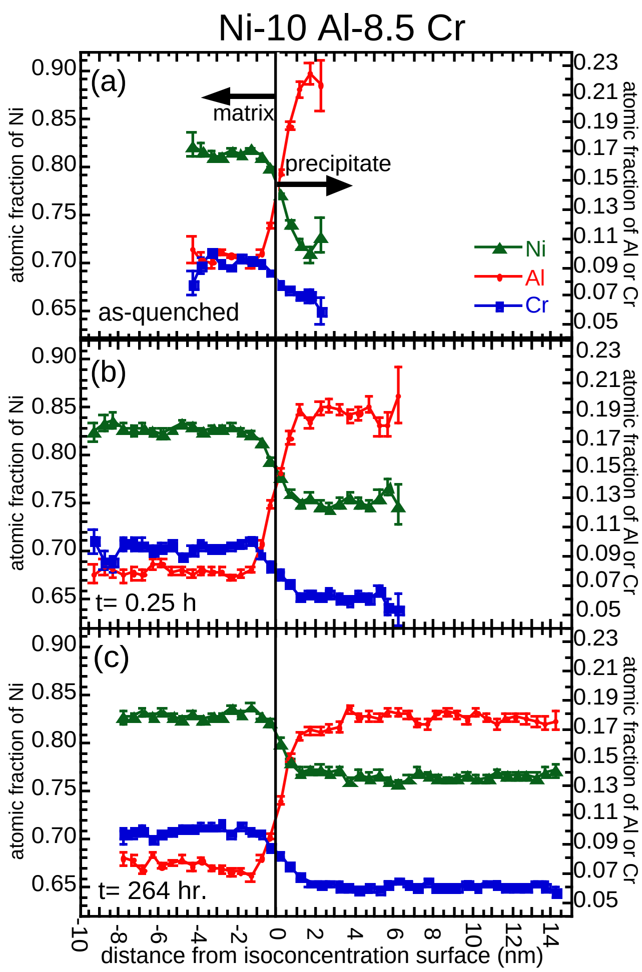

FIG. 3 - Proxigram concentration profiles across matrix-precipitate interfaces of the γ' precipitates in Ni-10 Al-8.5 Cr (at. %) after (a) quenching, after (b) aging for 0.25 h and (c) 264 h at 800°C.

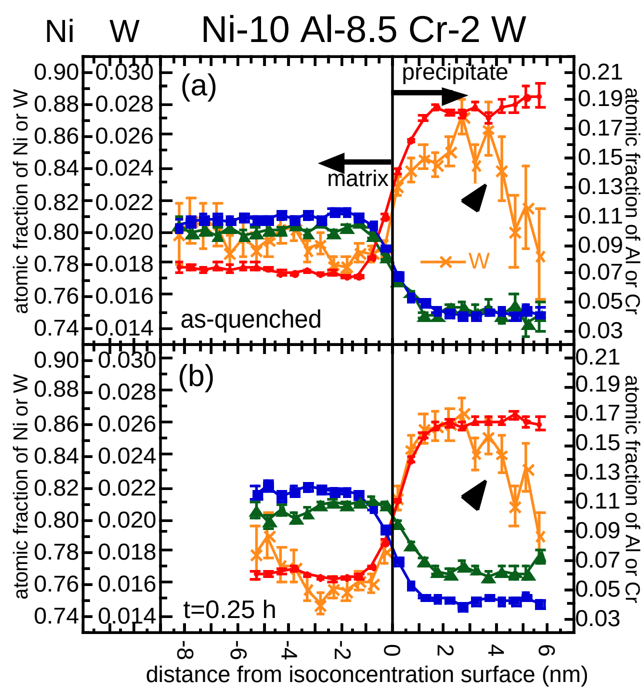

FIG. 4 - Proxigram concentration profiles across matrix-precipitate interfaces of the γ' precipitates in Ni-10 Al-8.5 Cr-2 W (at. %) after (a) quenching and (b) aging for 0.25 h at 800°C.

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