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Subnanoscale characterization of lamellar interfaces in a complex TiAl Alloy

S.S.A. Gerstl[1], Y.W. Kim[2], D.N. Seidman[1]

[1] Materials Science and Engineering Department, Northwestern University, Evanston, IL 60208
[2] Wright-Patterson Air Force Research Laboratory, Dayton, OH 45432

Titanium aluminides are of high interest due to their high-temperature mechanical stability and lightweight. Fine lamellar microstructures composed of alternating α_2 and γ lamellae, 10-30 nm thick, are a critical aspect of the overall microstructure because they provide high temperature creep resistance. Microalloying elements have been shown to form strengthening precipitates, refine the lamellar spacings, and improve creep and oxidation resistance. Little is known, however, concerning where all the alloying elements ultimately reside within the microstructure. We report on a unique experimental alloy, which has achieved high-temperature carbide strengthening above 840°C, which is approximately a 100°C improvement over conventional TiAl alloys (Y.W. Kim, unpublished). Creep resistance is due to both the carbide precipitates and additional microalloying elements. This article focuses on the latter mechanism with respect to the interface between α_2 and γ lamellae. A three-dimensional atom-probe microscope (3DAP) is utilized for analyzing this new complex TiAl alloy, which contains 3 at.% Nb, 1.5 at.% Cr, and 0.2 at.% each of B, C, Hf, Mn, W, and Zr. 3DAP microscopy is the only technique that can directly provide both subnanometer scale spatial resolution and atomic chemical information on such a complicated alloy.

A three-dimensional reconstruction of a small volume (19x19x318 nm^3) of alloy is displayed in Fig. 1, which was obtained employing a 3DAP microscope. The analysis direction is parallel to an α_2-γ lamellar interface. The compositions of the α_2 and γ phases are 60.4 ± 0.9 at.% Ti and 49.3 ± 0.7 at.% Ti respectively which is close to the stoichiometric compositions. The interface is defined by a 55 at.% Ti isoconcentration surface, from which the proximity histograms in Fig. 2 are calculated employing *ADAM* [2]. This analysis demonstrates the partitioning of all the elements in the system except boron, which was not detected because it resides in boride precipitates that are at a low number density and therefore not observed on the length scale of the present experiment. Carbon, Mn, and Cr partition to the α_2 phase, whereas Nb and Zr prefer the γ phase. These results are in agreement with previous 3DAP results performed on simpler TiAl alloys [3]. The partitioning behaviors of W and Hf on the α_2 side are similar. Both W and Hf exhibit concentration gradients within approximately 6 nm of the interface on the α_2 side and the near interfacial excesses are 1.4 atoms nm^{-2} and 0.6 atoms nm^{-2}, respectively. It has been suggested that W may provide an impurity drag effect [4], thereby reducing interface mobility. Hafnium has been shown to improve high temperature oxidation resistance and also improve secondary creep resistance (Y.W. Kim, unpublished). Thus it is suggested that Hf, or the combination of W and Hf as microalloying elements, provide an additional stabilizing effect for the lamellae structures at higher operating temperatures. Complimentary experiments are being performed to obtain similar atomic scale information on other matrix/precipitate interfaces in this unique system [5].

[1] R.V. Ramanujan, P.J. Maziasz, and C.T. Liu; Acta Mater. **44**, 2611(1996).
[2] O.C. Hellman, J.A. Vandenbroucke, J. Rüsing, D. Isheim, and D.N. Seidman, Microsc. Microanal. **6**, 437 (2000).
[3] D.J. Larson and M.K. Miller. Materials Characterization **44**, 159-176 (2000).

[4] D.J. Larson, C.T. Liu, and M.K. Miller. Intermetallics **5**, 497 (1997).
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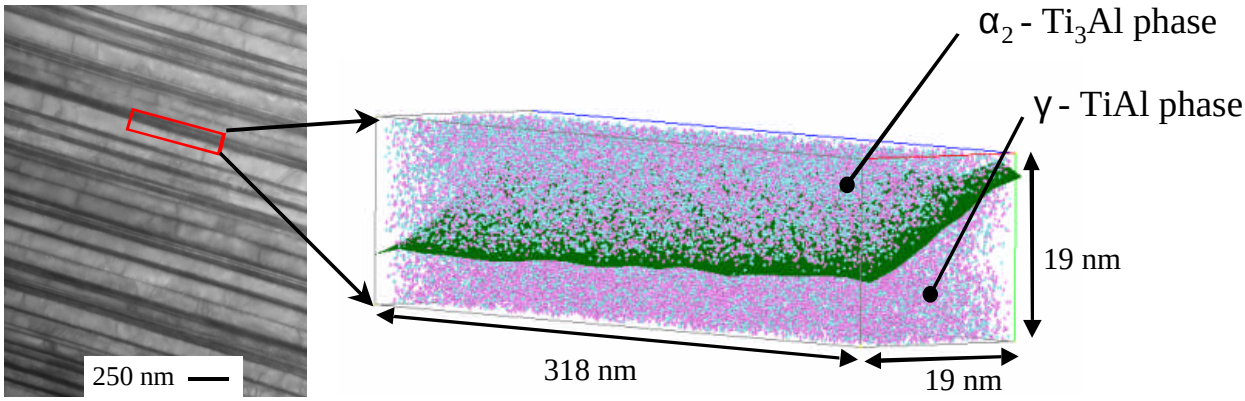

FIG. 1. A three-dimensional reconstruction of a 3DAP analysis (1,124,934 atoms) parallel to an α_2-γ interface derived from lamellar microstructure (TEM micrograph) shown at left. The color coding for the atoms is consistent with Fig. 2.; only the Cr and Nb atoms are displayed, while the other elements are not shown for the sake of clarity.

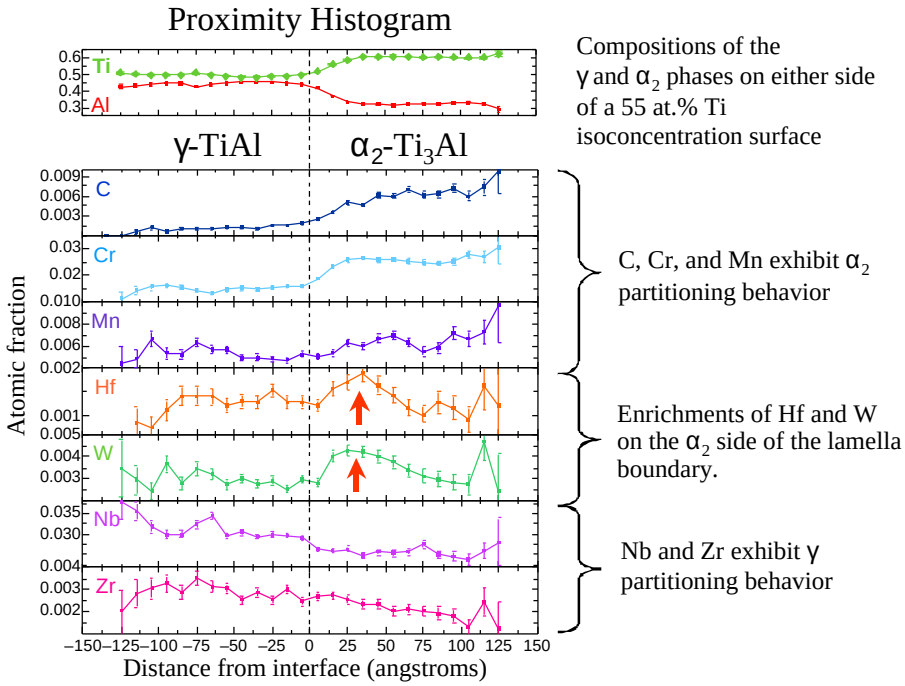

FIG. 2. The topmost graph is a proximity histogram for the Ti and Al concentrations of the γ and α_2 phases. The elemental distributions of the minority elements are displayed in the proximity histograms below the topmost graph. The heavy red vertical arrows indicate the excesses of Hf and W on the α_2-side of the 55 at.% Ti isoconcentration surface. Boron is below the detection limit for this analysis because it resides in boride precipitates at a low number density.

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