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ATOM PROBE FIELD ION MICROSCOPY OF TITANIUM ALUMINIDES

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Titanium aluminides have a number of potential high temperature applications due to their good elevated-temperature mechanical properties, low density, and good creep and oxidation resistance. However, fabrication of commercial components of these materials has been impeded by their poor mechanical properties at ambient temperatures. Significant efforts with various degrees of success have been made to improve the mechanical properties of these TiAl alloys by doping them with a variety of different elements including B, C, Cr, Er, Fe, Mn, Mo, Ni, Nb, P, Si, Ta, V and W.¹ One of the optimum analytical tools for investigating the effects of these additions on the microstructure is the atom probe field ion microscope.² However, relatively few studies of titanium aluminides, compared to some other intermetallic compounds, have performed by atom probe field ion microscopy. This lack of attention can be attributed to the brittle nature of the material, in-situ transformations that occur during the field ion microscopy and preferential evaporation problems that were encountered in some of the early studies. The atom probe field ion microscope used for the current experiments has a low base pressure ($\sim 2 \times 10^{-9}$ Pa) and careful attention was paid to optimizing the experimental parameters. All the examples shown were obtained from specimens prepared by standard electropolishing techniques.²

To demonstrate the suitability of the technique to these materials, several different titanium aluminides have been characterized in the atom probe. A field ion micrograph of a stoichiometric Ti_3Al (α_2) material is shown in Fig. 1. Many crystallographic poles and little indication of zone contrast are evident in this micrograph. A field ion micrograph of a higher aluminum level Ti-44 at. % Al-0.4% B alloy that was processed to retain the α phase is shown in Fig. 2. Some zone contrast and a few bright spots, presumably due to the boron addition, are evident. In contrast, few crystallographic poles are evident in the field ion micrograph of a single α_2 -phase ternary Ti-20 at. % Al-10% Zr alloy shown in Fig. 3. Zone contrast is also evident in the γ phase in a Ti-52% Al alloy, as shown in Fig. 4. In two phase alloys, the α_2 phase images with brighter contrast than the γ phase, as shown in Figs. 5 and 6 for a simple ternary Ti-44 at. % Al-0.5% O alloy and a more heavily alloyed Ti-47 at. % Al, 2% Cr, 1.8% Nb, 0.2% W, 0.15% B alloy, respectively. Another example of a more complex microstructure with a brightly-imaging phase is shown in a Ta-modified Ti-47% Al, 2% Cr, 1% Nb, 0.8% Ta, 0.2% W and 0.15% B alloy in Fig. 7. From its composition (Ti- 19.5 at. % Al, 43.1% Cr, 1.6% Nb, 12.2% Ta, 2.4% W), this precipitate was determined to be a TiCr_2 -based Laves phase. In addition to the α_2 phase, borides were also found to image brightly in these alloys, as shown in Fig. 8. Although all borides exhibit similar bright contrast in the field ion microscope, several different types of borides including MB, MB_2 and M_2B have been identified from the compositions determined in the atom probe. An atom probe composition profile across an α_2 - γ interface in a Ti-47 at. % Al, 2% Cr, 1.8% Nb, 0.2% W, 0.15% B alloy is shown in Fig. 9. In this example, the oxygen partitioning between the α_2 and γ phases is clearly evident. However, no segregation of Cr or Nb to the interface was observed. The results presented in this paper illustrate that titanium aluminides can be examined routinely by atom probe field ion microscopy.³

1. S. C. Huang, *Structural Intermetallics*, ed. R. Darolia, et al., TMS, Warrendale, PA, 1993, p. 299.
2. M. K. Miller et al., *Atom Probe Field Ion Microscopy*, Oxford, Oxford University Press (1996).
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Fig. 1 Field ion micrograph of a stoichiometric Ti_3Al (α_2) alloy.
 Fig. 2 Field ion micrograph of a Ti-44 at. % Al-0.4% B alloy that was processed to retain the α phase.
 Fig. 3 Field ion micrograph of a single α_2 phase Ti-20 at. % Al-10% Zr ternary alloy.
 Fig. 4 Field ion micrograph of the γ phase in a single phase Ti-52% Al alloy.
 Fig. 5 Field ion micrograph of α_2 (bright contrast) and γ phases in a Ti-44% Al -0.5% O alloy.
 Fig. 6 Field ion micrograph of two α_2 lamellae and γ matrix in a Ti-47% Al, 2% Cr, 1.8% Nb, 0.2% W, 0.15% B alloy aged for 30 days at 800°C.
 Fig. 7 Field ion micrograph of a TiCr_2 -based Laves phase plate, an α_2 lamella and γ matrix in a Ta-modified Ti-47% Al, 2% Cr, 1% Nb, 0.8% Ta, 0.2% W and 0.15% B alloy.
 Fig. 8 Field ion micrograph of a boride precipitate in the Ta-modified alloy.
 Fig. 9 Atom probe composition profile from the γ phase into the α_2 phase in a Ti-47% Al, 2% Cr, 1.8% Nb, 0.2% W, 0.15% B alloy aged for 30 days at 800°C.

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