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Microstructural Study of a Bond Coat Type Al-Rich Intermetallic Alloy for Nb-Silicide Based Alloys for High Temperature Structural Applications

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Bond coat (BC) alloys are used in coating systems for turbine aerofoils to increase oxidation resistance at high temperatures and improve the adherence between the substrate alloy and top coat [1]. BC alloys allow structural materials to withstand aggressive environments. Their thermally grown oxide acts as barrier to oxygen and other contaminants. To fulfil this function, BC alloys contain elements that form protective oxide scales under oxidation conditions at medium and high temperatures. The most protective oxide scales are those of Al_2O_3, SiO_2 and Cr_2O_3. Nb-silicide based alloys do not form protective oxide scales thus for their use, suitable coating systems are required [2].

Thermal stability and compatibility of a coating with the substrate are key characteristics to be considered in the design of a coating system. The microstructures of Nb-silicide based alloys consist of Nb_5Si_3 silicides and Nb solid solution (Nbss) but other intermetallics can be present [2]. This study considered an Al rich BC type alloy with alloying additions that are common in Nb-silicide based alloys

The alloy had nominal composition Nb-24Ti-15Si-40Al-5Cr-0.5Hf (at.%) and was prepared using pure elements (≥ 99.9 wt % purity) and clean melting with non-consumable tungsten electrode in a copper water cooled crucible. The cast microstructure was characterised using X-Ray powder diffraction (XRD, Scanning Electron Microscopy and Energy Dispersive X-Ray spectroscopy SEM/EDS analyses.

The preliminary results showed four phases in the cast microstructure. These are shown in Figures 1, 2 and 3a. The XRD data (figure 3b) suggested the hexagonal Ti_5Si_3 (JCPDS card 29-1362), the tetragonal $NbAl_3$ phase (JCPDS card 13-0146), the τ (JCPDS card 43-1099) and the Cr_2Nb C14 Laves phase (47-1637). The Ti_5Si_3 exhibited light contrast, the $NbAl_3$ light grey contrast, the τ phase ($Al_{67}Cr_8Ti_{25}$) [4] with dark grey contrast and the Cr_2Nb C14 Laves phase light grey contrast. EDS confirmed that the phases were heavily alloyed. The composition of the Cr_2Nb C14 Laves in the alloy was in good agreement with γCr_2Ti reported in [3,4] however XRD data best fit was with Cr_2Nb C14 Laves.

The typical microstructure in the centre of the ingot is shown in the figures 1a, 2a and 2b. It consisted of primary faceted dendrites of Ti_5Si_3, and $NbAl_3$ with the τ phase and a very low volume fraction of the Cr_2Nb C14 Laves in the inter-dendritic regions. The EDS analyses indicated that the concentrations of Nb and Ti in the Ti_5Si_3 phase varied from the centre to the grain boundaries, with the centre being richer in Nb, and the grain boundaries richer in Ti. The figure 2b suggested the presence of a fine microstructure in the inter-dendritic regions. Figure 3a shows the microstructure in the bottom of the alloy where the volume fraction of the Ti_5Si_3 silicide was lower compared with the bulk and the microstructure was finer owing to solidification under higher cooling rates (melt in contact with the water-cooled crucible).

References:

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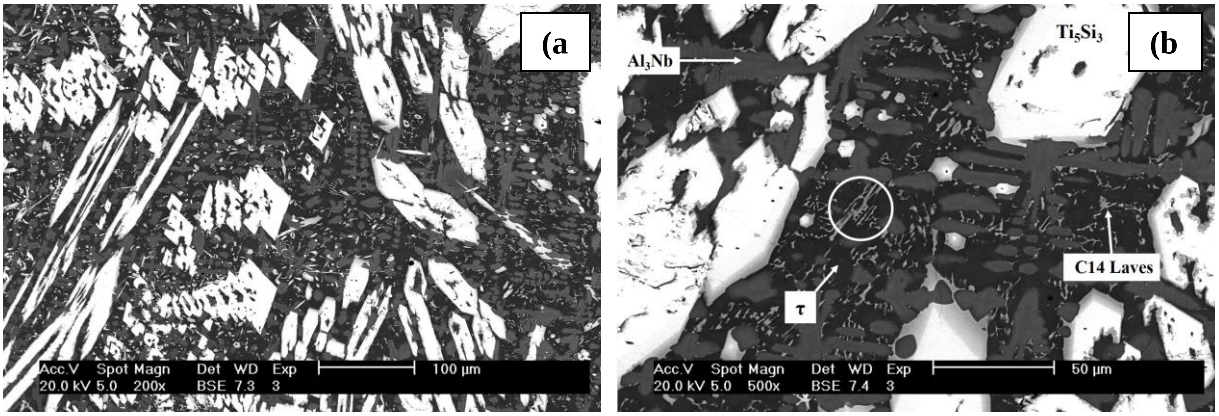

Figure 1. BSE images of typical microstructure of the centre of the as cast alloy, a) at X200, b) The encircled area indicates formation of fine microstructure, at X500.

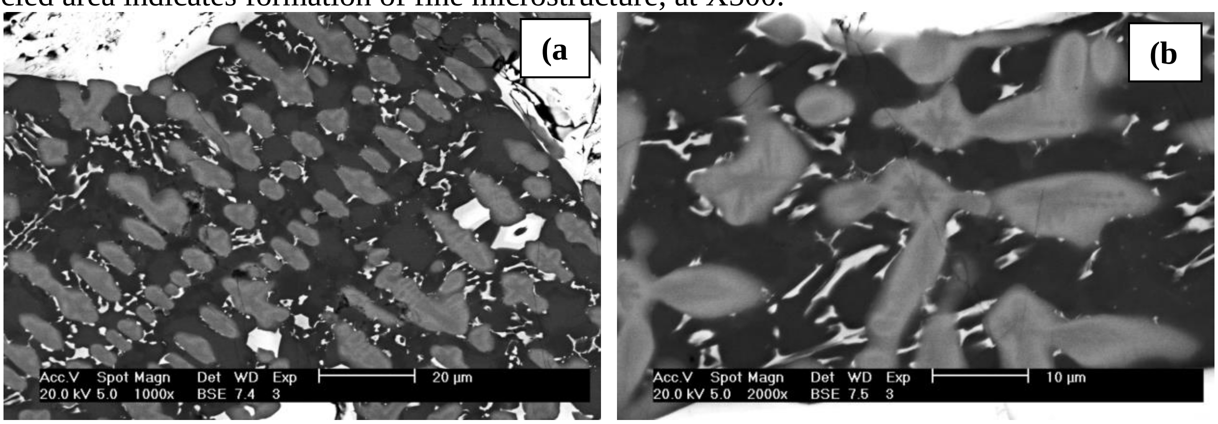

Figure 2. BSE images of typical microstructure of the centre of the cast alloy, a) The Al_3Nb dendrites, at X1000, b) Details of fine microstructure which consisted of Al_3Nb, τ and Ti_5Si_3 phases, at X2000.

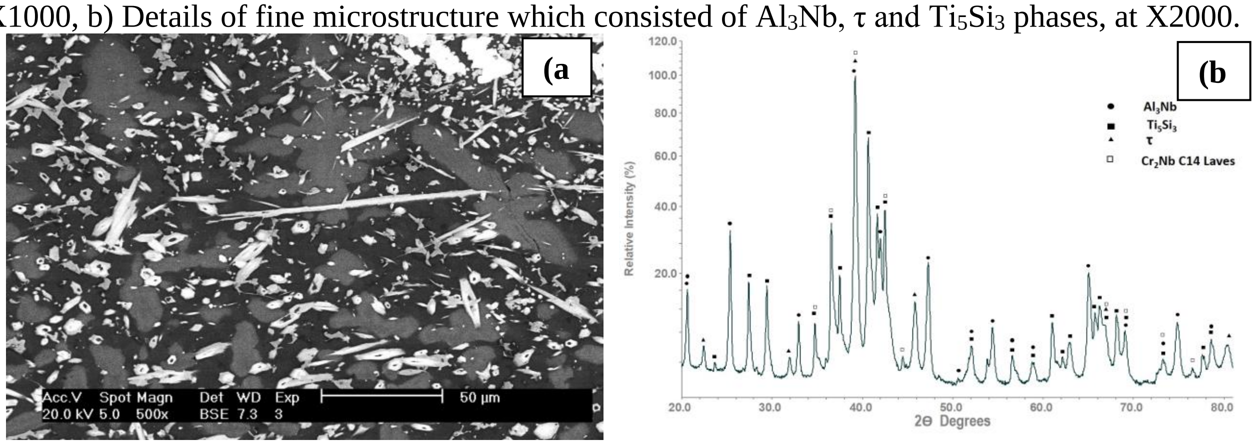

Figure 3. a) BSE image of typical microstructure in the bottom of the cast alloy, the Ti_5Si_3 silicide presented a finer microstructure and a lower volume fraction, at X500, b) XRD diffractogram of the alloy powder showing the phases present in the cast condition.

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