Abstract

The dissertation envisions a novel alloy space in an advanced multi-component γ-TiAl alloy system (Ti-xAl-yNb-1Mo-1Cr-0.2C-0.2B (at.%)) and explores the compositional impact on solidification, phase stability, microstructure, and deformation at different temperatures in both as cast and as heat-treated conditions. Discrete Al variations (44, 46, 48 (at. %)) and Nb variations (5, 7.5, 10 (at. %)) constituted a set of 9 alloys. Fine and chemically homogeneous microstructure with random crystallographic texture identifies β-solidification (L→L+β→β+α) in the Nb rich alloys, 44Al-(5, 7.5, 10) Nb and 46Al-(7.5,10) Nb. Long orthogonal β-dendrites constituting a heavy alloy-rich dendritic core surrounded by the peritectic collar and a dark interdendritic Al-rich region, coarse microstructure, and a strong texture of $(111)_{\gamma}$ and $(011)_{\gamma}$ // solidification directions (SD) indicate hypo-peritectic solidification (L→L+β→L+α+β→α+β), as found in alloys like 48-10 and 46-5. The simultaneous presence of orthogonal β-dendritesand some hexagonal α-dendrites indicate hyper-peritectic solidification (L→L+β→L+β+α→L+α→α), as found in 48-7.5 alloy. The high fraction of hexagonal α-dendrites, the presence of γ at the Al-rich interdendritic regions, and a strong texture of $(111)_{\gamma}$ // SD indicate the α-solidification (L→L+α→α→α+γ), as observed in 48-5 alloy. Multitudes of solid-state phase transformations, like β → α, α → α + γ → α_2 + γ, α+β→γ, α → β+γ(Cellular), β → γ, α → γ (Massive γ) as a function of alloy composition are thoroughly discussed in light of corresponding microstructure. Substantial changes in microstructure stimulated the choice of (44-48) Al-7.5Nb and 46Al-(5-10) Nb alloys to evaluate the effects of Al and Nb variations, respectively, on room temperature (RT) compressive, flexural properties, and high temperature (HT) compressive strengths. The low Al and high Nb alloys increase the RT and HT compressive strength. The RT flexural strength and strain to failure also show the same trend with composition. The elastic properties show higher anisotropy in high Al and low Nb alloys, corresponding to their stronger crystallographic texture. The increase in Al content leads to an increase in phase fraction of γ, specifically in lamellar morphology. While Nb increases the phase fraction of β/B2 and equiaxed-γ. Nanoindentation studies show that the equiaxed γ and the β/B2 are the softest and the hardest microconstituents, respectively, in all the alloys. The hardness of all the microconstituents increases with a decrease in Al and an increase in Nb content. The differential scanning calorimetry (DSC) scans of all the alloys in their homogenized conditions reveal the transition temperatures for α↔α_2(T_{eu}), β↔B2(T_{B2}), and α↔γ($T_{\gamma\text{-sol}}$), which are found to increase with Nb addition for each Al level. The Al variation does not affect T_{eu}; however, the T_{B2} and $T_{\gamma\text{-sol}}$ increase. The presence of peaks corresponding to α↔β+γ are observed only in 46 Al and 48 Al alloys, which signifies that the α phase gets destabilized at a temperature below the $T_{\gamma\text{-sol}}$, in high Al alloys. The mechanical benefits of low Al and high Nb cast alloys accentuate the choice of 44-7.5, 44-10, and 46-10 alloys for studying the effect of heat treatment on compressive properties. Ice-water quenching and air cooling (AC) from the α+β+γ and the α+β phase fields of the respective alloys generated vast varieties of γ phase morphologies formed within the α and the β phases. Corelative analysis reveals an inverse relationship between RT and HT compressive strengths and the γ phase fraction. The best combination of HT strength and RT strain to failure was obtained for 44Al-7.5Nb and 44Al-10Nb alloys in the (α+β+γ)--AC heat treated condition.

Keywords: γ-Titanium Aluminide; Peritectic solidification; Segregation; Backscattered electron imaging; Electron backscattered diffraction. Ultrasound Phase Spectroscopy; X-ray diffraction; Rietveld analysis; Phase transition; Differential Scanning Calorimetry; Compression; 3-point bending; Heat treatment.