# EBSD characterisation of the B2 orientation in γ-TiAl based alloy

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**Abstract**. Electron backscattered diffraction (EBSD) has been conducted to determine the orientation relationship of the remnant B2 phase in an α-solidified γ-Ti-45Al-2Nb-0.3Si (at. %) based intermetallic alloy. The morphology and microstructural characterisation was investigated using conventional methods. The results showed that the B2-grains exhibits a Blackburn orientation relationship (BOR) with the $\alpha_2$ grains viz. {111}B2 // {0001}$\alpha_2$ and {110}B2 // {11-20}$\alpha_2$. Moreover, mis-orientation axes of B2-grains were found in the clusters between <101> and <111> in 57-63$^0$ angles, in the Y0 directions. In addition, it was also observed that the overall B2 grains in the alloy structure was textured and comprised of high angle boundaries of misorientations above 15$^0$ angles.

## 1. Introduction

The γ-based titanium aluminides are lightweight materials and are in continuous demand because of the higher temperature engine efficiencies in automotive, aerospace and energy industries. These intermetallic alloys offer a good combination of mechanical properties, and therefore, can withstand temperatures up to 800 $^0$C, especially with additions of Nb and Mo, alloying elements [1]–[3]. The cast intermetallic alloys based on Ti-45Al, which solidify via the β-phase (retained as B2-phase at room temperature) consist of an isotropic equiaxed and texture-free microstructure with modest micro-segregation whereas, peritectic alloys (solidification via α-phase) show anisotropic microstructures with significant texture and segregation, respectively [1].

The β→α transition is a critical phase transformation in titanium and its alloys, because it plays a predominant role in ascertaining the microstructure and mechanical properties. This transformation reaction occurs by the Burger orientation relationship (BOR) viz. $\{110\}_\beta$ // $\{0001\}_\alpha$ and $<111>_\beta$ // $<1100>_\alpha$ , which can result in crystallographic equivalent twelve α-variants [4]. Studies [5-8] have shown that the α-phase exhibits an orientation relationship between the inherited γ-phase. Through the EBSD technique, nucleation mechanism of the γ-grains originated at α/α-grain boundaries was extensively investigated. It was reported that further cooling lead to a diffusion-controlled precipitation of γ-grains to a Blackburn orientation relationship with the α-phase i.e. (0002)α // (111)γ and [11$\bar{2}$0]α

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// $[1\bar{1}0]\gamma$ with one of the neighbouring α-grain, forming α/γ colonies and few of the γ-grains did not exhibit this BOR [5-8].

Therefore, the aim of this study is to investigate the orientation relationship of the remnant B2-phase with respect to the α-peritectic grains of the heat-treated α-solidified γ-Ti-45Al-2Nb-0.3Si based intermetallic alloy.

## 2. Experimental work

An arc button melted Ti-45Al-2Nb-0.3Si (at. %) alloy was isothermally heat-treated in the α-transus temperature of 1335 $^0$C and cooled slowly in the $(\alpha_2+\gamma)$ phase region in order to obtain a fully lamellar structure [2-3]. The alloy was characterised by SEM equipped with energy-dispersive X-ray spectroscopy (EDS) capabilities for chemical analysis. Phase identification was investigated by X-ray diffraction (XRD) using CuKα radiation $\lambda = 0.154062$nm and 2θ from 20-90$^0$ angles. PANalytical's X'pert High Score program equipped with data organised in ASCII OR XRDML files was used to indexed lattice parameters of the obtained phases [2,9]. Orientations of the B2 and α (retained as $\alpha_2$) phases and their relationships were investigated through orientation imaging microscopy (OIM) software in SEM-EBSD, using Channel 5™ system developed by HKL® of which the procedure is reported elsewhere [6].

## 3. Results and discussion

### *3.1. Microstructure analysis*

The phases formed after the isothermal treating and cooling process reported in our previous study [3] were: γ-TiAl, $\alpha_2$-$Ti_3Al$, and B2-($Ti_5Si_3Al_xNb_x$) evenly distributed as shown in **Fig. 1**. The chemical composition of the phases by SEM-EDS method is illustrated in **Table 1**:

**Table 1**. Chemical composition of the heat-treated Ti-45Al-2Nb-0.3Si alloy (at. %).

| **Element** | **Composition (γ)** | **Composition ($\alpha_2$)** | **Composition (B2)-$Ti_5Si_3$** |
|---|---|---|---|
| **Ti** | 49.29±1.58 | 62.89±0.72 | 54.24±1.47 |
| **Al** | 48.15±0.46 | 34.41±1.89 | 33.38±0.81 |
| **Nb** | 2.32±0.89 | 2.12±0.63 | 2.62±1.19 |
| **Si** | 0.23±1.28 | 0.57±1.51 | 9.76±1.30 |

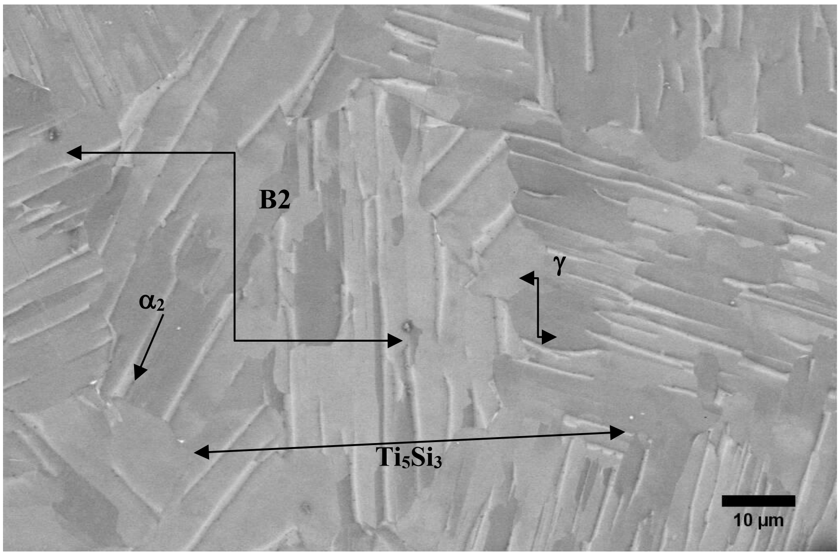

**Figure 1**: SEM-backscatter image (BSI) of the as-heat treated γ-Ti-45Al-2Nb-0.3Si intermetallic alloy.

### *3.2. EBSD analysis*

The alloy was isothermally treated at temperatures of 1335 $^0$C, for attempting to minimise the γ and β phases, followed by thermal stabilisation at 900 $^0$C with subsequent furnace cooling. This resulted in a fully lamellar (FL) structure in **Fig. 1** mailny comprising of ($\alpha_2$+γ). This resulting microstructure $\alpha_2/\gamma$ colonies, with small amount B2 phase retaining after solution annealing along with few $Ti_5Si_3$ particles as shown in **Fig. 1**. In addition, the XRD results in **Fig. 2** validates the stable phases present at room temperature. The lamellar structure ($\alpha_2/\gamma$) emanated from the γ lamellae precipitating in the transformed α-grains during the cooling process (β→α solid state transformation) [3].

**Fig. 3** demonstrates that the {111}B2 // {0001}$\alpha_2$ and {110}B2 // {11-20}$\alpha_2$ is in agreement with the Burgers orientation relationship, see dotted circles in **Fig. 3b**. This is supplemented by the inverse pole figures in **Fig. 4a** showing the most intensity of B2 grains in the Y0 direction. According to the corresponding colour coding in **Fig. 4b** the highest intensity at a value of 10 indicates that the misorientation axes of the B2-grains is seen in the clusters between <101> and <111> directions in 57-63$^0$ angle **Fig. 4b**. This is substantiated by the mis-orientation angle distribution in **Fig. 4c** which, exhibits a large number of boundaries with misorientations above 15$^0$ when compared to the uncorrelated distribution. Furthermore, the results demonstrate that the misorientation angles 10-63$^0$ between the α-grains originate from the same β-grain, corresponding to 10$^0$ 53′, 60$^0$, 60$^0$ 83′, 63$^0$ 26′ or 90$^0$ [6]. As may be seen, the high angle boundary is a notable feature of the microstructure.

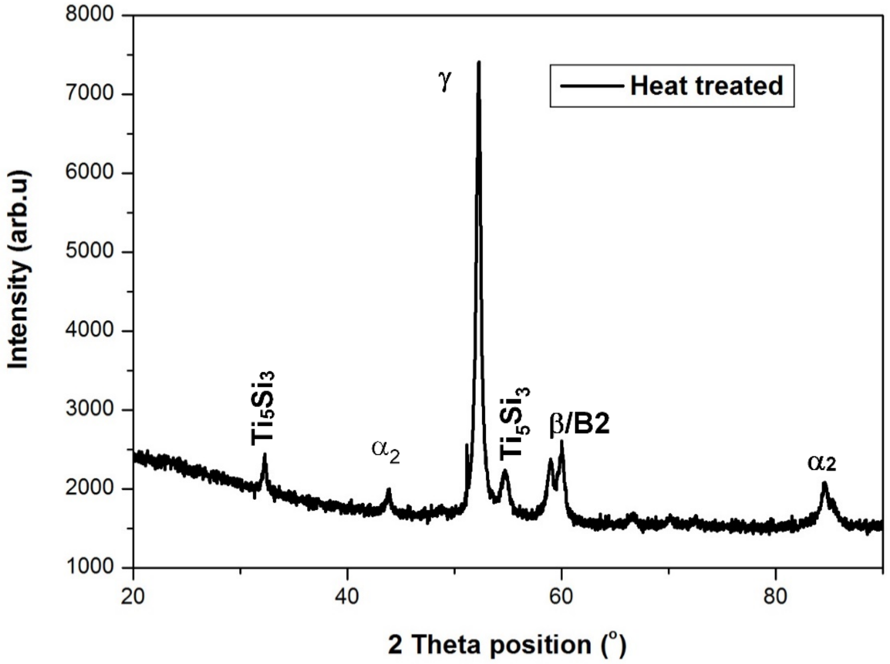

**Figure 2.** XRD pattern of the heat-treated γ-Ti-45Al-2Nb-0.3Si based intermetallic alloy.

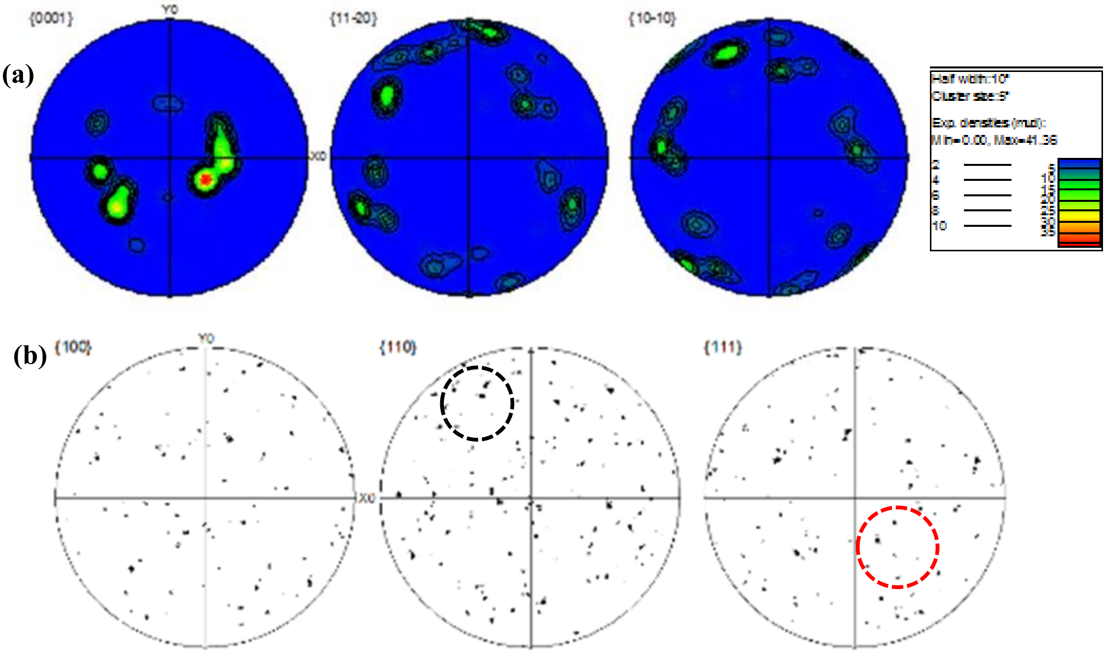

**Figure 3.** Pole figures of a) $\alpha_2$, and b) B2 grains indicating orientation relationship.

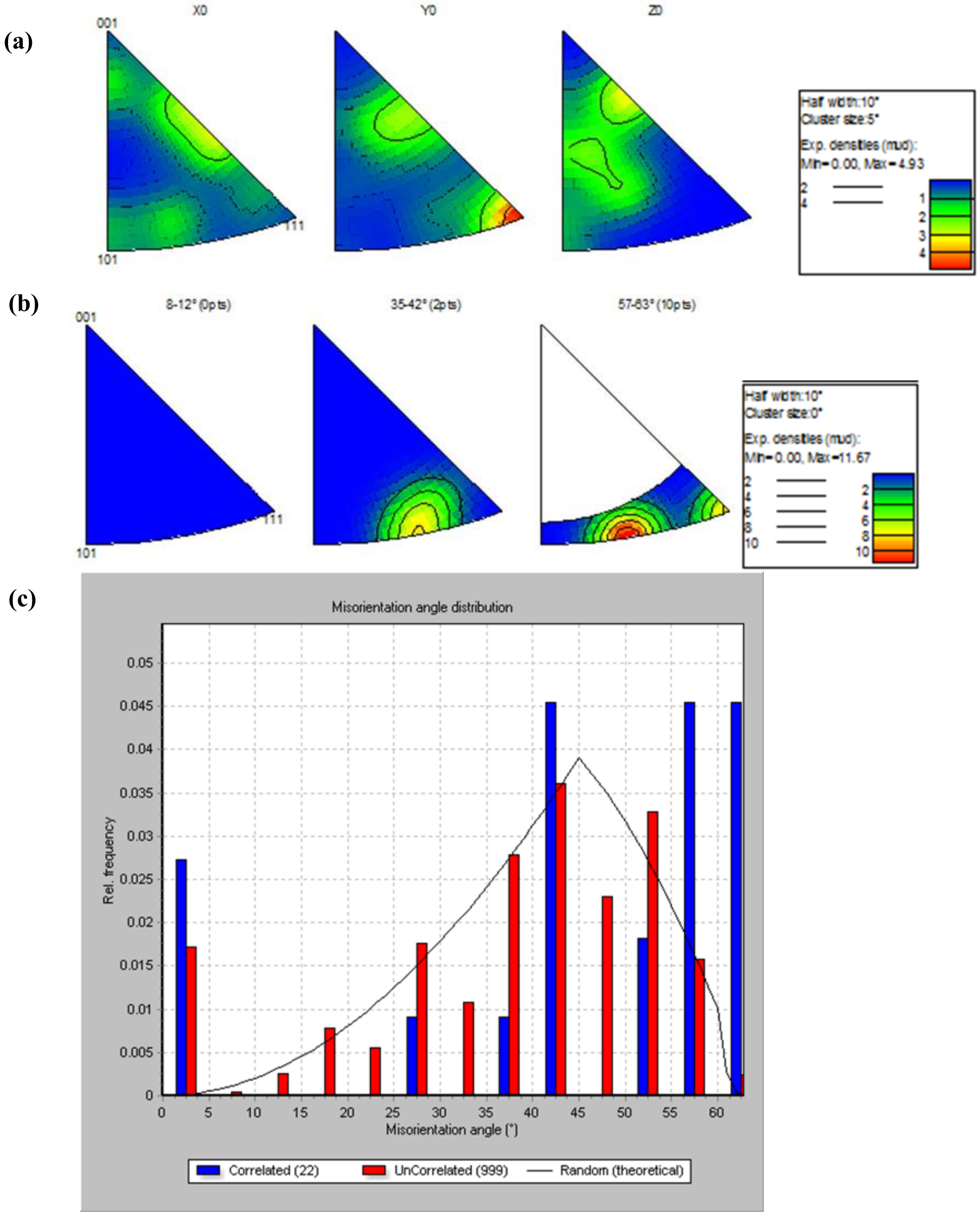

**Figure 4.** (a) Inverse pole figure maps, (b) Misorientation axes, and (c) Misorientation angle distribution.

## 4. Conclusions

The EBSD analysis was conducted in order to characterise the orientation of the residual B2 phase of the heat-treated and stabilised $\gamma$-Ti-45Al-2Nb-0.3Si alloy, and the following conclusions were drawn:

- The orientation of the B2 phases, with respect to peritectic $\alpha$-grains followed the Burger OR: $(0002)\alpha$ // $(111)\gamma$ and $[11\bar{2}0]\alpha$ // $[1\bar{1}0]\gamma$ and $\{111\}B2$ // $\{0001\}\alpha_2$ and $\{110\}B2$ // $\{11\text{-}20\}\alpha_2$, respectively.
- It has been shown that the mis-orientation axes of B2-grains were found in the clusters between <101> and <111> in 57-63$^0$ angle, in the Y0 direction.
- Misorientation angle distribution showed that a large number of boundaries with misorientations above 15$^0$ (high angle boundary) were a significant feature of microstructure and possible product of texture.

## References

[1] Clemens H, Chladil H F, Wallgram W, Zickler G A, Gerling A, Liss K D, Kremmer S, and Güther V 2008 *Intermetallics.* **16** 827-833

[2] Mathabathe M N, Bolokang A S, Govender G, Mostert R J, and Siyasiya C W 2018 *Vacuum* **154** 82–89

[3] Mathabathe M N, Govender S, Bolokang A S, Mostert R J, and Siyasiya C W 2018 *J. Alloys Compd.* **757** 8–15

[4] Chen Y, Cheng L, Yang G, Lu Y, and Han F 2018 *Metals.* **8** 605

[5] Dey S R, Bouzy E, and Hazotte A 2006 *Intermetallics.* **14** 444–449

[6] Mathabathe M N, Bolokang A S, Govender G, Mostert R J, and Siyasiya C W 2018 *J. Alloys Compd.* **765** 690–699

[7] Schwaighofer E, Clemens H, Mayer S, Lindemann J, Klose J, Smarsly W, Güther V 2014 *Intermetallics* **44** 128-140

[8] Schmoelzer T, Liss K –D, Kirchlechner C, Mayer S, Stark A, Peel M, Clemens H 2013 *Intermetallics* **39** 25-33

[9] Mathabathe M N, Govender G, Siyasiya C W, Mostert R J, Bolokang A S 2019 *Mater. Charact.***154** 94-102