MICROSTRUCTURE AND MECHANICAL PROPERTIES OF TiAl-Nb ALLOY PREPARED BY PLASMA METALLURGY

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Abstract

Microstructure and microhardness features of Ti-45Al-10Nb alloy plasma melted and annealed had been studied. The content of 46.5 at.% Ti, 42.6 at.% Al and 10.8 at.% Nb in final alloy was determined using EDS microanalysis. In both conditions, after plasma melting or annealing, the two-phase microstructure consisted of γ (45 at.% Al) and α_2 (41 at.% Al) phases. Microhardness values of plasma melted alloy achieved higher values (520 HV) than after annealing and quenching (406 HV). The region of inhomogeneity formed of β matrix and α_2 precipitates was observed.

Key words

TiAl-based alloys, plasma metallurgy, intermetallics, microhardness, microstructure

Introduction

Intermetallic Ti-Al based alloys offer a combination of low density, good oxidation resistance and suitable mechanical properties, particularly high specific strength at elevated temperatures exceeding those of conventional titanium alloys [1]. Alloy properties are modified by ternary or more complex alloy additions and control of microstructure. High temperature strength of TiAl alloys are improved effectively by addition of Nb [2]. Alloying with 5-10 at.% Nb and small amount of other elements (Cr, Ta, Mo, C and B) allows higher resistance to creep and oxidation and remaining the yield strength up to 750-800°C [3]. Two-phase microstructure (α_2+γ) enables to achieve higher ductility. Therefore, this third generation of γ-TiAl alloys has great promising high-temperature applications in aircraft and automobile industry.

In the present study, microstructure and microhardness features of Ti-45Al-10Nb in plasma melted and annealed conditions are investigated.

Experimental

Considering high temperature melting of prepared alloy and high differences in melt points of constitutional elements, the experimental Ti-45Al-10Nb (at.%) alloy was melted from the master alloy TiNb (55/45 wt. %) and elemental Ti (3N8) and Al (5N) pieces by means of a Ar-operated plasma torch in a water cooled copper crucible with feed rate of 1cm per minute and three times remelted to minimise compositional differences in the ingot. The composition and melting temperature of master alloy are pointed out in Fig.1a. The binary diagram Ti-Al in Fig. 1b represents the composition and phase content for Ti-45Al alloy. The ternary phase composition for Ti-45Al-10Nb is plotted in ternary Ti-Al-Nb diagram available for 1000°C (Fig.2). In both phase diagrams, the chemical composition leads to lamellar microstructure.

The alloy was annealed for 12 hours at 1100°C in flowing Ar gas and water quenched from 700°C. The samples prepared in this way were subjected to metallographic analysis and measurement of microhardness.

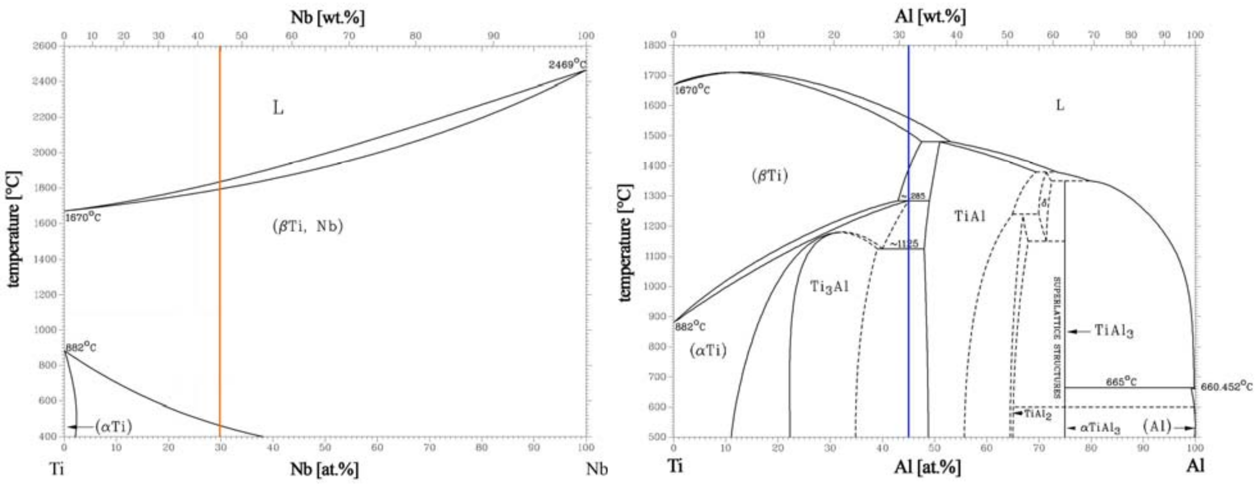

Fig. 1 *Binary diagrams of a) the Ti – Nb system (master alloy composition) and b) the Ti –Al system (binary Ti-45Al alloy) [4]*

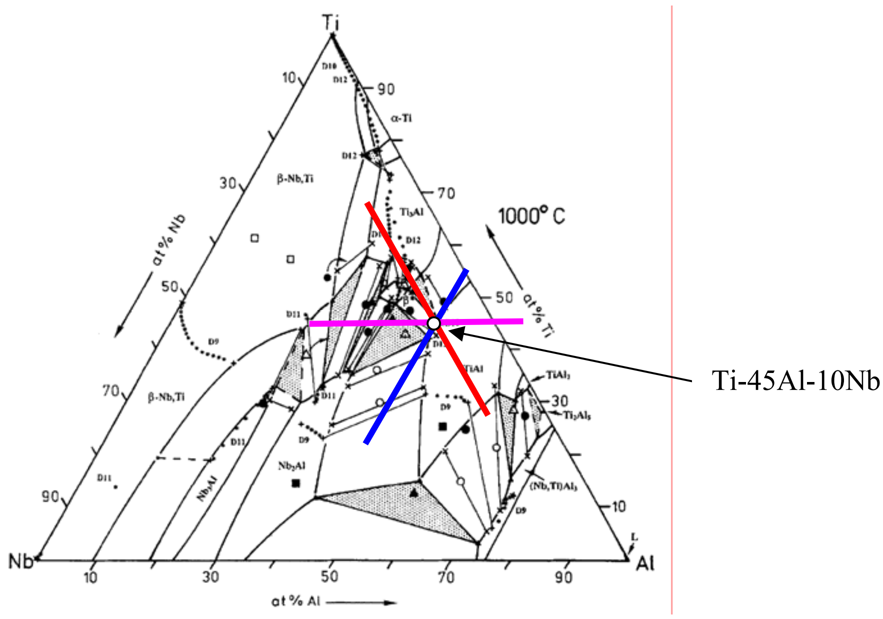

Fig. 2 *Section of ternary Ti-Al-Nb diagram for 1000 °C [5]*

Metallographic observation of as-plasma melted and heat treated specimens was performed after etching (Kroll's reagent: 2 ml HNO_3 : 1 ml HF : 330 ml H_2O) by means of metallographic microscope Olympus GX51.

Phase and microstructure analysis were carried out using scanning electron microscope JEOL JSM - 6490LV equipped with EDS INCA X - ACT probe.

The LECO LM-100 instrument was used for microhardness measurement with load of 0.2 kg and step of 1mm across the specimen diameter.

Measurement and results

The microstructure of plasma melted alloy represented in Fig. 3a consists of large grains and (α_2+γ) laths. After annealing and quenching the microstructure was formed of smaller grains and (α_2+γ) laths (Fig. 3b). Fig. 4 shows an inhomogeneity in the centre of specimen produced during the plasma melting. Upon the EDS analysis, this region contains higher amounts of Ti and Nb and less one of Al (57.41 at.% Ti, 21.70 at.% Nb and 20.89 at.% Al), so the microstructure is composed of β matrix (51.69 at.% Ti, 30.92 at.% Nb and 17.39 at.% Al) with martensite and α_2 precipitates (62.49 at.% Ti, 12.84 at.% Nb and 24.66 at.% Al), as seen in Fig. 4b.

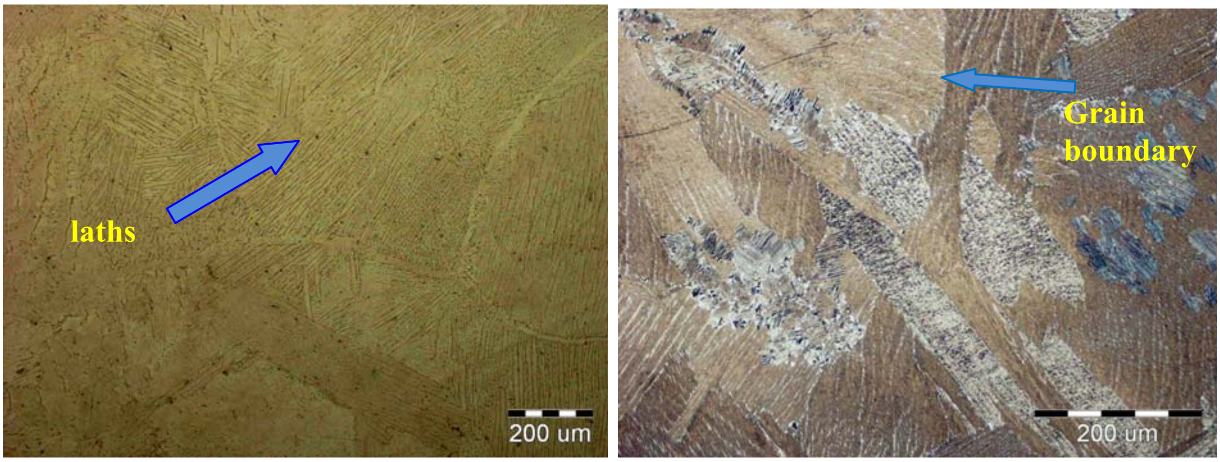

Fig. 3 *Optical microstructure Ti45Al-10Nb with laths (γ +α_2) a) after plasma meeting and b) after annealing and quenching*

The average contents of elements resulting from general and spot analysis of prepared alloy are given in Tables 1 and 2. The results of general analysis distinct from nominal alloy composition relate with inhomogeneity domain in the centre of specimen. However, the concentrations of Ti, Nb and Al in dark and bright laths of lamellar (α_2+γ) microstructure (Fig. 5 and 6) correspond well to nominal composition of Ti-45Al-10Nb alloy.

The results of measurement are summarised in Tables 3 and 4 and graphs of microhardness plots are given in Figures 7 and 8. Microhardness of plasma melted alloy showed higher values than after annealing and quenching that should be related to the microstructure feature, as it can be seen in Figures 5 and 6. The values of microhardness after plasma melting reached 520 HV and after annealing decreased to 406 HV.

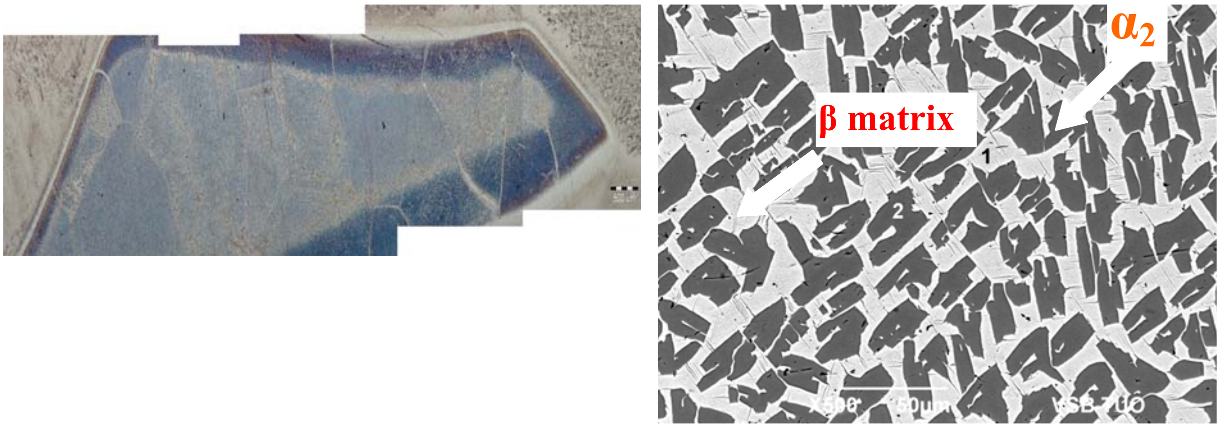

Fig. 4 *TiAl-Nb alloy annealed and quenched a) inhomogeneity in the centre of the sample, b) SEM micrograph of heterogenous region – detail of Fig. 4a)*

RESULTS OF GENERAL MICRO-ANALYSIS of Ti-45Al-10Nb PLASMA MELTED ALLOY Table 1

Element / **Measurement**	**Al** [wt. %]	**Ti** [wt. %]	**Nb** [wt. %]
1	25.69	51.46	22.85
2	26.96	49.57	23.46
3	26.21	50.82	22.97
4	26.05	51.57	22.38
mean value [wt.%]	**26.22**	**51.60**	**22.92**
mean value [at. %]	**42.62**	**46.56**	**10.82**

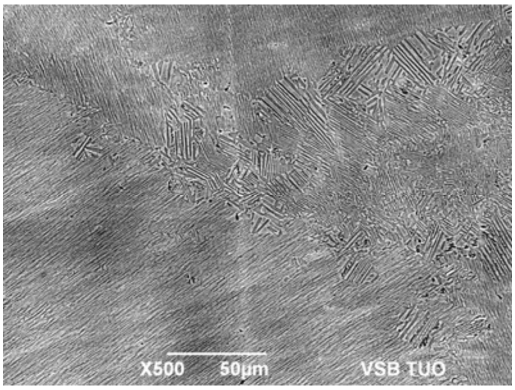

Fig. 5 *SEM micrograph of annealed sample*

MICROANALYSIS RESULTS OF BRIGHT AND DARK LATHS IN Ti-45Al-10Nb AFTER ANNEALING

Table 2

Element	**Al** [at. %]	**Ti** [at. %]	**Nb** [at. %]
bright lath 1	41.10	44.68	14.22
bright lath 2	40.74	44.94	14.32
bright lath 3	39.18	46.13	14.68
mean value	40.34	45.25	14.40
dark lath 4	45.79	42.87	11.34
dark lath 5	45.68	42.95	11.37
dark lath 6	45.79	43.48	10.73
mean value	**45.75**	**43.1**	**11.14**

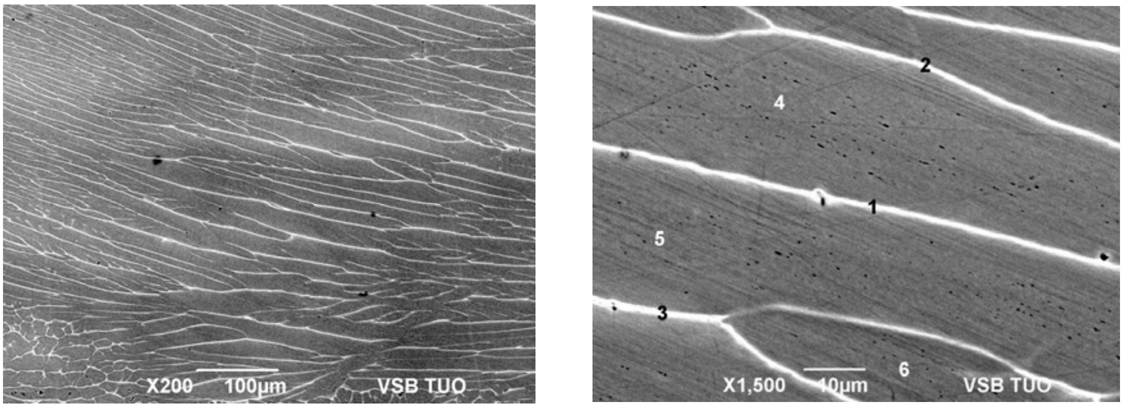

***Fig. 6** SEM micrographs of Ti-45Al-10Nb sample a) lamellar structure, b) detail of Fig. 6a)*

MICROHARDNESS RESULTS MEASURED FOR TiAl-Nb SAMPLE AFTER PLASMA MELTING

Table 3

Ti-45Al-10Nb plasma melted			
Measurement	**Value HV**	**Measurement**	**Value HV**
1	523	12	604
2	381	13	582
3	455	14	543
4	448	15	546
5	447	16	563
6	531	17	531
7	512	18	539
8	539	19	551
9	487	20	519
10	559	21	497
11	580	22	539
		23	487
Mean value	520	Standard deviation	50

MICROHARDNESS RESULTS MEASURED FOR TiAl-Nb SAMPLE AFTER ANNEALING

Table 4

Ti-45Al-10Nb annealed			
Measurement	**Value HV**	**Measurement**	**Value HV**
1	437	12	434
2	434	13	388
3	404	14	392
4	446	15	392
5	425	16	380
6	449	17	394
7	425	18	423
8	382	19	376
9	377	20	380
10	434	21	394
11	432	22	387
		23	372
Mean value	407	Standard deviation	25

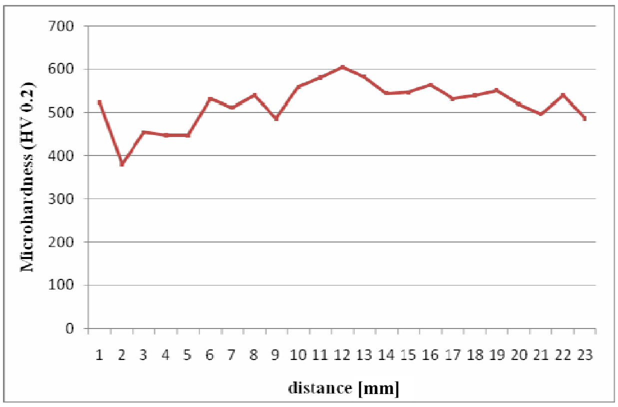

***Fig. 7** Microhardness results for TiAl-Nb sample plasma melted*

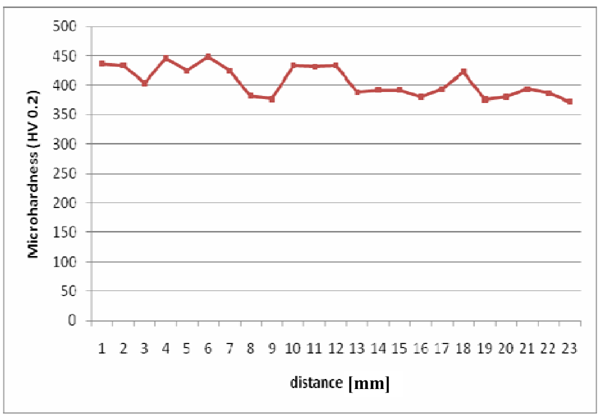

***Fig. 8** Microhardness results for TiAl-Nb sample annealed at 1100 °C*

Conclusions

Based on experimental results, the following conclusions are drawn:

- Intermetallic Ti-45Al-10Nb alloy was prepared from Ti-Nb master alloy using plasma melting.
- Final alloy composition was determined as follows: 46.5 at.% Ti, 42.6 at.% Al and 10.8 at.% Nb.
- After plasma melting and subsequent annealing, the two-phase microstructure consisted of γ (45 at.% Al) and α_2 (41 at.% Al) phases.
- The region of inhomogeneity was formed of β matrix (51.69 at.% Ti, 30.92 at.% Nb and 17.39 at.% Al) and α_2 precipitates (62.49 at.% Ti, 12.84 at.% Nb and 24.66 at.% Al).
- Microhardness values decreased after the heat treatment

More investigation of the microstructure and mechanical properties of Ti-45Al-10Nb will be carry out in next stage of the research.

Acknowledgements

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