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STUDY OF TEXTURE PATTERNS FOR A Ti-Ta-Nb ALLOY PROCESSED BY ACCUMULATIVE ROLL-BONDING (ARB)

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Studiul de față investighează textura aliajului Ti-25Ta-25Nb, supus deformării plastice severe (DPS) prin procesul de laminare acumulativă prin lipire (ARB). Procedeul de laminare acumulativă (ARB) este un procedeu de deformare plastică severă, intens. Prin procdeul ARB, o bandă este aşezată cu precizie deasupra unei alte benzi. Cele doua straturi ale materialului sunt consolidate apoi prin laminare, ca şi in procesul de laminare conventională.

Textura aliajului(de tip β) a fost determinată prin masurarea figurilor de poli pentru planele cristalografice (110), (200) şi (211). Caracterizarea texturii, distribuția spațiala a direcțiilor cristalografice prin metoda "figurilor de pol", se cunoaşte a fi una dintre cele mai bune metode şi a fost descrisă in două moduri diferite cunoscute sub numele de tehnica de reflecție şi de transmisie.

In the present study, texture of a Ti-25Ta-25Nb alloy subjected to severe plastic deformation (SPD) by accumulative roll-bonding (ARB) process were studied. The accumulative roll-bonding (ARB) process is an intense plastic straining process. In the ARB process, a sheet is neatly placed on top of another sheet. The two layers of material are joined together by rolling like in roll-bonding process.

The texture of the β-phase alloy was determined by measuring three pole figures, namely for crystallographic planes(110), (200) and (211). Characterizing textures, the mapping of the spatial distribution of crystallographic directions by "pole figures" it is known to be one of the best methods and has been described in two different methods known as the reflection and transmission techniques.

Keywords: titanium alloy, pole figures, ARB, biocompatibility

1. Introduction

In the recent years, in titanium alloys research areas, nanocrystalline and ultra fined grained (UFG) alloys with a grain size of less than 1μm showed

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considerable interest due to their superior mechanical properties, compared to conventionally grained materials. Due to their good mechanical properties, corrosion resistance and biocompatibility, titanium alloys are used in a variety of applications [1].

The present paper proposes a new, promising and biocompatible alloy, Ti-25Ta-25Nb (% wt), which was processed by severe plastic deformation. Besides the mentioned biomedical constraints, the β-stabilizer elements like tantalum (Ta) and niobium (Nb) also improve the alloy biocompatibility and mechanical properties [2].

Titanium and titanium alloys are well-suited as clinically used biomaterials because their biological, mechanical and physical properties play significant roles in the longevity of the prostheses and implants. Tissue reaction studies have identified Ti, Nb, Zr and Ta as non-toxic elements as they do not cause any adverse reaction in human body [3].

The mechanical and structural properties of the discussed alloy were enhanced by severe plastic deformation (SPD), through a promising technique of accumulative roll bonding (ARB). The ARB process consists in cold-rolling of sheets of material, which is sectioned in half, cleaned, stacked and processed through the same method. The process can be indefinitely repeated.

The paper discusses only the texture of β-phase evolution of the ARB processed alloy which was also subjected to a recrystallization treatment. The β phase stability is dictated by the alloy composition and influences the deformation behaviour. For the texture characterization, the mapping of the spatial distribution of crystallographic directions by 'pole figures' is known to be one of the best methods and has been described in two different methods known as the reflection and transmission techniques [3].

2. Materials, Processing and Performed Tests

2.1. Material synthesis

The investigated alloys have been produced using a vacuum induction melting in levitation furnace FIVES CELLES, with nominal power 25 kW and melting capacity 30 cm^3, starting from elemental components. The required chemical composition for the tested alloys is 50% Ti, 25%Ta and 25%Nb (% wt). The resulted chemical composition for the tested alloys is presented in Table 1.

Table 1

Chemical composition of Ti-25Ta-25Nb alloy.

Alloy	Alloy composition (at. %)		
	Ti	Ta	Nb
TiTaNb	50.0	25.0	25.0

2.2. Cold rolling and ARB processing

The entire cycle of the alloy processing is presented in Fig.1

The samples were thermomechanically processed by cold-rolling and then submitted to a recrystallization heat treatement.

The cold-rolling process before ARB process was carried out using a laboratory roll-milling machine Mario di Maio LQR120AS and was performed up to a deformation degree of 82 %, at a roll speed of 2,4 m/min.

The recrystallization heat treatment was carried out in a GERO SR 100X500/12 furnace. Recrystallization parameters were as follows: temperature: 850^0C; duration: 0.15 h; heat treatment media: argon; cooling media: air.

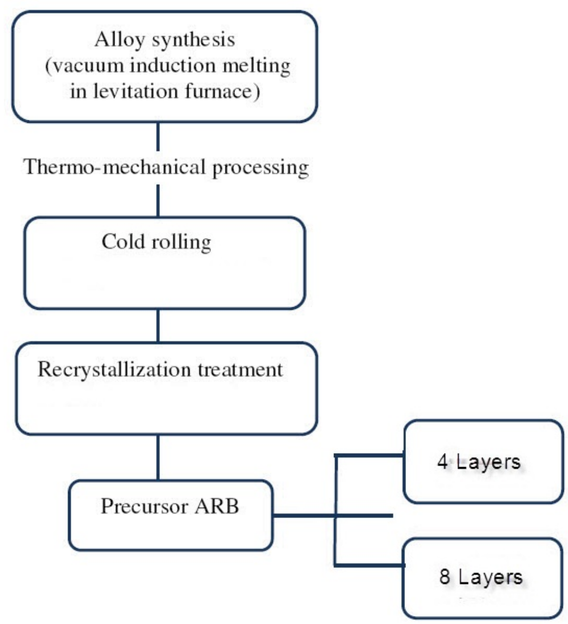

Fig.1. Schematic representation of the Ti-25Ta-25Nb experimental program.

The accumulative roll-bonding (ARB) process consisted in 2 cycles, the ARB process was conducted at room temperature using the same Mario di Maio LQR 120AS rolling-mill, at a roll speed of 2,4 m/min.

The starting precursor sheets were firstly deformed to approximately 82% reduction in thickness by conventional rolling. The resulted stack was cutted in half-length, surface treated and stacked again, resulting the first ARB cycle. The second ARB cycle was performed in the same manner.

In order to initiate the ARB cycles, mechanically machined to 0.09x8x70 mm precursor samples were used. Before each ARB cycle, the samples were mechanically and chemically cleaned, in order to assure a certain roughness which is helpful to realize a good adhesion between sheets.

Table 2 presents the scheme of ARB procedure. The first was the precursor sample. At the end of the ARB process, samples consisting in stacks of 4 and 8 layers were obtained. After each rolling cycle, the samples have been cleaned using an ultrasonic bath (ethyl alcohol, at 60°C, for 5 minutes).

Table 2

Scheme of ARB procedure.

Cycles	Layers	Layer thickness (mm)	
		Initial	Final
1 (ARB)	1	0.09	-
2 (ARB)	4	0.07	0.05
3 (ARB)	8	0.05	0.02

2.3. Texture analysis by pole figure

All the processed samples, precursor and ARB, were subjected to a texture analysis using the Philips PW3710 diffractometer. By now, the pole figure is most frequently used to characterize the texture in polycrystalline materials by using X-ray diffraction. The deformation and transformation textures exhibited by the Ti–25Ta-25Nb alloy have been studied by X-ray diffraction.

The pole figure is the two-dimensional stereographic projection, with a specified orientation relative to the specimen, which shows the variation of pole density with pole orientation for a selected set of crystallographic planes $\{h\ k\ l\}$.

3. Results and Discussion

One of the most common directions associated with the external shape of a rolled product – according with the cubic crystal symmetry of the β-Ti lattice structure – are the rolling direction (RD), the transverse direction (TD) and the normal direction (ND). The center of the pole figures corresponds to the direction normal to the specimen surface (ND). The top and the right of the pole figures correspond to the rolling direction (RD) and transverse direction (TD), respectively. The crystallographic texture is usually presented in the Euler's space 0°≤φ1, Φ, and φ1≤90°. In the cubic system there are, for the most general case, four different orientations having the same Miller indices families, {hkl} <uvw>.These are: $(hkl)[uv\overline{w}]$, $(hkl)[\overline{u}\overline{v}w]$, $(hkl)[vu\overline{w}]$, $(hkl)[\overline{v}\overline{u}w]$ [4]. The texture analysis of Ti-25Ta-25Nb alloy, ARB processed, was carried out using an X-ray diffraction method detecting very easily the presence of β phase.

The presence of an unusually high intensity for the Ti-25Ta-25Nb β alloy whose structure factor is otherwise low, together with decreasing of intensities is a signature of crystallographic texture [5]. From the texture analysis of the Ti-25Ta-25Nb alloy it was noticed that the rolling direction RD is parallel to [110]; a texture developed because of the severe plastic deformation of the material. After cold-rolled processing, the texture formed for {110} <110> is representative for the β type titanium alloys.

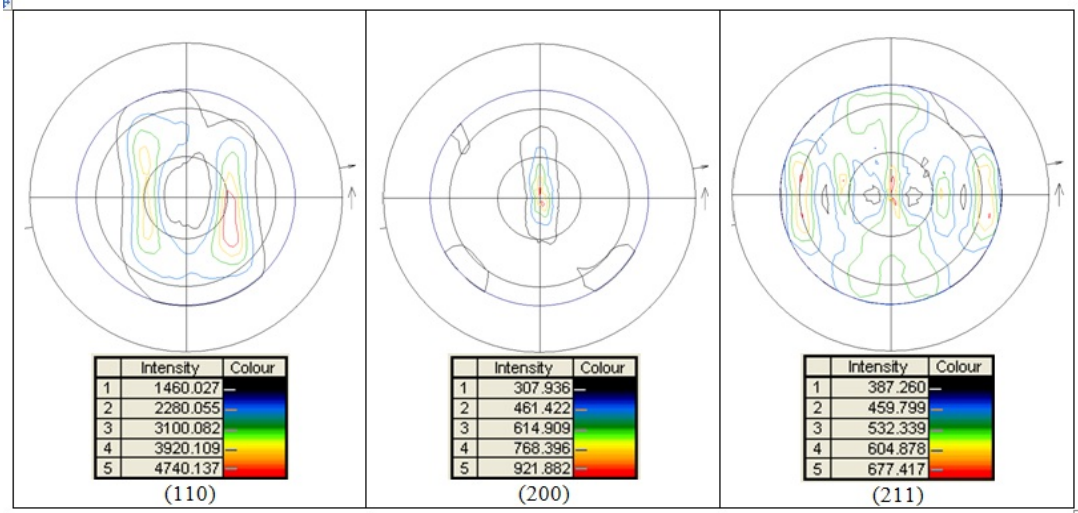

Fig.2 Pole figures of Ti-25Ta-25Nb (110), (200), (211) -1 layer- .

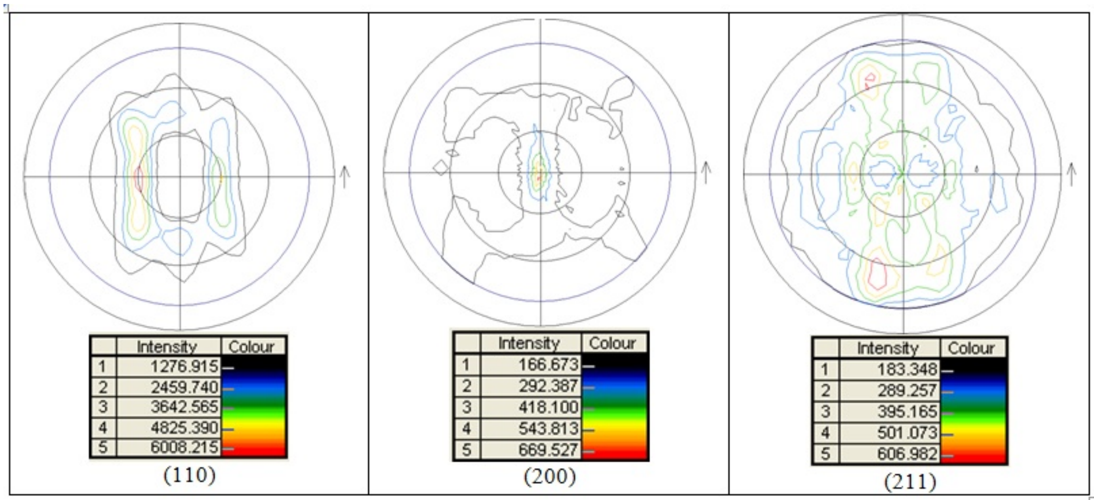

Fig. 3 Pole figures of Ti-25Ta-25Nb (110), (200), (211) – 4 layers -.

esides this type of texture, for the Ti-25Ta-25Nb alloy it can be also noticed a texture in the {200} <110> and {211} <110> systems, (Figures 2, 3 and 4). The conventional XRD studies in θ–2θ geometry give only qualitative information on the type of texture [4]. Figures 3 and 4 represent {110}, {200} and {211} pole figures obtained from the severely deformed alloy – Ti-25Ta-25Nb – after 4 and 8 cycles of ARB processing, while figure 2 represents the pole figures for the precursor samples. The results indicate that the alloy acquires deformation textures dictated by the deformation mode, which in turn depends on the nature of applied stress. A structure typical of a heavy deformation with elongated grains aligned along the wire axis and rolling direction is obtained [4].

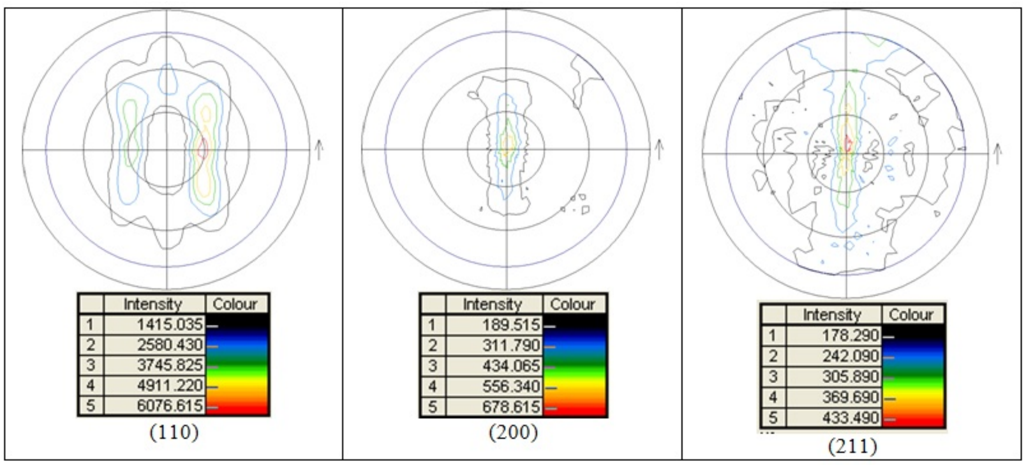

Fig. 4 Pole figures of Ti-25Ta-25Nb (110), (200), (211) – 8 layers -.

The observation of an unusually high intensity of a peak whose structure factor is otherwise low [4], together with decreasing of intensities of other peaks is a signature of crystallographic texture.

The study of deformation texture in the Ti–25Ta–25Nb alloy, figure 2, revealed that the (110) pole figure shows four symmetric texture types from the center of the pole figure, arranged at an approximate angle of 45° from the center and at a approximate angle of 45° from the rolling direction and transverse one; as for the (200) pole figure, one texture type is observed in the center of the pole. In figure 2, (211) pole figure shows 4 symmetric texture types, at an angle $0° \le \varphi \le 90°$ related to the rolling direction and the transverse one.

In figures 3 and 4, for the deformed Ti-25Ta-25Nb alloy, texture can be observed for the (110) pole figure as 4 symmetric types at an angle of 45° from the center, and from the transverse and rolling directions; in the case of the (200) pole figure a single type can be observed, related to the rolling and transverse direction. In figure 3 and 4 for the (211) pole figure no texture can be observed.

4. Conclusions

From all testing data, changes in alloy texture in precursor and ARB processed condition were observed.

The texture that developed during deformation was studied using XRD analysis. The texture developed by the severe plastic deformation of Ti-25Ta-25Nb alloy showed that the rolling direction is parallel with (110) plane. The deformation texture exhibited by the Ti–25Ta–25Nb alloy was dependent on the mode of deformation for the precursor sample.

The β phase stability is dictated by the alloy composition and influences the deformation behavior. A general aspect is that the layers deformation degree is not homogeneous. Therefore all samples present strong textures which enables us to conclude that promising β-Ti alloys – in this case Ti-25Ta-25Nb alloy – can be used in new medical applications due to their favorable properties.

The deformation texture developed by the Ti-25Ta-25Nb shows its dependance on the mode of deformation. For the deformed alloys texture was observed for (110) and (200) pole figures, but for the (211) pole figure of the ARB processed alloy, no texture was observed.

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