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ALLOYING OF TITANIUM BY OXYGEN DURING CHAMBER ELECTROSLAG REMELTING

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Abstract:

The paper presents the results of alloying titanium by oxygen in the process of chamber electroslag remelting. As an oxygen-containing ligature, we used the electrodes-satellite from the reaction mass residues mixture from the retort lid for magnesium thermal reduction of a titanium sponge, a specially prepared gaseous argon oxygen mixture containing 30% oxygen applied directly to the melting space, micro-size (10-15 mm) powder particles of titanium oxide and titanium oxide nanopowder with a particle size of 21 ± 5 nm. The structure and the properties of titanium alloyed by oxygen from the oxygen-containing ligature, gas phase and titanium oxide powder during chamber electroslag remelting of the titanium sponge are investigated. It was found that at the oxygen content of $0.053\%_{mas.}$ to $0.22\%_{mas.}$ in the metal formed a homogeneous single-phase structure typical for commercial titanium formed by polyhedral grains of the α-phase. The increase of the oxygen concentration in titanium for more than $0.22\%_{mas.}$ leads to the formation of the microstructurewith a typical needle structure, which allows it to be classified as the α′-phase.

Key words: *titanium, oxygen, alloying, chamber electroslag remelting, structure, properties.*

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Introduction

Today Vacuum Induction Melting, Vacuum Arc and Electroslag Remelting processes, Electron Beam and Plasma-Arc Cold Hearth Melting are the main technological processes of producing metals and alloys for critical fields of application, aviation for example. It seems that these processes are well studied and standardized. Nevertheless, at recent years, new information concerning a standard process such as Electroslag Remelting appeared. This information is the evidence of principally new possibilities of ESR for metal and alloy refining and alloying. These investigations have been conducted in the Donetsk National Technical University for more than thirty years. The objective of this research is to investigate the refining possibilities of ESR in controlled atmosphere in a chamber furnace under calcium-containing fluxes. The presence of a chamber and controlled atmosphere creates favorable conditions for effective refining and alloying of metals and alloys due to the use of metallic calcium during the remelting process (Ryabtsev, Troyanskyy, 2005a).

Currently, the theoretical bases of Chamber Electroslag Remelting process are being developed, basic laws are investigated and technologies of manufacturing commercial ingots from different metals and alloys, including titanium, are created and realized (Ryabtsev, Troyanskyy, 2005b, pp.25-32).

Among perspective structural materials, titanium and its alloys occupy a special place. Due to its properties, titanium is a basic structural material for many industries, including medicine. In this case, the most important requirements for medical titanium alloys, along with high specific strength and resistance to impact loading, are corrosion resistance, biocompatibility and absence of their toxic elements (Ryabtsev, et al, 2009, 4, pp.1-3), (Troyanskyy, Ryabtsev, 2007, pp.28-31).

In medicine, most common is type VT6 titanium alloy (Grade 5). However, the presence of alloying element vanadium in its composition, under certain conditions, leads to the formation of toxic compounds in the body. Unalloyed titanium of VT-1-0 grade is safer. However, its strength characteristics are almost twice lower than those of alloy VT-6. Therefore, improving the strength characteristics of this titanium by doping "safe" elements, from a medical point of view, is a very urgent task. Such a "secure" component may be oxygen. In contrast to nitrogen and hydrogen, it can provide not only a negative effect on the properties of titanium, but also a positive one. Thus, a small amount of oxygen is an economical alloying element that enhances the strength of titanium. By controlling its content in the metal, it is possible to reach the optimal ratio of plastic and strength characteristics of the titanium alloy (Ryabtsev, et al., 2012, pp.7-11), (Ryabtsev, et al., 2011, pp.39-42).

It is very important in this case to ensure uniform distribution of oxygen in the metal and the desirable form of its existence in it. This is achieved by applying appropriate technologies of melting and heat treatment of titanium. As a melting technology, chamber electroslag remelting (ChESR) can be used, which, along with the refinement in a controlled atmosphere, can further organize additional alloying of titanium. Moreover, because of its specificity, additional alloying can be done from the gas phase and by using different alloys. Similarly to other remelting processes, ChESR provides a good structural and chemical homogeneity of ingots with a typical as-cast structure (Reitz, et al, 2007), (Friedrich, et al, 2009, pp.295-301) (Benz, et al, 1999, pp.364-368), (Ryabtsev, Troyansky, 2008, pp.39-42).

Insufficient knowledge of the structure and properties of titanium alloys alloyed by oxygen during ChESR as well as the impact of different heat treatment methods on them is a constraint to a wider application of these materials instead of, for example, expensive and unsafe alloys of VT6 type.

In this paper, studies of different techniques of titanium alloying by oxygen are investigated. The effect of oxygen and heat treatment on forming the structure and the properties of titanium produced by chamber electroslag remelting is studied.

The goal of the investigation is to establish the basics of the structure and the properties of titanium alloyed by oxygen formation in the process of chamber electroslag remelting, and to develop the methods of controlling the process of structure formation by thermal and deformation effects.

Experimental

In this work,, chamber electroslag remelting was used for obtaining samples of titanium alloyed by oxygen. As an oxygen-containing ligature, we used the electrodes-satellite from the reaction mass residues mixture from the retort lid for magnesium thermal reduction of the titanium sponge (Ryabtsev, et al, 2007, pp.3-6) specially prepared gaseous argon oxygen mixture containing 30% oxygen applied directly to the melting space (Ratiev, et al, 2010, pp.8-12), (Ryabtsev, et al, 2011, pp.39-42), (Ryabtsev, 2011, pp.175-188); micro-size (10-15 mm) powder particles of titanium oxide and titanium oxide nanopowder with a particle size of 21 ± 5 nm (Ryabtsev, et al, 2012, pp.7-11).

Alloying by oxygen was carried out in accordance with the scheme shown in Fig. 1.

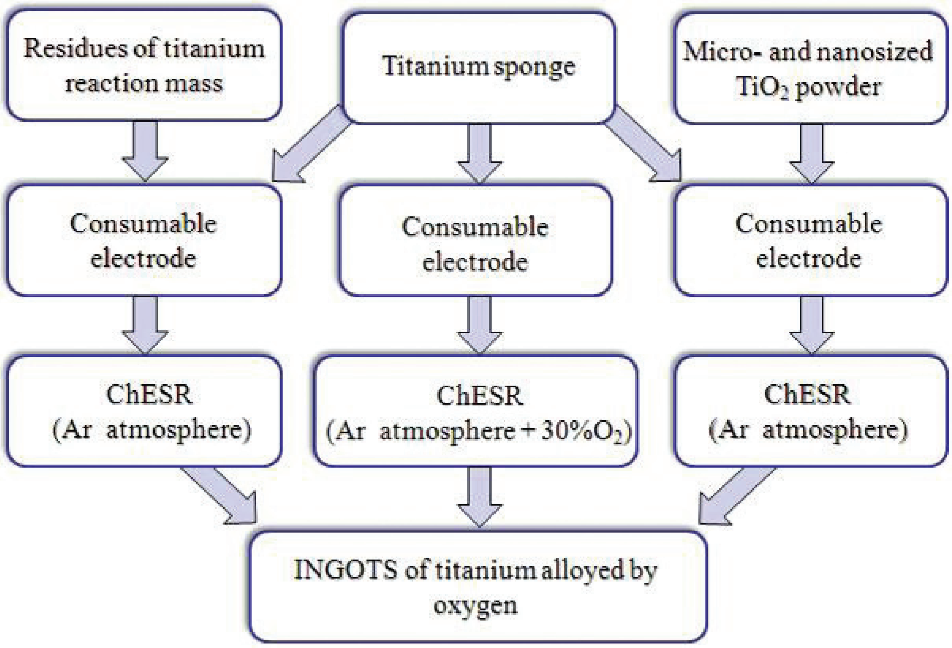


Fig. 1 – Principle of titanium alloying by oxygen
Slika 1 – Princip legiranja titanijuma pomoću kiseonika

The ingots of titanium with oxygen content up to 0.40%$_{mas.}$ alloyed by the reaction mass residues mixture, up to 0.27%$_{mas.}$ - alloyed from the gas phase and up to 0.73%$_{mas.}$ - by the introduction of powdered TiO_2 are obtained.

In the first variant, the so-called oxygen-containing ligature was used as an oxygen-containing material. As a row material for its preparation, the residues of the reaction mass from the retort lid for magnesium recovery of a titanium sponge were used. In the case of the application of the residues, the electrodes – «satellites» were made, which were welded on to the basic electrode, pressed from a titanium sponge of TG-110 grade (Fig. 2).

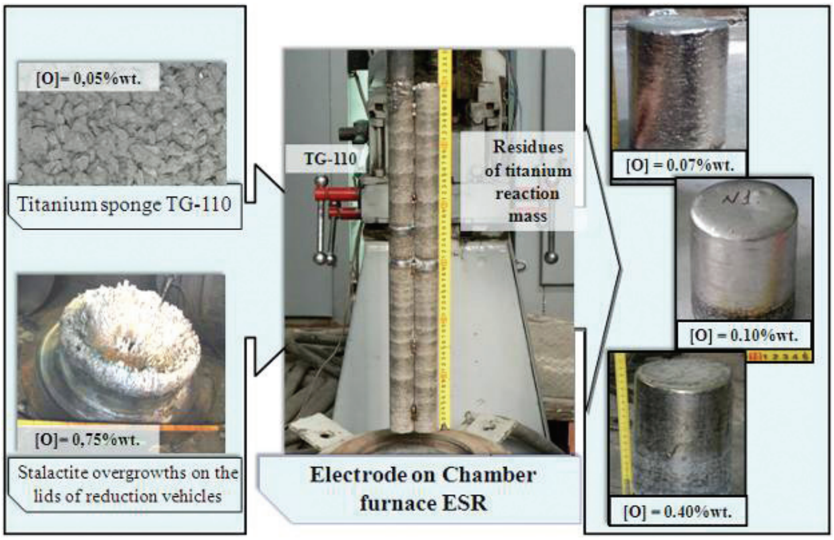


Fig. 2 – Alloying of titanium by oxygen from satellite electrode
Slika 2 – Legiranje titanijuma pomoću kiseonika iz elektrode „satelita"

The resulting composite electrodes were melted in a copper water-cooled crusible with a diameter of 115 mm and a height of 500 mm. The following variants were conducted: melting 1 - 100% of the electrode from the titanium sponge TG-110; melting 2 - 100% of the electrode from the reaction mass, melting 3 - a composite electrode from 50% of the titanium sponge TG-110 and 50% of the reaction mass, melting 4 - 100% of the electrode of the titanium sponge TG-110. During melting, the pressure of argon was around 15-30 kPa to compensate for its possible loss.

The powder of calcium fluoride (CaF_2), grade "Ch" - (TU 6-09-5335-88) annealed at 973K for 3 hours and metallic calcium (Ca) were used as flux- forming materials.

The flux was melted directly in the crucible using a "solid" start. Remelting was conducted under pure CaF_2 (meltings 1-3) and the flux system CaF_2 + Ca (melting 4). The electrical parameters were kept constant (U = 47 V,I = 3.0 kA.), providing good quality surface formation of cast ingots. As a result of remelting, the ingots of titanium were obtained with the oxygen content: № 1 -0.10%$_{mas.}$, № 2 - 0.40 %$_{mas.}$, № 3 - 0.30 %$_{mas.}$, № 4 - 0.07%$_{mas.}$.

This is due to the fact that the reaction mixture contained an increased amount of impurities in comparison with the titanium sponge,. Thus, the nitrogen content is 10 times greater (0.011% of the original titanium sponge and 0.11% in the reaction mass), iron is almost 2 times higher (0.06% in the sponge and 0.09% in the reaction mass), carbon content is 4 times higher (0.004% and 0.16% respectively). Thus, the oxygen in the titanium impacts on the changes in the morphology of the phases and can significantly increase the hardness and strength of titanium in the as-cast condition. This type of ligature can be used for commercial purity titanium with a relatively low content (0.25%$_{mas.}$.) of oxygen, such as Grade 1 - Grade 2.

In this work, the possibility of alloying titanium by oxygen directly from the gas phase in the process of chamber electro-slag remelting of a titanium sponge with different initial content of oxygen is considered. The application of the gaseous oxygen for alloying appears to be most economical. Out of the known metallurgical processes of melting titanium, chamber electro-slag remelting (ChESR) is, to the greatest extent, suitable for using such a source of oxygen, because alloying titanium by oxygen from the gas phase during the process of vacuum-arc and electron beam remelting is difficult due to the presence of vacuum in the working space. ChESR, unlike "canonical" ESR, allows to create any atmosphere in the working space and to refine effectively and additionally alloying the metal.

The pressed electrodes of 40 mm in diameter and 600 mm long have been remelted in the crucible with a diameter of 60 mm in an electro-slag furnace chamber developed on the basis of A-550 equipment. The equipment was additionally equipped with cylinders with an argon-oxygen mixture and with devices for the control of the consumption and pressure of gases (Fig. 3). As the source of gaseous oxygen, argon of the first grade, containing 0.002% oxygen, and a specially prepared argon-oxygen mixture (O_2=30%) were used. The ingots of titanium with different content of oxygen (from 0.035 to 0.270 % O) were obtained.

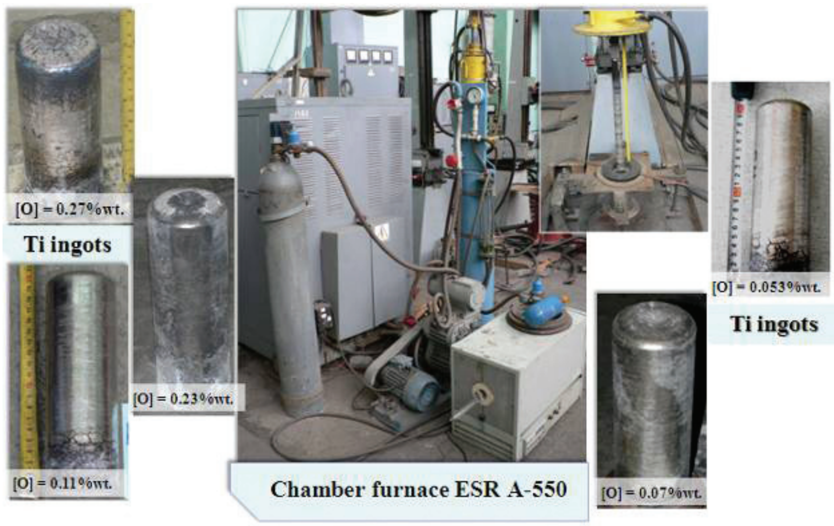


Fig. 3 – Alloying titanium by oxygen from gas phases
Slika 3 – Legiranje titanijuma pomoću kiseonika iz gasnih faza

The following investigations were devoted to the study of the possibility of alloying titanium by oxygen from titanium powder oxide. For this purpose, titanium oxide particles with a grain size of 10-15 mm and titanium oxide nanopowder with a grain size of 21±5 nm (nanometers) were pressed in a consumable electrode made from a titanium sponge. The ingots with oxygen content up to 0.73%$_{mas.}$ were obtained (Fig. 4).

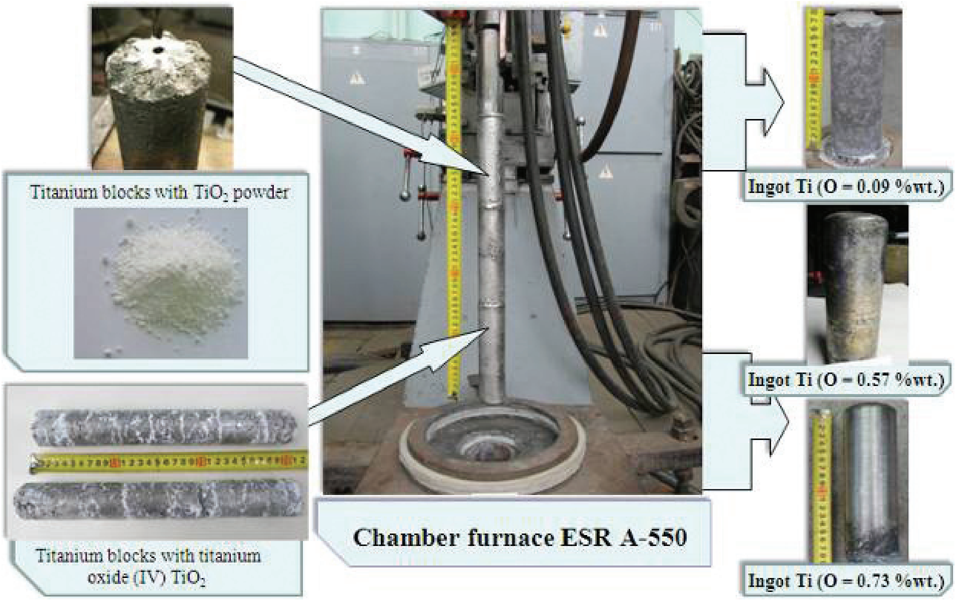


Fig. 4 – Alloying titanium by oxygen from TiO_2 particles
Slika 4 – Legiranje titanijuma pomoću kiseonika iz čestica TiO_2

The samples for chemical analyses and metallographic studies were cut from the ingots. Metallographic investigations at magnifications from × 50 to × 5000 were carried out on optical microscopes «Axiovert 40 MAT» (Carl Zeiss) and «Neophot 2" and a scanning electron microscope JEOL JSM-6490LV (JEOL, Japan), equipped with the energy dispersive spectrometer INCA Penta FETx3 (Oxford Instruments , England), the wave spectrometer INCA Wave (Oxford Instruments, England) and the backscattered electron diffraction detector HKL (Oxford Instruments, England).

The chemical composition of the metal was determined on an optical emission spectrometer «SPECTROMAX» company «SPECTRO» (Germany). The gas content was determined in the laboratories of IEW named E.A. Paton NAS of Ukraine, Zaporozhye titanium and magnesium plant and Aachen University (Germany) on analyzers TN-114, RO-316 and RH-2, RH-3 "LECO" Company (USA). The mechanical tests and hardness measurements were carried out by standard methods.

Obtained results and discussion

The following data was obtained. The distribution of hardness and the dependence of the mechanical properties of cast titanium on the oxygen content for oxygen introduction from the satellite electrode and from the gas phase are shown in Fig. 5.

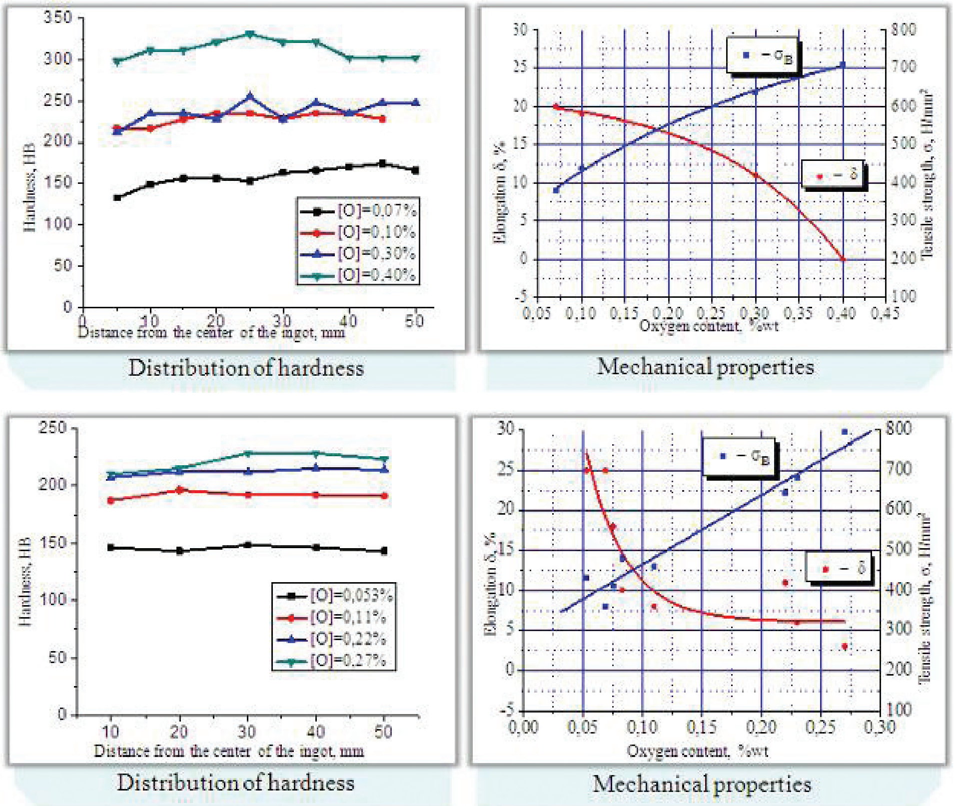


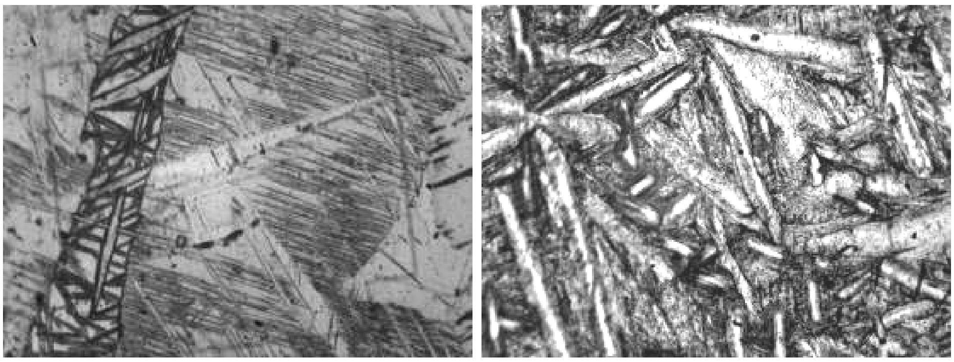
Fig. 5 – Distribution of hardness and the dependence of the mechanical properties of cast titanium on the oxygen content: a – alloying by oxygen from the satellite electrode; b – alloying by oxygen from the gas phase

Slika 5 – Raspodela tvrdoće i zavisnost mehaničkih karakteristika livenog titanijuma od sadržaja kiseonika: a – legiranje pomoću kiseonika iz elektrode satelita; b – legiranje pomoću kiseonika iz gasne faze

For both technologies, the uniform distribution of hardness in the cross section of the ingots is observed. This is the evidence of uniform distribution of alloying elements (oxygen in that number) in the ingot. As for the dependence of the properties on the oxygen content, it is different for the used technologies of alloying. For the alloying from satellite electrodes, the strength is increasing intensively from 350 – 370 N/mm^2 (for oxygen content 0.05 – 0.07%) to 700 N/mm^2 (for oxygen content 0.4%). The growth of strength properties corresponds to the decrease of relative elongation from 20% to a level close to 0%. The technology of alloying from the gas phase provides more active strengthening from 350 – 370 N/mm^2 for the oxygen content 0.05 – 0.07% to 800 N/mm^2 (for oxygen content 0.27%). Higher strengthening corresponds to more intensive decreasing of plasticity. The elongation reached values 5 – 7% at the oxygen content of more than 0.1%.

The addition of titanium oxide in the form of nanopowder ([O] = 0.175 - 0.73%$_{mas.}$) not only leads to an increase of hardness of as-cast metal but this technology permits to receive the refinement of the ingot structure. The highest hardness - 294 HB is observed in a metal sample with an oxygen content of 0.73%$_{mas.}$, obtained by uniform titanium oxide nanopowder input during ingot remelting. Thus, the examination of the metal showed that the use of TiO_2 powders as an oxygen ligature leads both to an increase in the oxygen content in the metal and to a beneficial change in the structure and hardness of titanium.

The microstructure of titanium (Fig. 6), obtained by alloying from the reaction mass residues mixture, containing from 0.07 to 0.40%$_{mas.}$. oxygen, is formed by the α and α' phases, respectively. Dispersibility depends on the oxygen content. Increasing the oxygen content to 0.3 %$_{mas.}$. does not lead to a substantial change in the morphology of the α-phase. With further increase of oxygen in titanium to 0.4%, the microstructure obtains a typical needle character that allows it to be classified as the α'-phase. The formation of this structure is accompanied by a sharp increase in hardness.

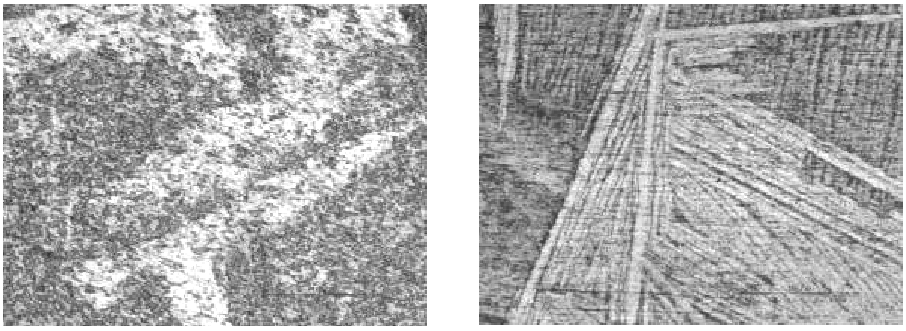


a b

Fig. 6 – The microstructure of titanium alloyed by oxygen from the ligature:
a – [O]=0.07%$_{mas.}$; b – [O]=0.4%$_{mas.}$, ×500

Slika 6 – Mikrostruktura titanijuma legiranog kiseonikom iz ligature:
a – [O]=0.07%$_{mas.}$; b – [O]=0.4%$_{mas.}$, ×500

The structure of titanium alloyed from the gas phase is shown in Fig. 7. In the as-cast state, in the metal forming a homogeneous single-phase structure, morphology is also dependent on the oxygen content. Thus, the microstructure of the metal with the oxygen content in it at $0.053\%_{mas.}$ is typical for technical titanium. Increasing the oxygen content to $0.22\%_{mas.}$ does not lead to a substantial change in the morphology of the α-phase. With the further increase of the oxygen content in titanium up to $0.22\%_{mas.}$, microstructure becomes a typical needle character that allows to classify it as the α'-phase. In this case, the needle α'-phases have a considerable extent: their length reaches 200 - 400 microns.



a b

Fig. 7 – The structure of as-cast titanium alloyed by oxygen from the gas phase :
a – $[O]=0.075\%_{mas.}$; b – $[O]=0.27\%_{mas.}$, ×100

Slika 7 – Struktura termički neobrađenog titanijuma legiranog iz gasne faze:
a – $[O]=0.075\%_{mas.}$; b – $[O]=0.27\%_{mas.}$, ×100

The structure of titanium alloyed from the gas phase is shown in Fig. 8. During using micro-and nano-size powders of titanium oxide as an oxygen-containing ligature, changes in the structure of titanium were observed as well as the increase of its hardness. Using nanosize particles leads to the increase of oxygen content and the refinement of structure.

a-$[O]=0.09\%_{mas.}$ b-$[O]=0.57\%_{mas.}$ c-$[O]=0.73\%_{mas.}$

Fig. 8 – Structure of titanium obtained by ChESR: a-not alloyed by oxygen,
b and c-alloyed by oxygen from the titanium oxide powder (b – microsize, c-nanosize), ×100

Slika 8 – Struktura titanijuma dobijenog u peći za elektopretapanje pod troskom:
a – nelegiranog kiseonikom, b i c – legiranog kiseonikom iz praha titanijum-oksida
(b – mikroveličina, c – nanoveličina) x 100

One of important techniques of structure and properties control is the heat treatment of alloy. Fig. 9 shows that in the annealed state with increasing the oxygen content, the morphology of the structure is still similar. It is formed from elongated grains. Separate groups of grains have a similar spatial orientation, forming a so-called "basket weave" pattern. The effect of oxygen realizes itself in the formation and coarsening of the structure of larger grains. At the same time, attention is drawn to the fact that the structure consists of dark- and light-etched areas, and, with the oxygen content increase, the proportion of the light phase increases. It has been suggested that different etchability takes place due to the formation of different structural or phase components in the alloy.

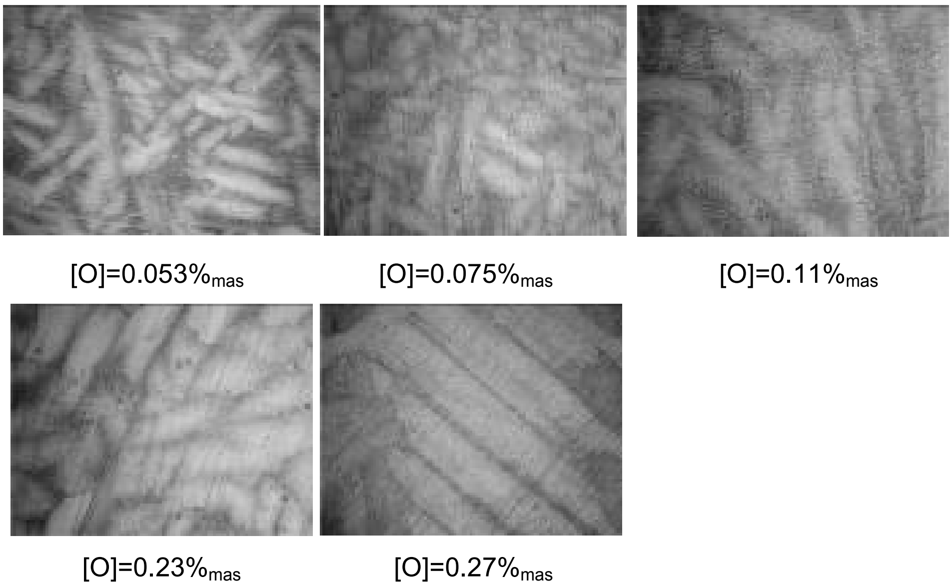


Fig. 9 – Microstructure of titanium samples with different oxygen content after annealing, x100 (numbers below figures indicate the oxygen content in % by weight)
Slika 9 – Mikrostrukture uzoraka titanijuma s različitim sadržajem kiseonika nakon žarenja, x100 (brojevi ispod slika označavaju sadržinu kiseonika u težinskim procentima)

To check this assumption, the X-ray analysis of the samples with the oxygen content $0.053\%_{mas.}$ and $0.27\%_{mas.}$ was conducted and the microhardness of the structural components was identified. The results of the X-ray analysis showed that, despite the formation of heterogeneous structure in terms of phase composition, the alloys are single phased and have a hexagonal lattice α- modification of titanium.

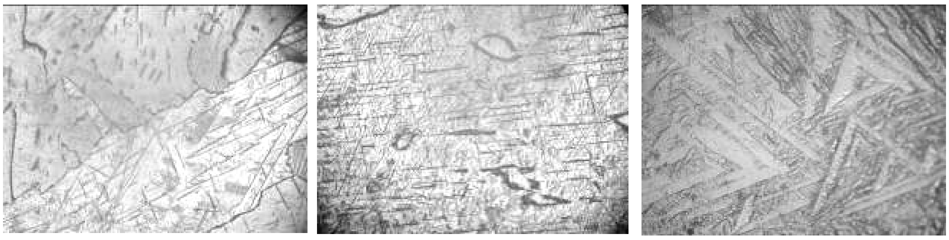
The microhardness of the dark component in both alloys is constant at 2760 - 2850 N/mm^2. The microhardness of a light component is much higher and changes depending on the content of oxygen in titanium. It was significantly higher than the microhardness of the dark component, and its value statistically significantly increases with the increase of oxygen content. To explain this fact, the assumption about the decomposition of the solid solution of oxygen in the α-Ti into two components at room temperature was made. Herewith, the content of oxygen in one of them (dark) remains constant and lower than in the other (light). In the light component, it is higher and changed. With the growth of the total oxygen content in the alloy, its concentration in the light component increases, which leads to an increase in microhardness. Since oxygen forms a solid solution, the parameter of the hexagonal lattice ***c*** of titanium alloyed by oxygen is slightly higher than for pure titanium and is 0.4686 nm as compared to 0.4679 nm.

The analysis of the obtained data shows that the decomposition of the solid solution can lead to a further hardening of the alloy, but increases the risk of brittle fracture. To decrease the harmful influence of structure coarsening, a method of its refinement must be found. The heat treatment that includes the quenching at temperatures which correspond to the β-field of state diagram was tested as a way of obtaining a refined grain structure.

Taking into account the influence of oxygen on the temperature of the α-β phase transformation, it was necessary to determine the temperature of the phase transformation for the alloys with different oxygen content.

By the method of trial quenching, we identified the temperature at the beginning and the end of the phase transformation $\alpha \rightarrow \beta$ for titanium which was alloyed by oxygen from the gas phase to the content of 0.053%$_{mas..}$ and 0.27%$_{mas..}$. The initial microstructure of both samples is typical for cast titanium alloy and has a coarse character, and the microstructure of the samples was formed by the α-phase grains structure that had irregular shapes, which is typical for the slow cooling of the alloy during the β-α transformation. After heating to temperatures below the temperature of α-β transformation and rapid cooling, the morphology of structure must be unchanged. With the heating of the alloy in the β-field of the state diagram and following the development of the β-α' transformation at a high cooling rate, a change of a structure type to needle-like shape grains will take place. It was established that for the alloy with [O] = 0.053%$_{mas.}$, the temperature of compete phase transformation is 940 – 950 ^{o}C, and for [O] = 0.27%$_{mas.}$ it is 990 – 1000 ^{o}C. The corresponding structures are shown in Fig. 10.

[O] = 0.053%$_{mas.}$



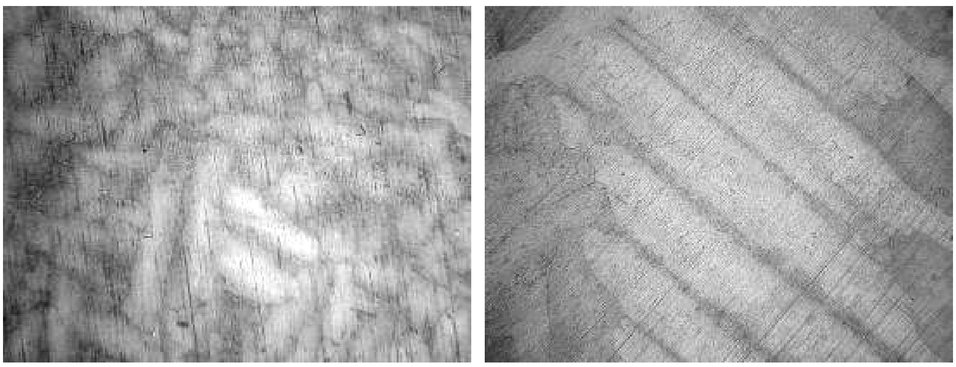
930°C 940°C 950°C

[O] = 0,27%$_{mas.}$

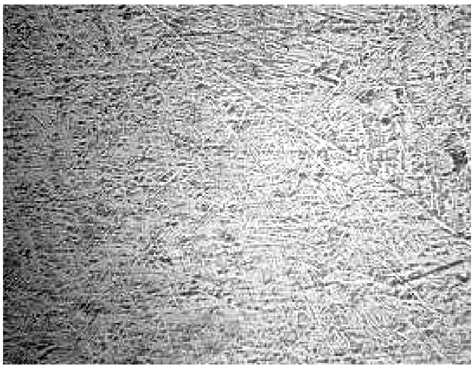
950°C 980°C 1000°C

Fig. 10 – Change of structure type after reaching the β-field temperature, ×500
Slika 10 – Promena tipa strukture nakon postizanja trmperature β-polja, x 500

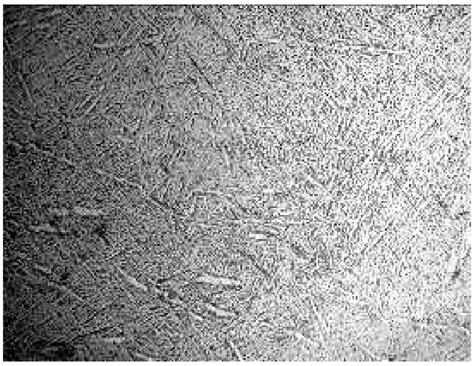
Fulfillment of quenching from temperatures of β-field permits to obtain the refinement of structure comparing with annealed state (fig. 11). It was determined, that coarsening of initial annealed structure has not influence on final size of structure elements after quenching.



a b



c

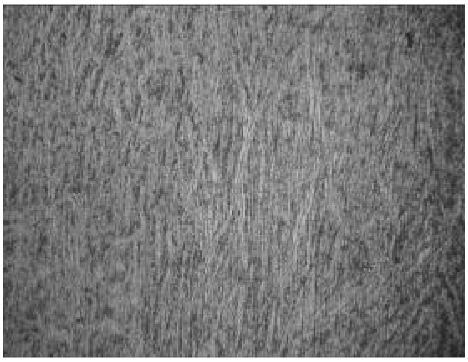


d

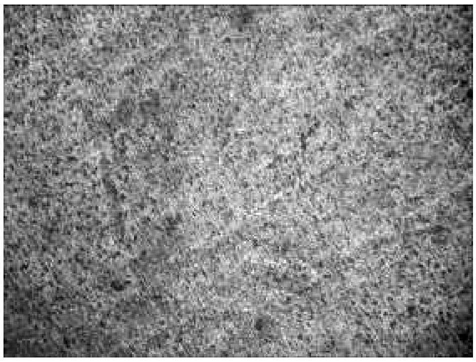
Fig. 11 – Structure of titanium, alloyed by oxygen from the gas phase, after annealing (a,b) and quenching (c,d): a,c - [O]=0.075%$_{mas.}$; b,d - [O]=0.22%$_{mas.}$, ×100

Slika 11 – Struktura titanijuma legiranog kiseonikom iz gasne faze, nakon žarenja (a,b) i kaljenja (c,d): a,c - [O]=0.075%$_{mas.}$; b,d - [O]=0.22%$_{mas.}$, ×100

Another promising way of structure refinement is severe plastic deformation by hydroextrusion. After the plastic deformation, the structure becomes finer. With increasing the oxygen content, significant differences in the structure are not observed (Fig. 12). However, there is an improvement in mechanical properties.



[O]=0.053%$_{mas.}$



[O]=0.22 %$_{mas.}$

Fig. 12 – Structure of titanium, containing various concentrations of oxygen, after plastic deformation by hydroextrusion, × 100

Slika 12 – Struktura titanijuma sa različitim koncentracijama kiseonika nakon plastične deformacije hidroekstruzijom, x 100

The mechanical properties after plastic deformation of titanium are presented in Table 1.

Table 1 – Mechanical properties after plastic deformation oftitanium
Tabela 1– Mehaničke karakteristike titanijuma nakon plastične deformacije

State of material	Oxygen content, $\%_{mas.}$	UTS N/mm^2	Yield limit N/mm^2	Relative elongation δ, %
as-cast	0.053	430	325	25
deformed	0.053	640	595	16
as-cast	0.22	645	575	11
deformed	0.22	840	775	10

The obtained results show that increasing the oxygen content of titanium to 0.053 to $0.22\%_{mas.}$ by weight increases the strength of the metal after severe plastic deformation on 31%, while ductility remains practically at the same level .

Conclusion

1. The chamber electroslag remelting as a metallurgical process illustrates an efficient way of alloying titanium with oxygen in the investigated range of 0.053 - 0.73 $\%_{mas.}$ at the application of reaction mass residues mixture, gas phase or micro-size (10-15 mm) powder particles of titanium oxide and titanium oxide nanopowder with a particle size of 21 ± 5 nm in the process of sponge remelting and provides good chemical and structural homogeneity of titanium ingots.

2. It was established that alloying titanium by oxygen in the chamber during the electroslag remelting from the reaction mass residues mixture permits to obtain the maximal concentration up to $0.4\%_{mas.}$, from the gas phase – up to $0.27\%_{mas.}$. Introducing oxygen in the form of nanoparticles permits to reach a maximal concentration up to $0.73\%_{mas.}$. All technologies permit to obtain uniform distribution of alloying elements in ingots.

3. Alloying of commercially pure titanium by oxygen during the chamber electroslag remelting allows obtaining structures with different morphologies in the cast and annealed condition. In the as-cast condition, increasing oxygen content higher than $0.22\%_{mas.}$ of the transition from the formation of structures of polyhedral type to needle-type structures is accompanied by an increase in hardness of the material.

4. The increasing of oxygen content in titanium from $0.053\%_{mas.}$ to $0.73\%_{mas.}$ provides significant increasing of the hardness and strength of titanium, but decreases the plasticity. Technology of alloying from the gas phase permits to obtain higher strengthening than alloying by reaction mass residues mixture, but it is accompanied by sharper decrease of plasticity.

5. It is established that the embrittlement of alloys of the system "titanium - oxygen" is the result of the formation of a coarsened as-cast structure. The increase of plasticity needs the refinement of the structure. It may be provided by quenching the alloy from temperatures that correspond to the β-field of the state diagram or by a severe plastic deformation (hydroextrusion).

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LEGIRANJE TITANIJUMA KISEONIKOM U PEĆI ZA ELEKTROPRETAPANJE POD TROSKOM

OBLAST: hemijske tehnologije
VRSTA ČLANKA: stručni članak
JEZIK ČLANKA: engleski

U radu su prikazani rezultati legiranja titanijuma kiseonikom u procesu elektropretapanja pod troskom u peći. Za vezivo, koje sadrzi kiseonik, korišćene su satelit elektrode iz reakcije masenih ostataka mešavine iz poklopca retorte za termalnu redukciju magnezijum-titanijumskog sunđera, specijalno pripremljena mešavina gasa argona i kiseonika sa 30% kiseonika primenjena direktno na mesto topljenja, čestice praha titanijum-oksida mikroveličine 10–15mm i nanoprah titanijum-oksida veličine čestica od 21± 5 nm. Ispitane su struktura i karakteristike titanijuma legiranog kiseonikom iz veziva , gasne faze i praha titanijum-oksida tokom elektropretapanja titanijumovog sunđera pod troskom u peći. Utvrđeno je da se pri sadržaju kiseonika od 0.053%mas.do 0.22%mas. u metalu formira homogena jednofazna struktura tipična za komercijalni titanijum formiran od poliedarnih zrna α-faze. Povećanje koncentracije kiseonika u titanijumu za više od 0.22%mas. dovodi do formiranja mikrostrukture s tipičnom igličastom strukturom, što omogućava da bude klasifikovana kao α′-faza.

Ključne reči: *titanijum, kiseonik, legiranje, peć za elektropretapanje pod troskom, struktura, karakteristike*.

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