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Producing Ti-Al coatings by mechanical alloying method

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Abstract.A research of microstructure of Ti-Al coatings received by method of the mechanical alloying on the surface of titanium was conducted by the scanning electron microscopy method and X-ray structure analysis. The morphology of coatings is formed depending on the efficiency of powder components staying in the zone of dynamic impact of spheres blow. The shift of the Ti diffraction line was found which is explained by internal stress of first order, induced as a result of spheres blows. It is supposed that the defect structural state promotes the increase in reactivity of components of processed materials, anomalously high mass transfer and a solid-phase mechanical alloying.

Introduction

Now the processes of mechanical alloying (MA) activated by means of mechanical blows of spheres became objects of intensive researches, because of their perspective application for receiving of coatings on the surface of metals and alloys. It is well known that the MA initiates and accelerates chemical interactions in a solid phase. There is a change of crystalline structure, formation of solid solutions and intermetallic compounds under the influence of strain energy in the processed materials[1-2]. The substance of this method consists that metal spheres and powder of the given chemical composition are inserted the camera which is set in vibration motion by the mechanical vibration generator in the given frequency range determined by composition of the applied mix and mechanical characteristics of the processed material [3]. During the MA the coatings formation depends on the effectiveness of contact of spheres with a surface of the processed material and powder particles.In this paper we present a titanium as the base layer fastened above the vibration camera for increase of coatings process effectiveness.

Experimental details

The SVU-2 (Stand Vibrating Universal) vibration installation was used for drawing of Ti-Al coatings on the surface of titanium. The plate of a titanium (Grade2) 70x70x3 mm in size was used as the base layer. The base layer was installed on the top of the vibrating chamber. The surface of the base layer was grounded before drawing of coatings. Ti powder (purity of 99%, the size of fractions of 45 μm) and Al powder (purity of 99%, the size of fractions of 5 μm) were used for drawing of coatings. The mass percent of powder composition is Ti – 37% and Al – 63%.

Process parameters for the drawing of coatings are: the frequency of vibration is 50 Hz, amplitude is 3.5 mm, the degree of chamber filling is 80%, the over covering time is 1 h, diameter of spheres is 4 mm, the mass of a sphere is 300 g, a ratio of mass of spheres to the mass of powder 50:1.

The morphology and elemental composition of a surface of coatings were investigated on a Quanta 200 3D microscope with system of electronic and an integrated focused ion beam. Researches of elements distribution on depth of an sample were conducted on a GD-Profiler HR

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spectrometer of an issue glow discharge. The phase composition of the samples was determined by X-ray phase analysis on Shimadzu XRD 6000 Diffractometer. X-ray analysis of the phase composition was performed using PDF4 database as well as a program of POWDER CELL2.4 full-profile analysis. The roughness of a sample surface was measured on the three-dimensional non-contact 3D Micro Measure surface analyzer.

Results and discussion

The morphology of coatings has peculiar structure for MA process. Irregular sections can be observed on a surface of coatings. The elemental analysis was performed on such sections (refer with: Fig.1).

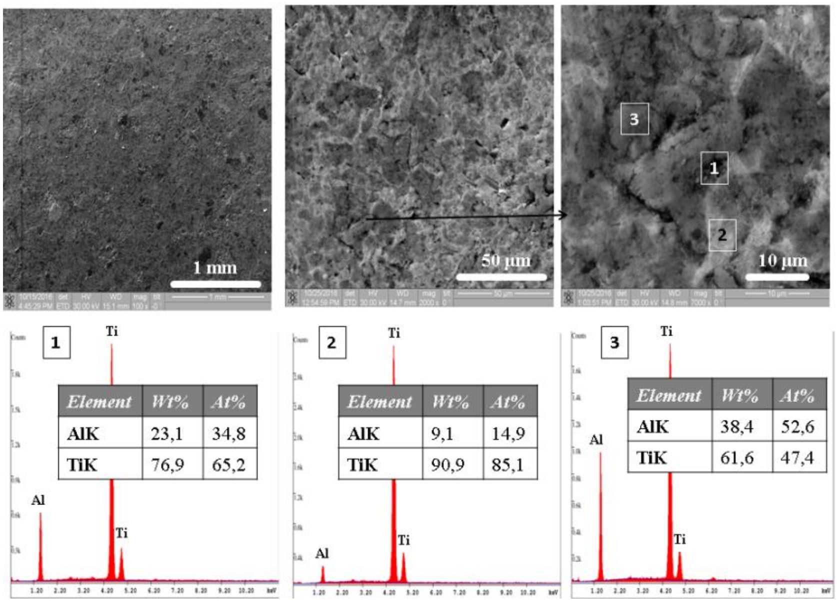

Figure1.SEM image of a microstructure of Ti-Al coatings on a Ti surface and

EDS results of a position 1-3 on the SEM image

According to the elemental analysis, a low content of aluminum on a covering surface compared to the original composition of powder can be explained on the basis of the mechanical properties of initial components. Data on a research of influence of mechanical characteristics of initial components on effectiveness of an alloying are cited in this paper [4]. Alloying effectiveness is higher than the smaller the difference of mechanical properties of the components in the initial state. The coalescence or alloying of powder can be result of cold welding of the deformed particles. If different materials are involved, their initial solidity can vary greatly. The alloying does not begin until a softer material obtains a solidity due to mechanical hardening, the solidity close to that of the second component. If it can not be achieved, there is an alternative version of the cold welding of particles when a solid component is enveloped by a soft element. Thus, there is a process of a particle coalescence of Ti and Al powders at the initial stages of coatings drawing, a particle of the weak element, in our case of Al, is more spent for formation of a ductile matrix for base layer surface. The dense and heavy-duty covering is formed as a result of the influence of blows of Ti particles are driven into a ductile matrix. On the basis of this mechanism it is possible to explain the formation of lighter sections on a surface of coatings which correspond to the maximum titanium content (refer with: Fig.1, Position 2). It is possible to assume that light sections are formed in blow situ of spheres with the minimum stress where there is no hashing of components of coatings, i.e. introduction of a Ti particle in a matrix of coatings. Within this framework, it can be said that the degree of coatings completion depends on the effectiveness of powder components in a zone of an inertial reaction of blow of spheres.

Fig.2a shows a qualitative profile of Ti-Al coatings at the surface of Ti, obtained by a glow discharge spectrometer. Maximum intensity of the Al line is registered at a depth of 500 nm, the thickness of coatings can be estimated around 1 micron. R_a is the roughness of coatings. It was determined according 10 basic lines on the three-dimensional non-contact surface analyzer, scan area was 3×3 mm (refer with: Fig.2b). Mean value of a roughness of coatings is equal to 0.44±0.08 μm.

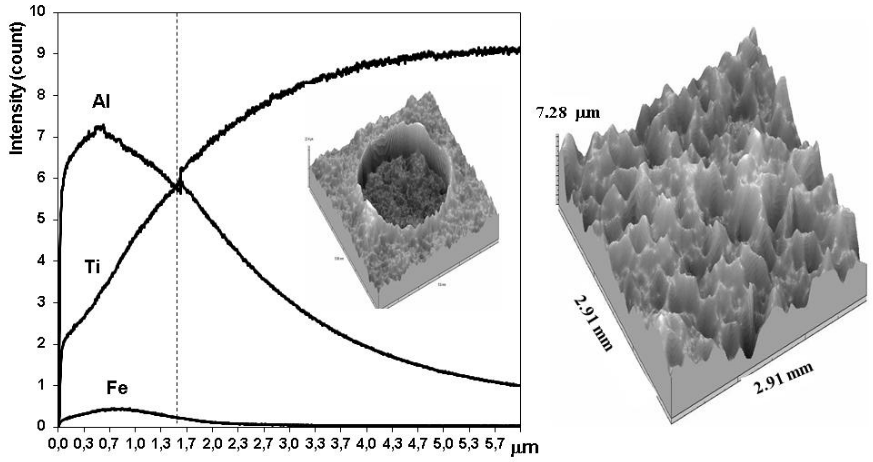

Figure 2.Ti-Al covering on Ti surface: a) qualitative profile of a sampler; b) 3D image of a surface

Fig.3 shows the diffractogram of Ti-Al coatings at the Ti surface. Ti and Al lines were registered.The shift of the diffraction of the Ti line was found which it is noticeable under larger Bragg angles. This shift is explained by internal stress of first order (macrostress), induced as a result of spheres blows. There is an angular displacement of the diffraction lines in the presence of macrostresses, bounded with changes of parameter of a grid [5]. The comparison of values of the Ti and Al latticeparameters from baseline values showed the increase in the grid latticeparameters of the detected phase during MA(refer with: Table 1).

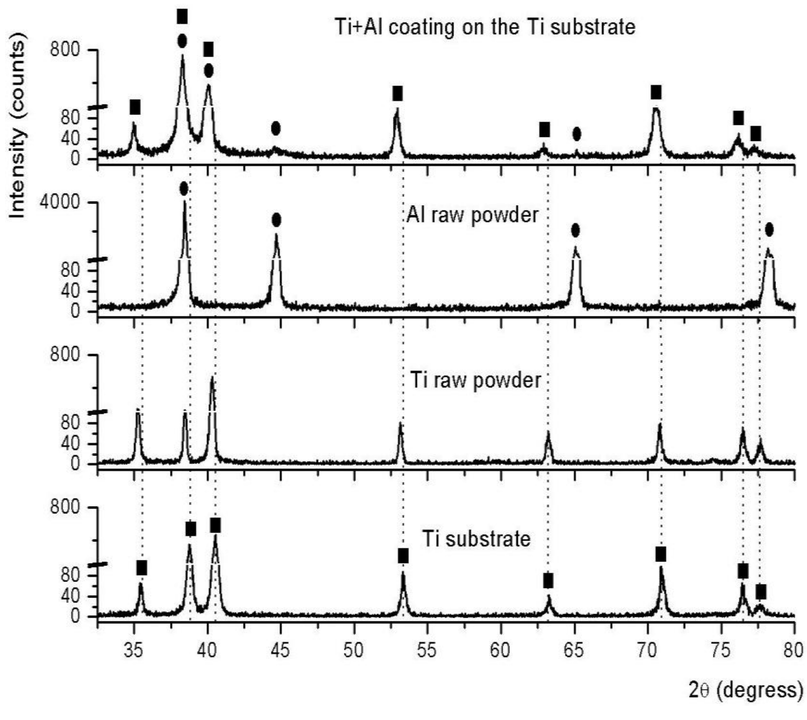

Figure 2. X-ray diffractionof Ti-Al coatings at the Ti surface

Table 1.The results of X-ray analysis

Sample	Phase	Phasecontent,%	Lattice parameters, Å
Ti-Al coating at the Ti surface	α- Ti	36.55	a = 2.9718; c = 4.6869
	Al	63.45	a = 4.0128
Ti substrate	α- Ti	-	a = 2.9549; c = 4.6874
Ti raw powder	α- Ti	-	a = 2.9407; c = 4.6800
Al raw powder	Al	-	a = 4.0501

The decrease of intensity of the diffraction Al lines and the broadening of Ti lines was revealed. However this fact is not enough for confirmation of disolution of Al in Ti, because of restricted resolving power of the X-ray phase analysis method. Various changes of the diffraction lines of sampler after MA demonstrate the existence of the defect structural states. These states are sources of high local internal stresses, and has an essential role in the phenomena of increase in reactivity of components of the processed materials, anomalously high mass transfer and a solid-phase MA.

Summary

In the MA process as a result of blows of spheres of a powder particle are besieged on a base layer surface. The formed structure of a covering is sated with a large amount of nonequilibrium defects and finely divided particles. The morphology of coatings is formed depending on the efficiency of powder components staying in the zone of dynamic impact of spheres blow. It is supposed that the defect structural states promote the increase in reactivity of components of processed materials, anomalously high mass transfer and a solid-phase MA. Now there is no uniform theory allowing to determine conditions of coatings drawing by method of the MA, it is necessary to conduct a number of the researches based on studying of mechanisms of coatings formation.

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