THE ETCHING PROCESS OF THE SURFACE OF Ti6Al7Nb ALLOY IN SF_6 PLASMA AND ITS INFLUENCE ON THE SELECTED PROPERTIES

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Introduction

In the field of surface engineering, continuous development is required in terms of technologies allowing for modifications of the materials surfaces that enable to obtain the most favorable properties for selected applications. Modification of the material surface affects its morphology and topography, at the same time changing specific properties. A well-known and most commonly used titanium alloy surface treatment is laser modification [1-3]. However, with a step forward, attention should be focused on the development of a promising and easy to implement in the industry method which is plasma etching, that achieves the intended topography of the titanium alloy surface. In the plasma etching process two fundamental etching mechanisms can be distinguished: chemical and physical one. In the case of the chemical mechanism the active species (radicals) originating from plasma react with the material of the substrate leading to the formation of stable volatile products, and as a result in the removal of a certain amount of matter. Whereas in the case of the physical mechanisms high-energy ions play an important role, removing particles from the modified surface. Depending on the chemical composition of plasma, process parameters and the substrate material, the obtained etching profiles show anisotropic or isotropic character [4,5]. The SF_6-based plasma etching processes promote a chemical etching without any noticeable coating of the surface with fluorine molecules. Moreover, studies show that increasing the amount of fluorine containing molecules increases the etching rate, but also affects the etching result of a more isotropic profile [6]. Currently, despite great potential of plasma surface treatment, there is a lack of studies in the world literature concerning the influence of the etching process parameters (i.e., pressure, bias, substrate temperature) in SF_6-based plasma on surface properties of titanium alloy etched using a mask of appropriate geometry. Therefore, in this study, the aforementioned method became the motivation for the modification of the Ti6Al7Nb alloy surface in the SF_6-plasma.

Materials and Methods

Samples of Ti6Al7Nb alloy with mechanically polished surface were chosen as the substrates for the study. Plasma etching processes were carried out using SF_6 gas. The surface topography was shaped using AISI 304L steel masks. The effects of various process parameters on the surface morphology and topography were investigated. Two different values of self-bias (-500V, -700V), pressure (0.65 Pa, 1.3 Pa) and substrate temperature (cooled, heated up to 230℃) were applied. The process time (30 min) and gas flow rate (10 sccm) remained the same for all the etching processes carried out.

The surface morphology and chemical composition of the modified surfaces were examined with the use of JSM-6610LV (JEOL) scanning electron microscope (SEM) integrated with the EDS X-MAX 80 analyzer (Oxford Instruments). The surface morphology was also studied by optical microscopy (Keyence VHX). The measurements of the etched structures and masks after the etching processes using the images captured through the optical microscope were performed. Surface roughness was measured and analysed using the contact profilometer (Hommel Tester T1000) and EVOVIS software in accordance with PN-EN ISO 4287. The depth measurements of the etched structures were also carried out. The etching directionality and selectivity were calculated.

Results and Discussion

SEM analysis of the samples etched in SF_6 plasma revealed the presence of by products on their surface. Microanalysis of the modified surfaces using energy dispersive spectroscopy (EDS) showed the presence of fluorine derived from SF_6 plasma and elements from the masks material (Fe, Ni, Cr). The higher concentration of fluorine was observed on the surface of the heated samples compared to the cooled substrates. The roughness parameters measurements of the etched surfaces (Ra, Rz) revealed the decrease in surface roughness for cooled samples with the decrease pressure value. The lowest etch selectivity was obtained at -700V self-bias value and pressure of 1.3 Pa due to higher ions energy resulting in sputtering of the mask material. The highest anisotropy was obtained for the cooled sample etched at a potential of -500 V and a pressure of 0.65 Pa.

Conclusions

This work deals with the SF_6 plasma etching of the surface of Ti6Al7Nb alloy. The changes in the chemical composition, morphology, roughness, etch directionality and selectivity were analysed depending on the pressure, bias and substrate temperature values applied during the etching process. It has been proven that higher substrate temperature increases the surface roughness. For etching processes in SF_6 plasma, the surface roughness increase with increasing bias values. The high value of the bias results in a decrease of the etch selectivity.

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