STUDIES OF THE INFLUENCE OF SURFACE TOPOGRAPHY OF TI6AL7NB ALLOY ETCHED IN CF_4 PLASMA ON ITS SELECTED PROPERTIES

NATALIA PŁUSA*, ADRIANNA BOROWSKA, MARCIN MAKÓWKA, ANNA JĘDRZEJCZAK

INSTITUTE OF MATERIALS SCIENCE AND ENGINEERING, LODZ UNIVERSITY OF TECHNOLOGY, POLAND
*E-MAIL: NATALIA.PLUSA97@GMAIL.COM

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Introduction

The subject of surface patterning of titanium alloys has been attracting a large interest among scientists for decades. However, so far, these materials have been surface structured mainly by laser ablation method, which allows to obtain a variety of shapes with an anisotropic profile. According to numerous literature reports, laser surface texturing affects wettability [1-3], improves mechanical properties and wear resistance [4], as well as biological properties, e.g. faster development and spreading osteogenic cells [5-7] or increasing antibacterial properties [8]. Plasma etching process seems to be a very promising method of patterning of titanium alloys surface and good alternative for laser structuring techniques. The abovementioned method has been widely studied for the last decades in the field of fabrication of silicon structures for microelectronics applications. In comparison with laser texturing method, a wider range of profile shapes could be obtained, from isotropic to anisotropic one. The etching directivity is determined by the dominant etching mechanism - chemical or physical, depending on numerous factors, such as e.g. process parameters, chemical composition of reactive gas, substrate and mask material and its geometry. The surface treatment of a silicon substrate using fluorine-based plasma leads to obtain mainly isotropic profiles [9]. Furthermore, the presence of CF_x radicals may cause a competitive process - formation of a fluorocarbon film [9]. So far, the knowledge in the field of etching mechanisms (including CF_4 plasma etching) of titanium alloys is insufficient and studies in this area require to be expanded. In this study, the high potential of the CF_4 plasma etching connected mainly with the possibilities of obtaining the different shapes of the etched profiles became the motivation for the modification of the Ti6Al7Nb alloy surface using this method.

Materials and Methods

In this study, CF_4 plasma etching processes on mechanically polished surface of the Ti6Al7Nb alloy were carried out. The surface topography was shaped using AISI 316L stainless steel masks of different geometry and different process parameters. Two values of self-bias (-500V, -700V) and pressure (0.65 Pa, 1.30 Pa) were applied. The process time (60 min) and gas flow rate (10 sccm) remained the same for all the conducted etching processes. The surface morphology was analysed by optical microscopy (Keyence VHX) and scanning electron microscopy (Jeol JSM – 6610L). The measurements of the etched structures and masks after the etching processes using the images captured through the optical microscope were also performed. The chemical composition of the patterned Ti6Al7Nb alloy surfaces was investigated using energy dispersive spectroscopy (EDS). The contact angle measurements were carried out using the sessile drop technique and KrussEasy Drop FM40 apparatus. Surface roughness was measured using the stylus profilometer (Hommel Tester T1000) in accordance with PN-EN ISO 4287. Using this method, the depth measurements of the etched structures were also carried out. Based on the dimensions of the etched structures and masks used during the etching processes, the etching directionality and selectivity were calculated.

Results and Discussion

Scanning electron microscopy (SEM) has shown the presence of the reaction products on the modified surfaces, especially located under the mask material. EDS microanalysis has confirmed the presence of elements derived from CF_4 plasma (C, F) and the mask material (Fe, Cr, Ni). The studies on the etching mechanisms have exhibited strongly isotropic profiles for the lowest self–bias value (-500V). The application of a higher negative self–bias value resulted in the action of both free radicals and ions, thus showing a mixed (chemical and physical) nature of the etching mechanisms. The highest selectivity was obtained applying -500V self-bias value and pressure of 0.65 Pa, probably due to the lower ions energy resulting in less effective mask material sputtering. The surface roughness of the etched titanium alloy has increased after CF_4 plasma modification. Vertical roughness parameters (R_a, R_z) have achieved the lowest values at -500V self – bias value. Surface roughness defined by R_{Sm} parameter depends on the geometry of the etched pattern. The contact angle has increased from approximately 70° for polished Ti6Al7Nb sample to 90° for the patterned one, thus increasing the hydrophobic properties of the modified surface.

Conclusions

Process parameters, especially self – bias and pressure values, have a significant influence on etching directivity and dominant etching mechanism, resulting in obtained profiles from strongly isotropic towards anisotropic one. The EDS microanalysis confirmed the presence of carbon and fluorine atoms on the patterned surface in CF_4 plasma, what can be related to a formation of a thin fluorocarbon film. The change in the wettability of the surface results from an increase in surface roughness and a change in the chemical composition after the plasma etching processes.

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