Evaluation of the Effect of Surface Preparation on Corrosion Properties of Cerametallic Composites in Titanium Matrix

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Abstract— *Metal matrix composites reinforced ceramic particles, are widely used in industry, wherever high resistance to abrasive wear, erosion and corrosion is necessary. Cermets, in which titanium carbide (TiC) is used as reinforcing phase, are particularly interesting for improving the strength, stiffness and wear resistance, especially at elevated temperatures. The paper presents the results of corrosion tests of titanium matrix composite reinforced nc-TiC particles, at different stages of surface preparation: grinding, polishing, electropolishing and oxidation in the furnance. Measurements of potentiodynamic polarization curves in 3% NaCl solution were performed. The results have showed the negative impact of the nanocrystalline TiC strengthening phase on corrosion resistance of composites. It was also found that electropolishing treatment is the most preferred way to prepare the surface for titanium as well as TiC reinforced composites.*

Keywords— Metal matrix composite, titanium, titanium carbide, corrosion resistance, SLM.

I. INTRODUCTION

Titanium (Ti) and its alloys are widely used in aviation, aerospace as well as chemical industries. This is influenced by their excellent properties such as high strength, adequate rigidity and high corrosion resistance [1]. However, titanium has reduced abrasion resistance, which is a significant disadvantage when used in environments where intense abrasion and erosion phenomena occur. One way of overcoming these limitations, which is presented in this work, is the use of hard ceramic materials, being the reinforcing phase in the resulting composites.

In conventional composites in order to improve the anti-abrasive properties ceramic powders of micrometric size, such as WC, TiC, TiN, SiC, TiB_2 are used [2,3]. However, the use of large ceramic particles causes that they remain unmelted or only partially melted in the processes of composites manufacturing. Additionally, a low wettability between the ceramic particles and the metal results in formation of a limited number of chemical bonds between the matrix and the reinforcing phase, and this may lead to deterioration in mechanical properties [4]. Therefore, now many research centers use powders of nanometric size as a reinforcing phase in the processes of composites manufacturing [5-7].

II. EXPERIMENTAL

In the process of composite powders preparation commercial pure titanium powders from SLM Solutions GmbH and nanocrystalline titanium carbide powders with crystallite size of 40 nm were used. The nc-TiC powders were obtained by the sol-gel method [8]. The mixtures of powders containing 0, 1, 10 and 20 vol% nc-TiC and the rest titanium powder were prepared for the SLM process. The mixtures were homogenized in a planetary mill Pulverisette 4 (Fritsch GmbH). The grinding balls made of WC/Co were used with a ball-to-powder weight ratio of 10:1. In the SLM process, an apparatus comprising Nd:YAG fiber laser and an automated powder layer feeder was used. Argon was used as a protective gas. The SLM process parameters were previously described [9]. The volumetric energy density of laser (ε) was in the order of 120 J/mm^3. The relative density of titanium and TiC/Ti nanocomposites was determined by the Archimedes method.

The morphology of titanium and titanium carbide powders were investigated, respectively, by SEM using a HITACHI SU apparatus and TEM method (JEOL JEM 1200EX). The average crystallite size and phase composition were determined by XRD method (PANalytical PW3040/60 X'Pert Pro). Each sample was subjected to four treatments aimed at the surface refinement, namely mechanical polishing, grinding, electropolishing, and anodic oxidation. The process of anodic oxidation was carried out in a solution containing 1.5 M H_2SO_4 and 0.3 M H_2O_2 at 25°C for 15 min. After each treatment, the samples were cleaned with the ultrasonic cleaner, and their microstructure was characterized by an optical microscope. The optical microscope Nikon Measuring Microscope MM-40 equipped with a Nikon Digital Sight DS.-U1 camera was used for these studies. Observation of an image sent from the camera was enabled by Lucia software. The microscope was equipped with a CFWN 10x/20 ocular eyepiece. After each of the four treatments the measurements of anodic polarization were conducted. The studies were performed, using ATLAS 9833 potentiostat. The POL-99win software enabled a comparison of the corrosion potential and corrosion current density on the chart (change in voltage as a function of current density). The studies

were conducted in the three-electrode system, where the working electrode (WE) was the sample, the counter (auxiliary) electrode (CE) was a graphite electrode, and the reference electrode (RE) was a calomel electrode inserted in a Luggin capillary filled with KCl solution. All the above-mentioned elements of the electrochemical three-electrode setup were placed in the corrosion cell filled with 3% NaCl. The area of the sample exposed to the electrolyte was $1cm^2$.

The aim of the study was to make a comparative assessment of the impact of the state of surface preparation of TiC/Ti nanocomposites, obtained in the above-described conditions, for their resistance to corrosion.

III. RESULTS AND DISCUSSION

The microscopic images of nc-TiC and microcrystalline titanium, obtained by TEM and SEM methods, respectively are shown in Figure 1. The summary of X-ray diffractograms of titanium and composites containing 1, 10 and 15 vol% nc-TiC manufactured by SLM method is presented in Figure 2.

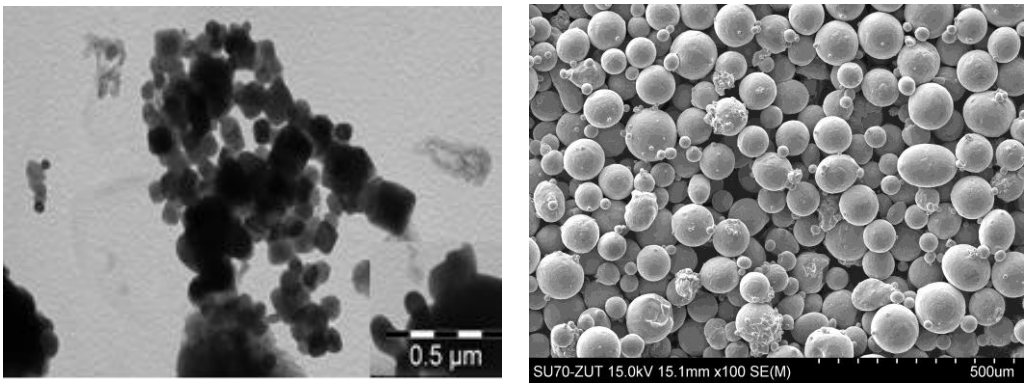

FIGURE 1: (A) TEM IMAGE OF NC-TIC, (B) SEM IMAGE OF TI POWDER.

The phase composition analysis of the samples carried out by XRD method confirmed the two-phase structure of the composites. The identified interference reflections corresponded to Ti and TiC. The size of TiC crystallites in the composites estimated by Scherrer method was slightly smaller than the crystallite size of the powder after the sol-gel synthesis.

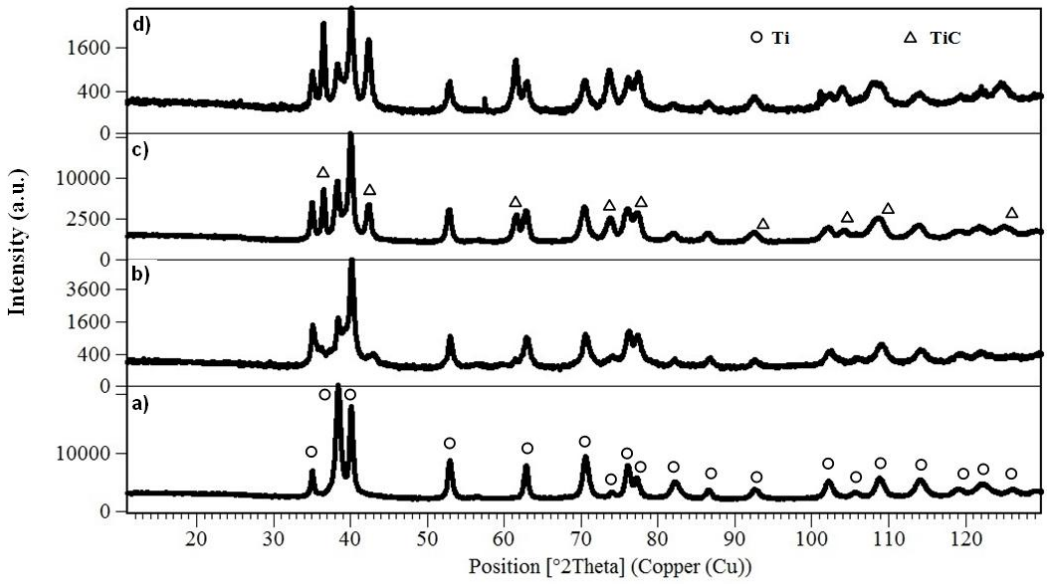

FIGURE 2: COMPARISON OF THE XRD PATTERNS OF NC-TIC POWDER AND TIC/TI NANOCOMPOSITES CONTAINING RESPECTIVELY 1, 10 AND 20 VOL% NC-TIC IN TI MATRIX

The measurements of relative density of TiC/Ti nanocomposites showed that it decreased with increasing fraction of titanium carbide, as illustrated in the bar chart (Figure 3). The microscopic images of the surface of the tested composites are shown in Figure 4. During the studies various kinds of surface defects resulting from the conditions of laser fusion process, such as porosity, presence of TiC aggregates, and defects formed during grinding, polishing or electropolishing, such as surface roughness and scratches, were observed.

Below, in Figure 5 the anodic polarization curves obtained experimentally for the titanium and TiC/Ti nanocomposites in 3 wt% NaCl solution are summarized. Prior to immersion into solution the samples were subjected to a suitable surface treatment, ie. mechanical polishing or grinding or electropolishing or anodic oxidation, followed by purification.

When analyzing the anodic polarization curves of the tested samples of titanium and composites, ie., the values of potential, corrosion currents, and passivation currents, it was found that after treatment the best properties from the point of view of corrosion resistance showed the composite after mechanical polishing comprising 1% TiC. This sample, visually, had the least amount of surface defects.

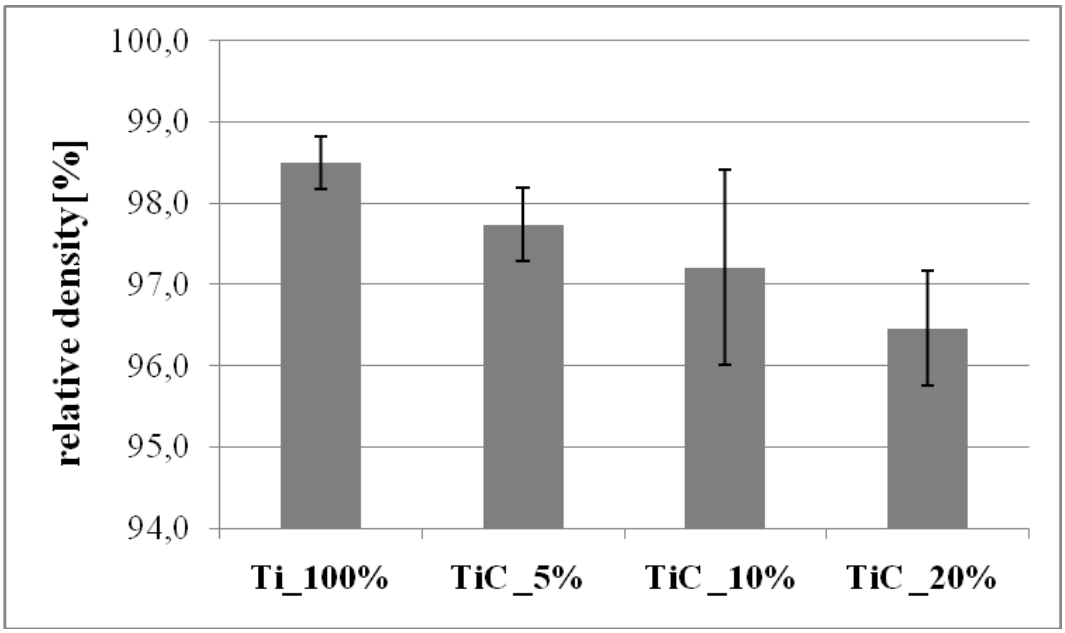

FIGURE 3: DEPENDENCE OF THE RELATIVE DENSITY ON TIC CONTENT

After the process of grinding and electropolishing the sample of titanium showed the best values of potential and current corrosion, whereas after the grinding process the passive layer formed on the surface of the composite containing 1% of nc-TiC particles was characterized by the highest stability, and after the electropolishing process the most stable was the passivation layer on the surface of the composite containing 20% of the nc-TiC particles. After the anodic oxidation the samples of titanium and 1% TiC composite were characterized by comparable corrosion current densities and the lowest passivation current densities. The composite containing 10% of TiC was covered with the thickest layer of oxides after anodic oxidation. The polarization curve indicates the greatest stability of the passive layers of this composite but worse barrier characteristics compared to the titanium and the composite containing 1% of nc-TiC.

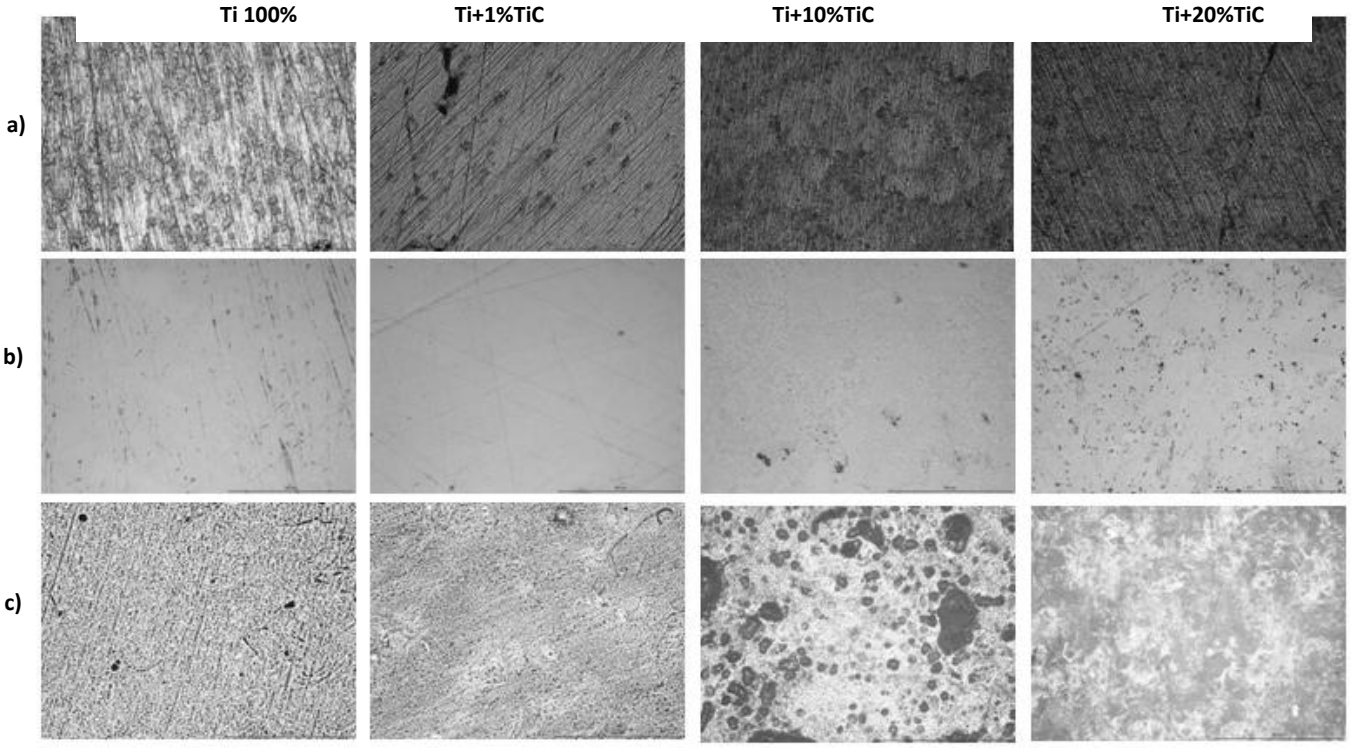

FIGURE 4: THE SURFACE OF THE THE TI 100%, (TI 99%+TIC 1%), (TI 90% + TIC 10%), (TI 80% + TIC 20%) SAMPLES AFTER (A) GRINDING, (B) POLISHING, (C) ELECTROPOLISHING; X 100

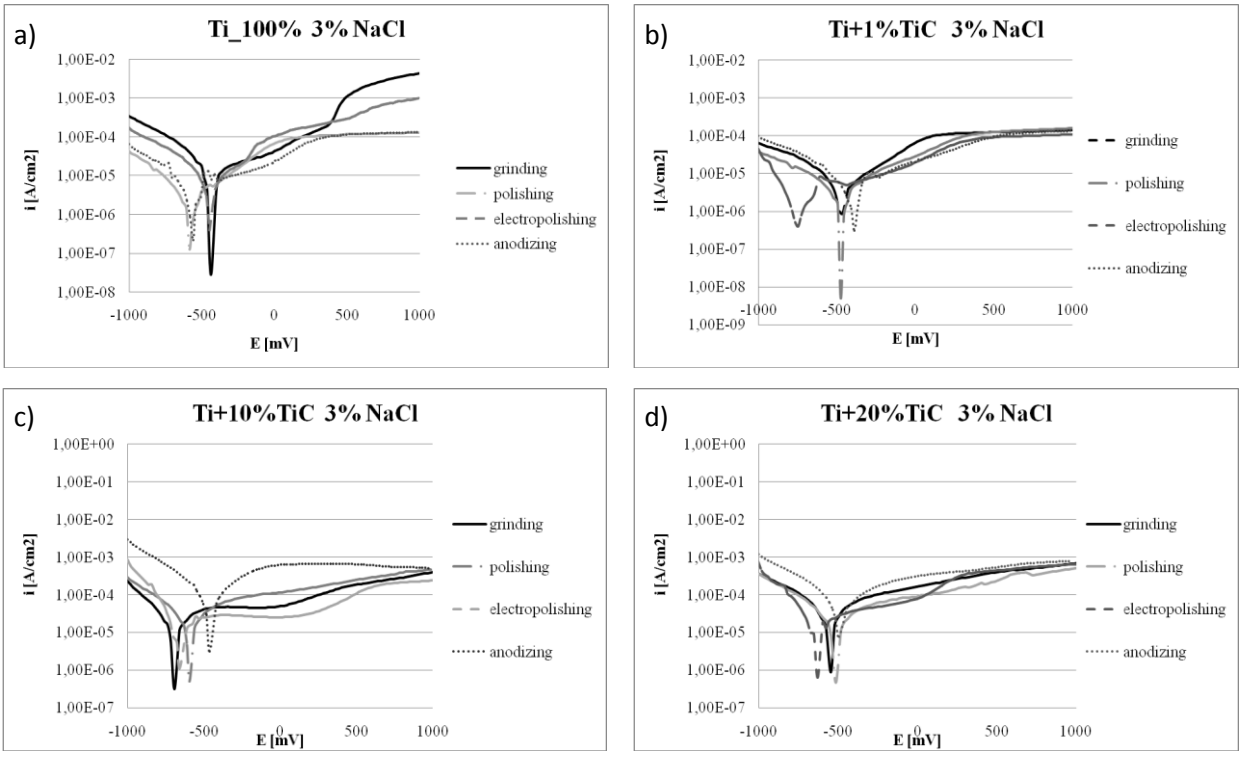

FIGURE 5: EXPERIMENTAL POLARIZATION CURVES FOR TIC/TI NANOCOMPOSITES IN 3 WT% SOLUTION OF NACL AT ROOM TEMPERATURE AFTER POLISHING, GRINDING, ELECTROPOLISHING AND ANODIZING; (A) TI 100%, (B) TI 99%+TIC 1%, (C) TI 90% + TIC 10%, (D) TI 80% + TIC 20%

IV. CONCLUSION

The results of testing samples of titanium and TiC/Ti nanocomposites showed that the most favorable properties from the point of view of corrosion resistance after mechanical polishing treatment showed the composite containing 99 vol% Ti + 1 vol% TiC. This sample was characterized by a surface with the fewest defects.

Grinding is the best procedure to prepare the titanium surface compared to the composites, as indicated by the corrosion potentials and currents. In contrast, a passive layer on the surface of the composite containing 1 vol% of nc-TiC particles was characterized by the best stability.

After electropolishing the titanium sample shows the best values of potential and corrosion current. The polarization curves of the samples show large variations. In the anodic section the course of the curve indicates instability of the oxides layer on the surface of titanium. The passive layer on the surface of the composite containing 20 vol% of nc-TiC particles is characterized by the best stability.

After the anodic oxidation the samples of titanium and 1% TiC composite were characterized by comparable corrosion current densities and the lowest passivation current densities
A conclusion section must be included and should indicate clearly the advantages, limitations, and possible applications of the paper. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

ACKNOWLEDGEMENTS

Project was financed means by NATIONAL SCIENCE CENTRE of POLAND was allowed by decision
No. DEC-2012/05/N/ST5/ 02331

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