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INFLUENCE OF COATING APPLICATION PARAMETERS ON SELECTED PROPERTIES

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In this paper, titanium coatings were deposited on steel using the plasma-assisted chemical vapor deposition (PACVD) process. These coatings were deposited at the same gas flow and power parameters, but at different times. This resulted in the creation of coatings with different properties. Increasing the time by half increased the thickness of the coating by about 78 %.

Keywords: 100Cr6 steel, Ti coating, chemical vapor deposition, wear, friction

INTRODUCTION

Coatings are applied to improve performance characteristics, e.g. tribological, strength, anti-corrosion [1–3], mechanical, and chemical [4] properties [1–4]. They can be applied by physical (PVD) and chemical vapour deposition (CVD) [1,5]. In addition, (PACVD) can be used to obtain lower deposition process temperatures [5,6]. Thanks to these techniques, it is possible to apply ceramic and metal coatings. The PACVD deposition process has some advantages such as low deposition temperature and better adhesion. In addition, coatings can be applied to samples with complex shapes. With PACVD, it is possible to deposit a uniform coating with good adhesion to steel at about 500 ℃ instead of 1000 ℃ as in the CVD method [5]. The use of different techniques leads to different coating morphologies and structures, which results in different mechanical and chemical properties.

Physical methods are usually used to deposit the titanium film. Chemical methods are rarely used for the deposition of a titanium coating, yet no research has been conducted on the relationship between the deposition parameters and the characteristics of the resulting layer. Little information is currently available on the use of plasma-assisted chemical vapour deposition and the influence of plasma parameters on coating properties [5].

Titanium is widely used as a heat exchanger material because of its properties: light weight [7], high strength-to-weight ratio and corrosion resistance. Moreover, titanium (Ti) has excellent biocompatibility [7,8].

Liu et al. [9] observed that a thin Ti or TiN coating effectively reduced corrosion and had good adhesion.

In the present article, titanium coatings were deposited on steel by PACVD process. These coatings were deposited at the same gas flow and power parameters, but at different times. This resulted in the formation of coatings with different properties.

MATERIALS AND METHODS

100Cr6 steel discs were used for the study; titanium (Ti) coating was applied by PACVD method at the same parameters but at different times of 1,5 hours and 3 hours.

The thickness of the resulting coatings (Form Talysurf PGI 1230 stylus profilometer), surface geometric structure (Leica DCM8 confocal and interferometric optical profiler), and chemical composition (Phenom XL scanning electron microscope) were measured. Then, tribological tests were performed (tribometer TRB^3) with the following parameters: load - 1N, number of cycles – 10 000, sliding speed – 0,02 m/s, sliding distance - 120 m, temperature T_0 = 26 ± 3°C, and humidity 30 ± 5%. The tests were conducted under dry friction conditions. Prior to tribological testing, the discs (Figure 1a, 1b) and the ball (Figure 1c) were examined using an interferometric confocal microscope. From the obtained results it was observed that the Ti coating had a more uneven surface after 3 hours of deposition, it had peaks and indentations of the order of 80 nm.

The chemical composition of the resulting coatings was examined using a scanning electron microscope (Figure 2).

Based on the obtained results, there was a higher mass amount of titanium on the sample that was coated in the longer, 3 hours process. In addition, a different structure is clearly visible. The sample, after 1,5 hours of coating, had an appearance similar to the substrate (steel), while the structure of the resulting titanium layer was clearly visible on the traces after 3 hours of the process.

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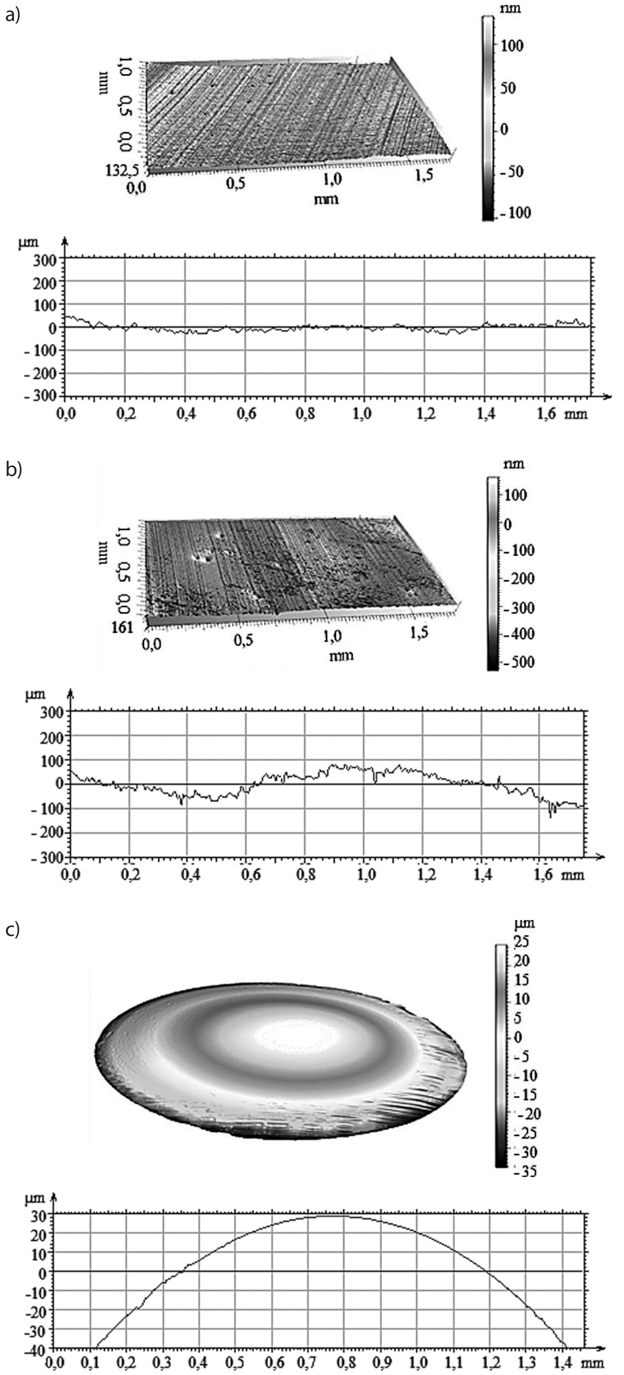


Figure 1 Surface textures before the tribological tests: isometric views and primary profiles of:
a) the Ti coated 1,5 h 100Cr6 steel disc,
b) Ti coated 3 h 100Cr6 steel disc, c) 100Cr6 steel ball.

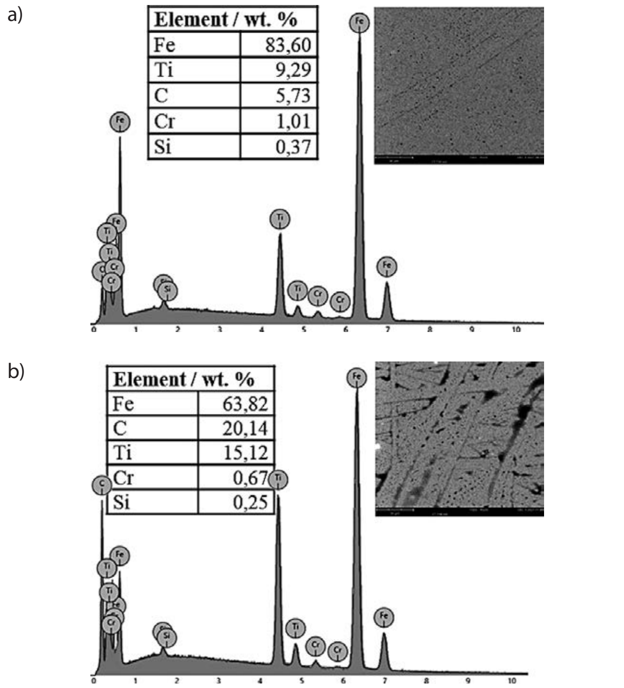
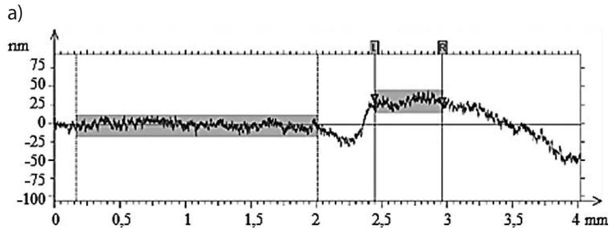


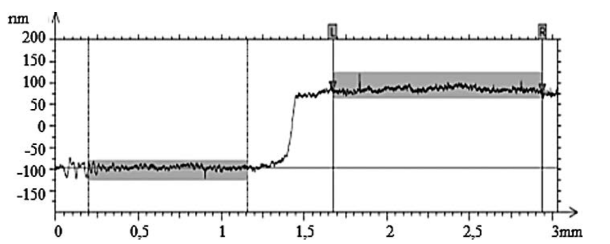
Figure 2 Energy dispersive spectroscopy (EDS) patterns for different points of the Ti coated steel discs: a) 1,5 h and b) 3 h

a)



Max. height	46,854 nm
Medium height	31,457 nm

b)



Max. height	218,630 nm
Medium height	181,409 nm

Figure 3 The thickness of the coatings after a deposition: a) 1,5 hours, b) 3 hours

RESULTS AND DISCUSSION

The thickness of the resulting coatings was measured using a contact profilometer, the results are presented in Figure 3.

From the results, it was observed that the coating after a deposition time of 1,5 hours (Fig. 3a) obtained a thickness of ca 47 µm, and after a time of 3 hours, the thickness was about 219 µm. Increasing the time by half increased the coating thickness by approx. 78 %.

The results of tribological tests under technically dry friction conditions are summarized in Figure 4.

It was noted that the coating obtained better tribological properties after a 3 hours application process. The result was an average coefficient of friction that was over 8 % lower than that of the coating that was applied for 1,5 hours. In addition, the wear intensity of the coating after a longer deposition time was 45 % less than the thinner coating.

Figure 5 and Figure 6 show signs of wear of discs and balls after tribological tests.

a)

b)

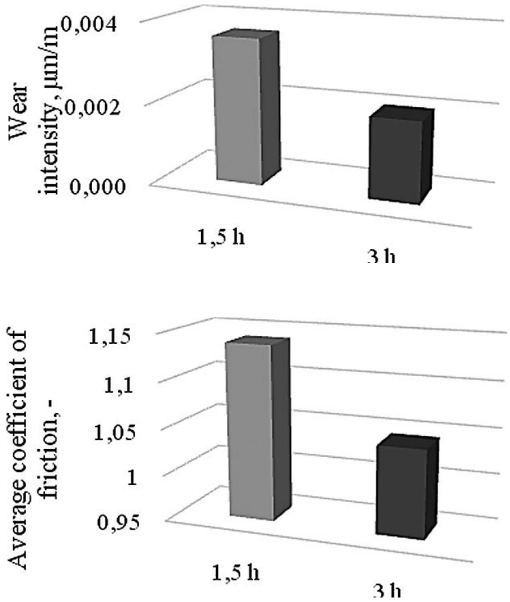
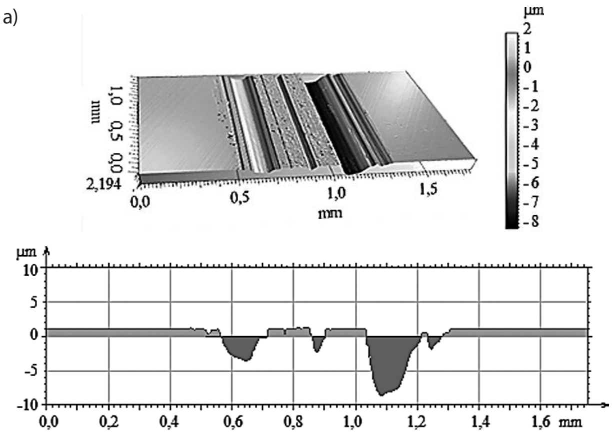


Figure 4 a) wear intensity, b) average coefficient of friction

a)



Max. depth	8,67 µm
Wear scar surface area	1 396 µm^2

b)

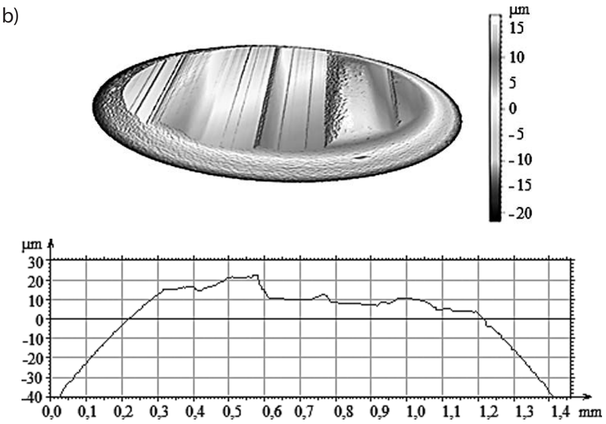
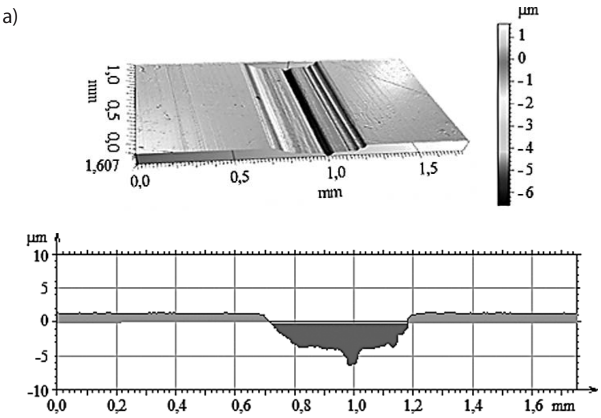


Figure 5 Isometric views and primary profiles of the discs and balls after the tribological tests (Ti coating 1,5 hour)

When analysing abrasion marks on discs, a greater maximum depth and width was recorded for the disc with the coating applied after a shorter deposition time (1,5 h).

a)



Max. depth	6,36 µm
Wear scar surface area	1 607 µm^2

b)

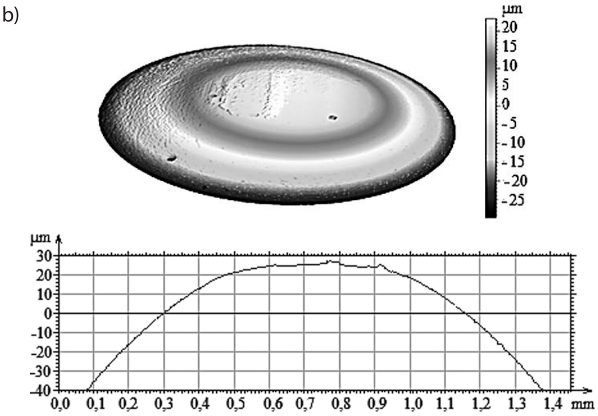


Figure 6 Isometric views and primary profiles of the discs and balls after the tribological tests (Ti coating 3 hour)

Comparing the parameters of the geometric structure (Tabele 1) of the discs, it was observed that after tribological tests, smoother surfaces were obtained for the ball and the disc after 3 hours of coating application.

Figures 7 and 8 show the chemical composition of the discs and spheres after friction tests using a scanning electron microscope.It was noticed that that the darker areas on the discs, where the wear marks are visible, are titanium and the lighter ones are the substrate.

The comparative analysis shows that more titanium was left on the sample and the counter sample after a shorter coating time.

Tabele 1 **Surface texture parameters for the steel discs and steel balls before and after the tribological tests**

Surface texture parameters	Before test			After test TTS			
	Disc 1,5h	Disc 3h	ball	Disc 1,5h	ball	Disc 3h	ball
Sa/µm	0,01	0,04	0,50	2,22	3,88	0,79	0,73
Sq/µm	0,02	0,05	1,01	2,59	4,54	1,09	1,03
Sp/µm	0,08	0,34	7,10	5,65	9,98	3,07	3,21
Sv/µm	0,11	0,29	8,77	4,74	15,29	3,03	17,76
Sz/µm	019	0,63	15,87	10,39	25,27	6,10	20,97
Ssk/-	1,55	-0,36	2,05	0,24	-0,20	-0,17	-2,17
Sku/-	6,27	4,13	19,42	1,85	9,98	3,85	1,03

a)

b)

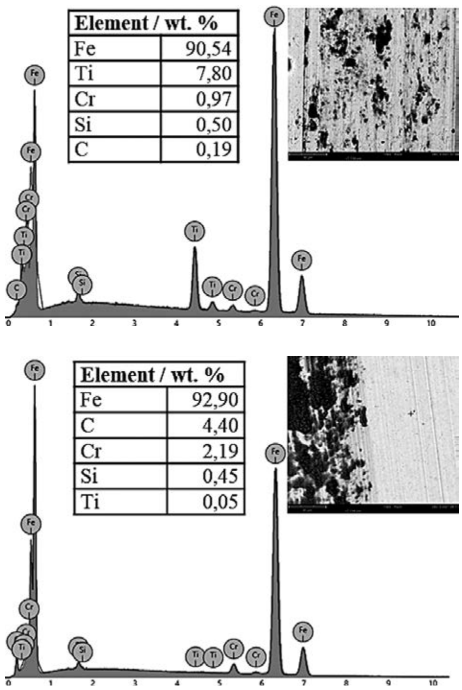


Figure 7 Energy dispersive spectroscopy (EDS) patterns for different points of the wear track resulting from the sliding contact of: a) the coated steel disc (1,5 hour) with b) the steel ball

a)

b)

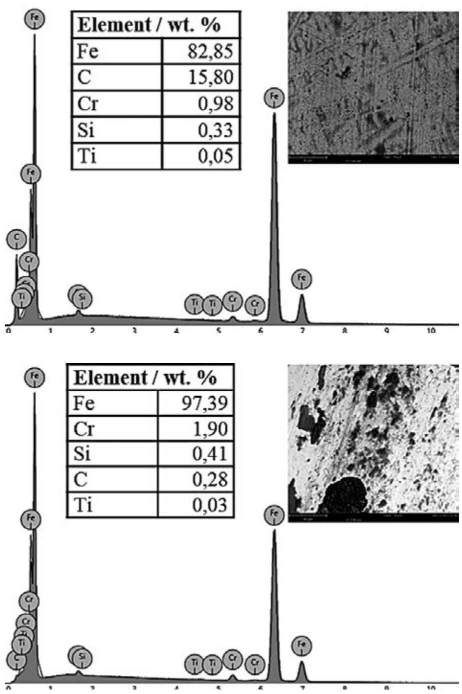


Figure 8 Energy dispersive spectroscopy (EDS) patterns for different points of the wear track resulting from the sliding contact of: a) the coated steel discs (3 h) with b) the steel balls

CONCLUSIONS

The following conclusions were drawn from the obtained results. When applying coatings, time is of great importance. Increasing the time by half resulted in an increase in thickness of about 78 %.

The thinner coating (1,5 hour) had a smoother surface than the coating deposited for a longer time (3 hours).

The tribological tests showed that the wear of the coating was higher after a shorter deposition time (1,5 hours).

After the friction tests, the disc and ball in contact with the coating formed after a longer deposition time had a smoother surface than the coating after a shorter deposition time.

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Note: The responsible for English language is: Małgorzata Dembińska Lingua Lab.