COMPARING TRIBOLOGICAL PROPERTIES, COEFFICIENT OF FRICTION AND ADHESION THIN LAYERS

MÁLEK Václav [1], BAKALOVA Totka [2], VOLESKÝ Lukáš [1,2]

[1] *Technical University of Liberec, Department of Materials, Faculty of Engineering, Liberec Studentská 2, Liberec I, 461 17, Czech Republic ,EU, vaclav.malek@tul.cz*

[2] *Technical University of Liberec, Institute for Nanomaterials, Advanced Technology and Innovation, Studentská 2, Liberec I, 461 17, Czech Republic , EU, totka.bakalova@tul.cz, lukas.volesky@tul.cz*

Abstract

Currently, the methods of material coating by CVD (Chemical Vapour Deposition) and PVD (Physical Vapour Deposition) are expanding considerably. These methods are used in engineering and other industries. There is a large variability of the second coating. Their properties can be combined using several layers of different materials. The coatings have excellent physical and chemical properties e.g. low friction, high hardness, abrasion resistance, high temperature (normally 550 °C but 750 °C or more), corrosion and acid resistance. For the use of materials with such coatings, the knowledge of their tribological properties is necessary.

Keywords: plasma modification, CVD, PVD, adhesion, coefficient of friction

1. INTRODUCTION

Nowadays materials can be described by several different parameters, see Fig.1. The main parameters of coated layers are adhesion and abrasion. The adhesion reflects the ability of thin coated layers to adhere on the substrate parts. The abrasion describes the resistance of coated layers to outer objects. The aim of this work is to compare these properties on three different layers using the Ball on Disc method.

2. MEASUREMENT

On the deposited layers were investigated properties of adhesion layer and abrasion resistance by means of the BALL on the DISC method, where the coefficient of friction is evaluated. The principal of the method is shown in the Fig. 2. Measurements were performed on a Bruker instrument that permits the measurement of a BALL on DISC. Progress was observed on the slide length when friction ceramic balls Si_3O_4 of surface area coated. To evaluate the adhesion it is important to determine the energy necessary to breach bonds at the interface layer-substrate. The force of 3N is applied perpendicularly by means of ball with diameter of 8 mm to investigate the layer. Damage to the layers, indicates the degree of adhesion of the layer [1].

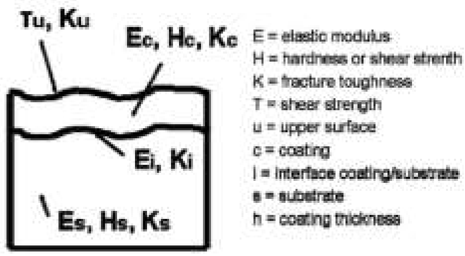


Fig.1 Symbols for material parameters [5].

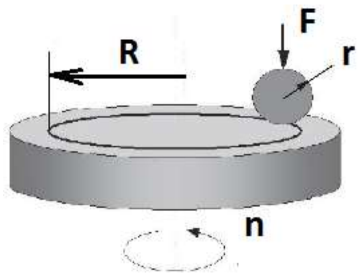


Fig.2 The principal of the BALL on DISC method.

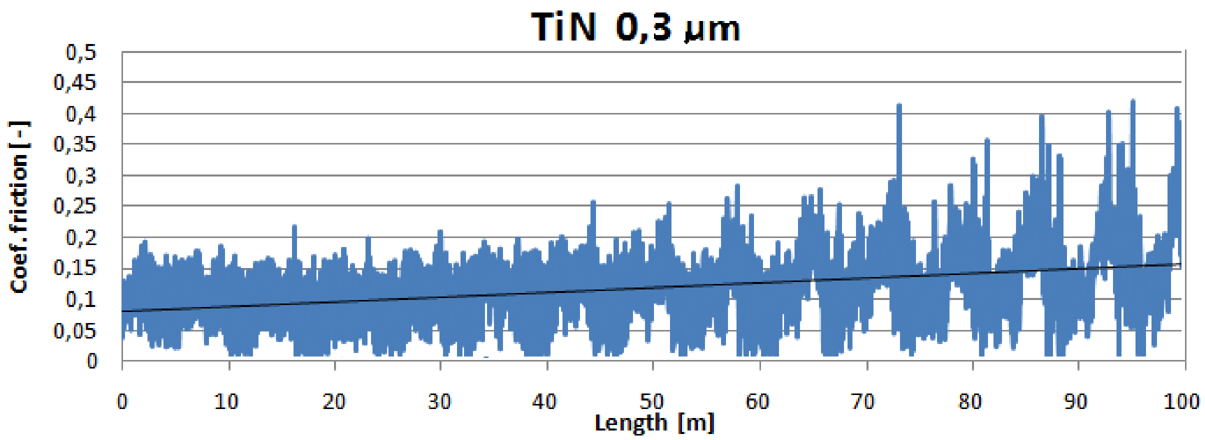


Fig.3 Tribological test layers TiN method BALL on DISC dependence coefficient of friction on the track ball.

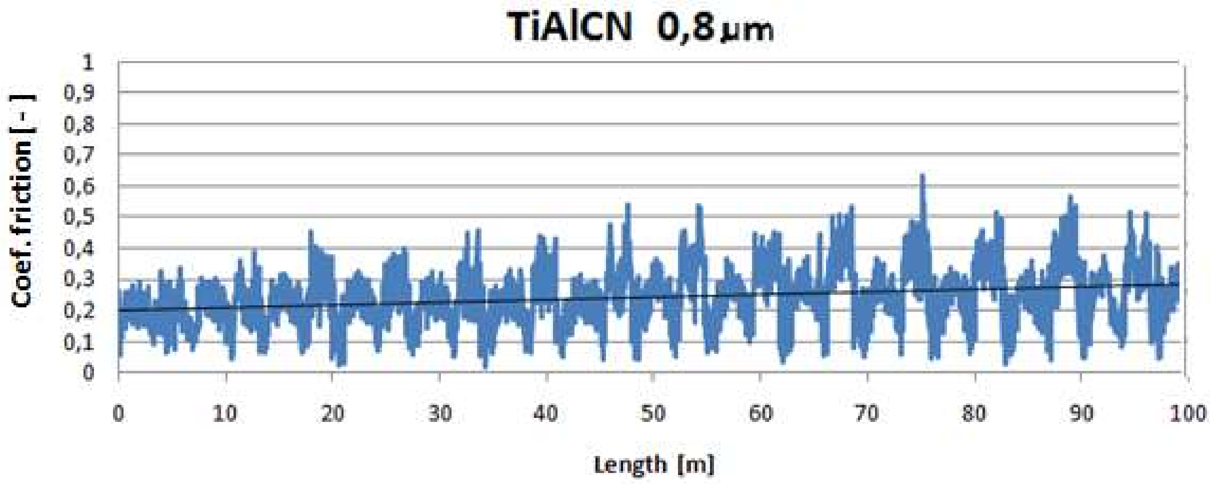


Fig.4 Tribological test layers TiAlCN 0,8 µm method BALL on DISC dependence coefficient of friction on the track ball.

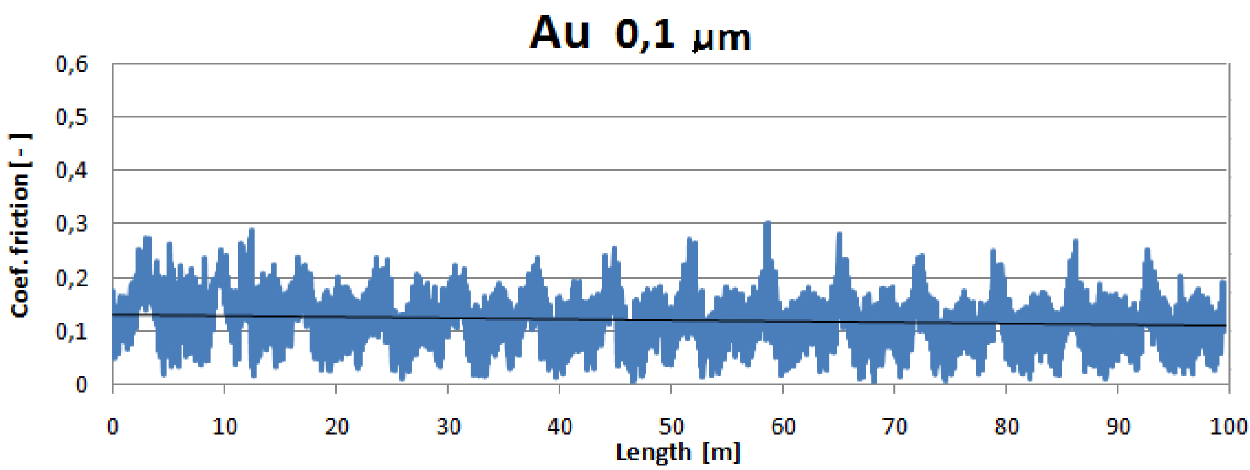
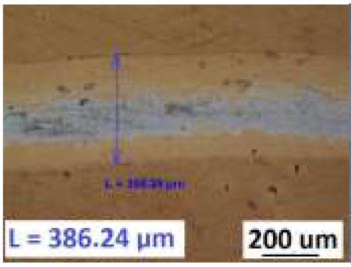
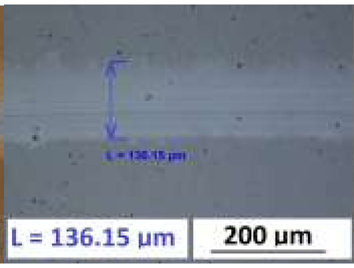


Fig. 5 Tribological test layer Au 0,1µm method BALL on DISC dependence coefficient of friction on the track ball.

3. DISCUSSION





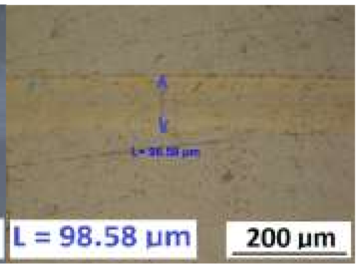


Fig. 6 layer TiN **Fig. 7** layer TiAlCN **Fig. 8** layer Au 0,1µm

Compare the three different layers TiN , TiAlCN, Au 0,1µm metodou BALL on DISC

Ti N

Layer Properties TiN. This TiN layer are very hard surfaces. For tribological test we see at the beginning of the curve, we see a low coefficient of friction 0.1-0.15

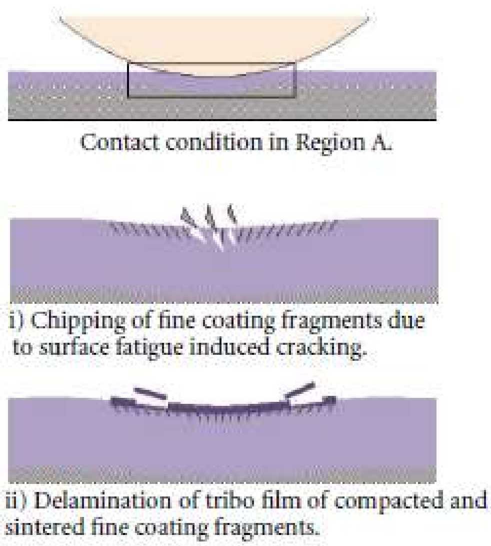
TiAlCN

Tribological testing shows friction coefficient 0.1-0.3 Directive trend shows a slight increase.

Au 0,1µm

0,1µm Au layer occurs quite early to remove the surface layer. For tribological test at the beginning of the curve we see a low coefficient of friction of 0.1 at a distance slide way.

Tribological contact mechanisms



The complete tribological process in a contact in relative motion is very complex because it involves simultaneously friction, wear and deformation mechanisms at different scale levels and of different types. To achieve a holistic understanding of the complete tribological process taking place and to understand the interactions, it is useful to analyse separately the tribological changes of four different types: the macro- and micro-scale mechanical effects, the chemical effects and the material transfer taking place, as shown in Fig 9. In addition, there has recently been an increasing interest in studying tribological behaviour on a molecular level; i.e. nanomechanical effects [2].

Fig. 9 Wear mechanisms observed in Region A [3].

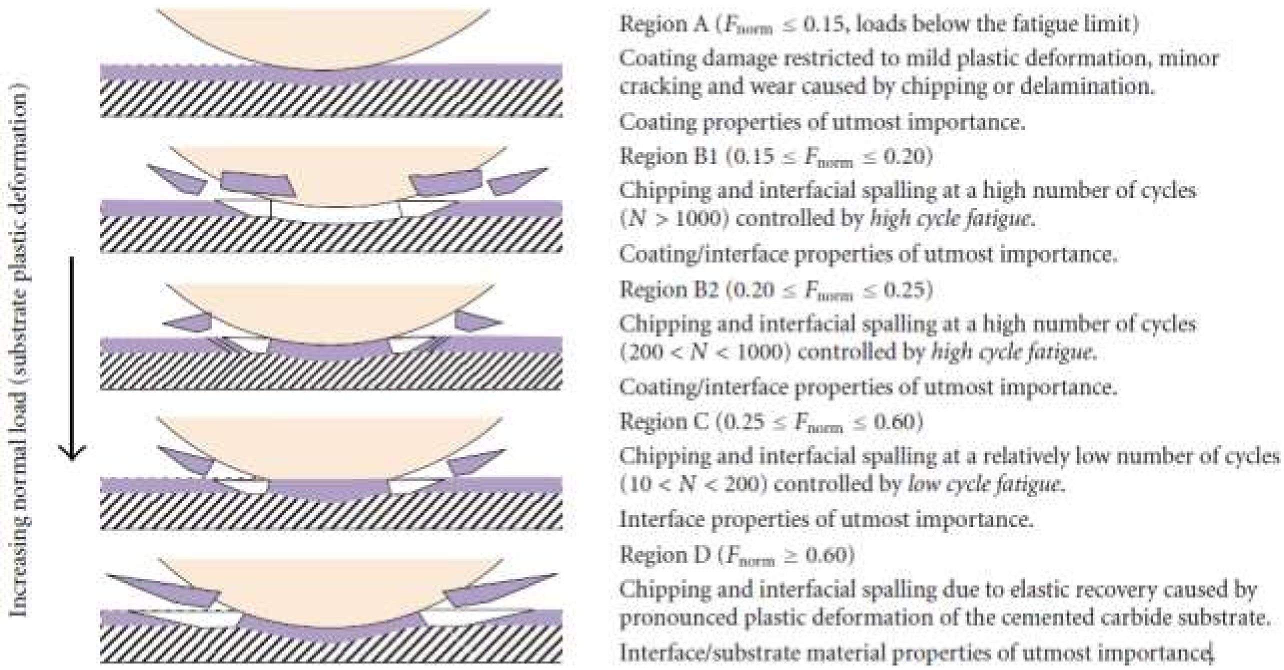


Fig.10 Schematic ilustrations summarizing the observed coating damage mechanisms during the circular testing using the ball-on-disc tribometer [4].

Two-dimensional graph

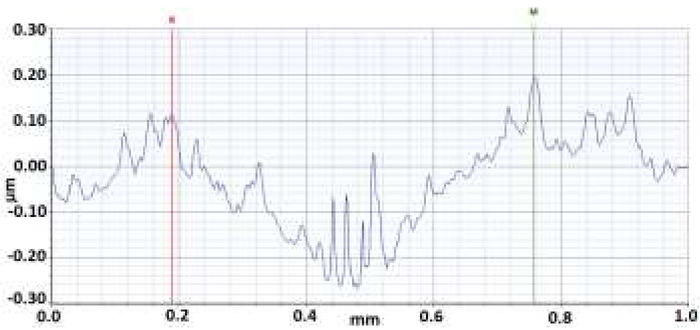


Fig. 11 Layer TiN (2D) profilometer parameters: load 6 mg, radius edge 2 µm.

Fig. 12 Layer TiAlCN (2D) profilometer parameters: load 6 mg, radius edge 2 µm.

Track ceramic ball Si_3O_4 after tribological friction tests was examined under the optical microscope Zeiss AXIO Imager. By tribological processes by BALL on DISC friction balls in exploring the surface leads to chipping of layers and their subsequent adhering to the balls. These particles layer on the bead and usually do not last long as they are peeled away from the ball surface. There is a abrupt change in the value of the coefficient of friction, which is recorded on the chart. There is a re-bonding and separation layer on the ball, the friction coefficient increases vice versa. In this way is explained phenomenon inequalities chart created in 2D and in 3D.

The profile Fig.12 is apparent roughness resulting attrition ball Si_3O_4. TiN is the lowest value on the y-axis is -0.25µm. The upper edge is 0.10µm. (Mean value), the difference is thus approximately 0.35 µm. In Fig.13 the profile layer TiAlCN the lowest point of the profile is the value on the y axis -0.9 micron on the top edge is 0.0 to 0.1 µm, the difference value is 0.8 to 0.9 µm.

Three dimensional graphs:

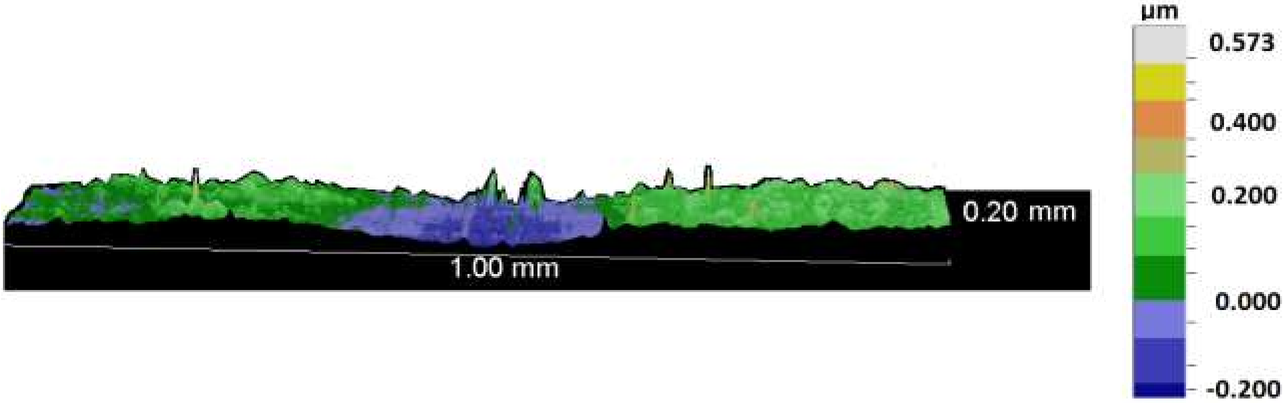


Fig. 13 Nr.1 layer TiN (3D) profilemeter parameters: load 6mg,radius edge 2 µm

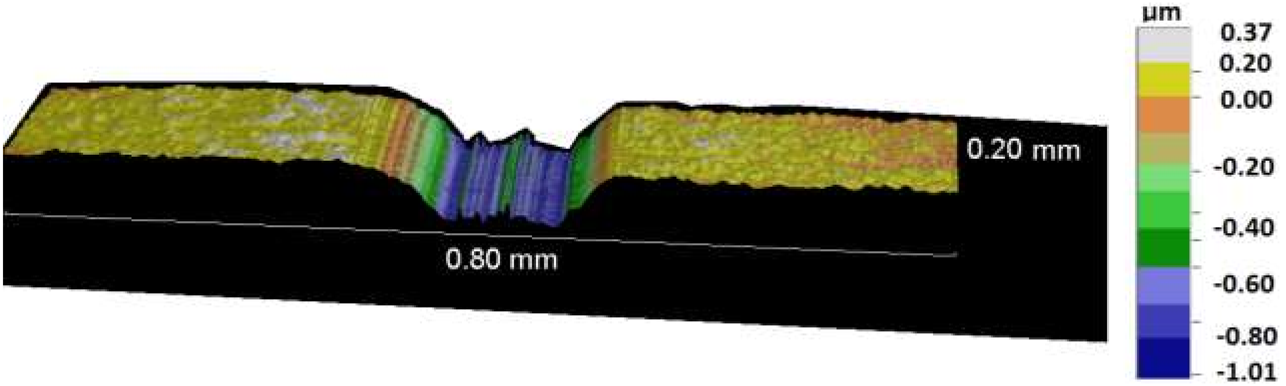


Fig. 14 Nr.2 layer TiAlCN (3D) profilometer parameters: load 6mg, radius edge 2 µm

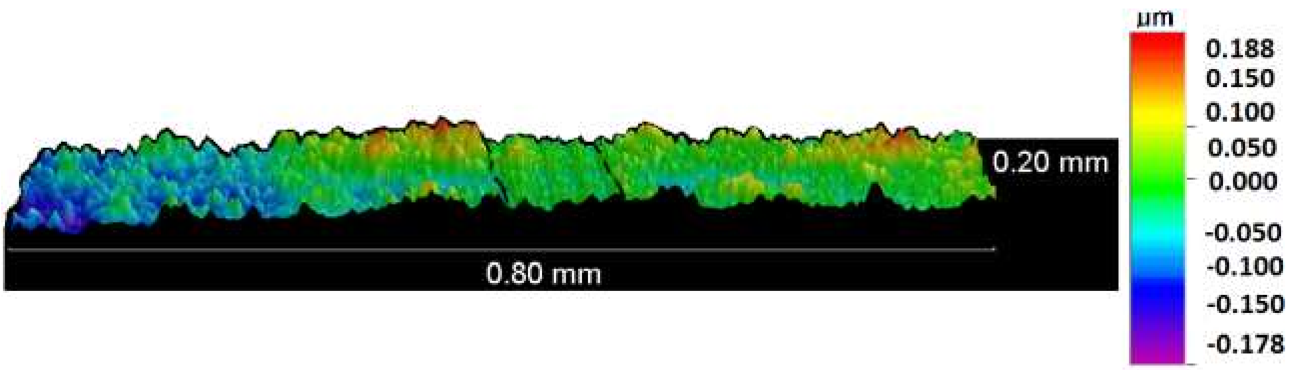


Fig. 15 Nr.3 layer Au 0,1µm (3D) profilometer parameters: load 8mg, radius edge 2 µm

CONCLUSION

In the presented work, adhesion properties of three different coated layers were compared. The best adhesion was evaluated in the sample Nr.3 of Au-layer with thickness of 0.1 µm (see the Fig 15). The surface of this layer was measured by the tip with radius of 2 µm and with a load of 8 mg. In the Figure 15, the negative depth values of more than -0.1 µm at the outer edge of the rounded shape-like plate sample correspond with a lower amount of sputtered gold particles deposited at this area. In the Figure 15, the groove marked with black lines indicates the path of the testing ball during the tribological test. The course of this profile has not changed over the sample area and there is no significant deviation of the depth during abrasion (tests). This is caused by the high ductility of gold particles, and the resulting friction improves the surface properties. The 2D graph was not be used as it does not enable the required distinguishing of the track profile from other curves. The second best adhesion was evaluated in the sample Nr.1 of TiN layer, where the difference of the ball track from the other surface area is approximately 0.2 µm (see the figure 13). The third evaluated sample, the Nr.2 with TiAlCN layer, shows a significant difference between the upper and lower surface. The profile path is not entirely semi-circular. During the tests the surface on the ball is modified in such a way, that it corresponds to a negative imprint of the tribological ball track (groove) on the sample surface.

Tribological properties of adhesion, abrasion and friction coefficient are important parameters for appropriate material selection for intended use in various industries, e.g. applications in medicine, food industry, engineering industry, etc.

ACKNOWLEDGEMENTS

The results of this project LO1201 were obtained through the financial support of the Ministry of Education, Youth and Sports in the framework of the targeted support of the "National Programme for Sustainability I" and the OPR&DI project Centre for Nanomaterials, Advanced Technologies and Innovation CZ.1.05/2.1.00/01.0005." a SGS.

REFERENCES

[1] HORÁK, M., BAKALOVA, T., KEJZLAR, P., ROŽEK, Z., FIJALKOWSKI, M., and VOLESKÝ. L., valutation of tne Thermal Resistance of Thin Layers. Fine Mechanics and Optics. vol.58, 2013, no.11-12, p.317-320 . ISSN 0447-6441.

[2] FALLQVIST M., M'SAOUBI R.,Mechanical and Tribological Properties of PVD-Coated, Advances in Tribology Vol. ,2012, Article ID 305209, pp.12

[3] HOLMBERG K., MATTHEWS A., RONKAINEN H., Coatings tribology-contact mechanisms and surface design, Tribology International Vol. 31, Nos 1–3, pp. 107–120, 1998

[4] HOLMBERG K., MATTHEWS A., RONKAINEN H., LAUKKANEN A., WALLIN K., Friction and wear of coated surface - scales, modelling and simulation of tribomechanisms. Surface & Coatings Technology 202, 2007, pp. 1034–1049

[5] SCHWARZER N., DUONG Q.-H., BIERWISCH N., FAVARO G., FUCHS M., KEMPE P., WIDRIG B., Optimization of the Scratch Test for specific coating designs, Surface and CoatingsTechnology, Vol. 206, No.6, 2011, pp. 1327–1335

[6] SEBASTIANI M., BEMPORAD E., Influence of Ti–TiN multilayer PVD-coatings design on residual stresses and adhesion, Materials & Design, Vol.75, 2015, pp. 47–56