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INFLUENCE OF ION IMPLANTATION ON WEAR BEHAVIOUR OF DUPLEX COATINGS

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S u m m a r y

Duplex coatings was applied on cold working steel 100Cr6. Samples were plasma nitrided at different thickness of plasma surface layers. TiN was deposited with classics BALZER PVD equipment and with IBAD technology in DANFYSIK chamber. Subsequent ion implantation was provided with N^{5+} ions. The tribological behavior of the coatings was studied by means of pin-on-ring contact configuration, in dry sliding conditions. A coefficient of friction is calculated by dividing the friction force by the normal force. The three basic points that are considered fundamental to studies of friction are the surface area and nature of the intimate asperity contacts, the surface adhesion and shear strength, and the nature of deformation and energy dissipation occurring at the asperity junctions. Special test equipment gives opportunity to monitoring continuously friction coefficient and contact temperature. Following the dry sliding tests, the wear zone morphology and characteristics of surface layer structure as well as important properties were investigated by scanning electron microscopy (SEM) and X-ray diffraction analysis (XRD). Scratch adhesion testing was performed using commercially available equipment (REVETEST CSEM).

Key words: *wear, coating, friction coefficient, IBAD, measuring.*

1. INTRODUCTION

The term "surface engineering" encompasses all of those techniques and processes which are utilised to induce, modify and enhance the performance, such as wear, fatigue and corrosion resistance, and biocompability, of surfaces. Wear of materials is one of the larger technical problem in today`s industry resulting in high financial loses. Adequate understanding and characterisation of tribological behaviour is essential to the successful future exploatation of surface engineering. In many cases single coating cannot solve the wear problems [1]. Surface treatment can yield better surface properties to reduce the deleterious effects of this wear. The various deposition techniques of coatings and process parameters differ widely in morphology and microstructure, in phases, grain size, texture, defects, impuriti content and state of stress [2]. However, the adhesion, structure and durability of coatings on various substrates can be substantially improved by irradiating the substrates and the condensing film with ions and energetic neutrals in the energy range of several electron volts. One of the most widely used physical vapour deposited coatings for engineering components is TiN. The combination of plasma nitriding (diffusion process) and hard coating allows the production of duplex coatings, which are distinguished by a high resistance against complex loads, since the advantages of both individual processes are combined here. The ion implantation allows us to form new structural-phase as well as high-density defect structures that cause an essential change in physical-mechanical and chemical properties defining the operational characteristics of materials [3].

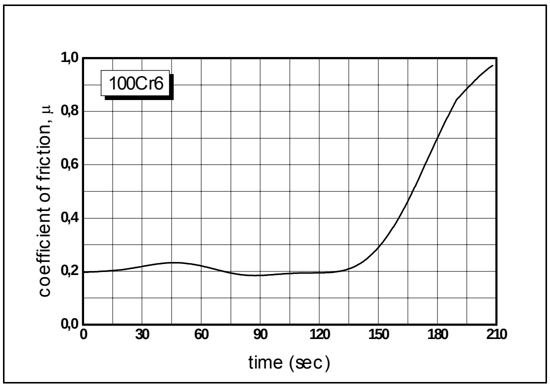
2. EXPERIMENTAL

Samples of 100Cr6, ball bearing material and cold work steel, were austenized and quenched to give a hardness of 409 $HV_{0.03}$. The PVD treatment was performed in a Balzers Sputron installation with rotating specimen. N^{5+} ions were implanted in channel for modification of materials (L3A). The channel is directly connected to the mVINIS Ion Source. The Ion Source is a multiply charged heavy ion injector, based on the electron cyclotron resonance effect. The ion energy was 120keV, dose was $1x10^{16}$ ions/cm^2. A quartz crystal monitor was used to gauge the approximate thickness of the film. Additional analyze the thickness of coatings, the ball crater method (calo-test), allows prompt and sufficiently precise results to be obtained. The IBAD coatings were deposited with ion beam bombardment in a DANFFOS machine. The base pressure in the vacuum chamber was 10^{-4} Pa for all experiments. System has Kaufman-type ion source, sample holder and quartz crystal thickness monitor. The tribological behavior is analyzed with pin-on-ring tribometer. The friction coefficient is calculated from the ratio of the elongation forces to the applied force. The wear scars are found to be elliptical in form. Instead of measuring the ellipse axes, as a wear intensity. Tribological pair with pin holder and piezoelectric sensor is shown elsevere [4]. . Scratch adhesion testing was performed using commercially available equipment (REVETEST CSEM). X-ray diffraction studies were undertaken in an attempt to determine the phases present, and perhaps an estimate of grain size from line broadening. The equipment was a θ-2θ goniometer (Philips APD-1700). The surface roughness was measured using stylus type (Talysurf Taylor Hobson) instruments.

3. RESULTS AND DISCUSSION

The first remarkable influence of the ion implantation on the properties of the investigated hard coatings is shown by the color of the films. The TiN coatings only show a golden surface and after ion implantation the color is dark golden. The analyzed nitrogen-to-metal ratio of the deposited films is given in the Table 1.

The nitrogen to metal ratio is stochiometries for IBAD technology and something smaller from PVD. For sample with additional ion implantation, value is significantly different, smaller. It is possibly diffused from the layer of TiN to the interface. Vickers microhardness measurements on substrates are given in Table 2.



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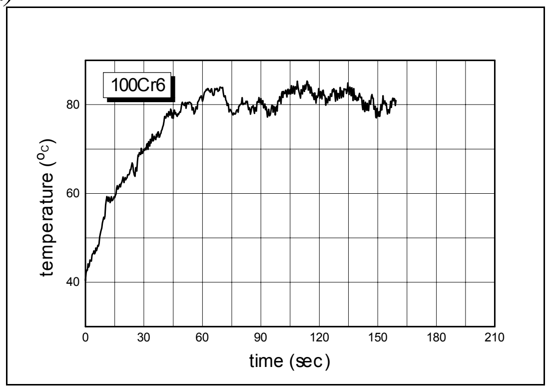

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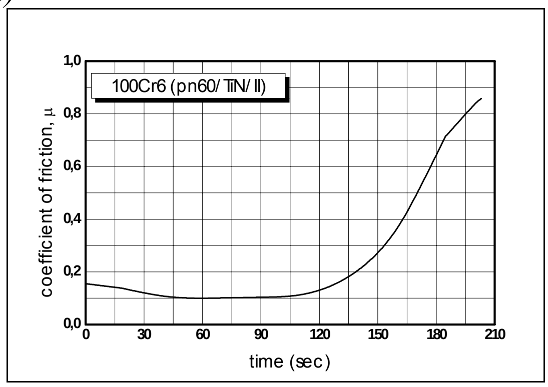

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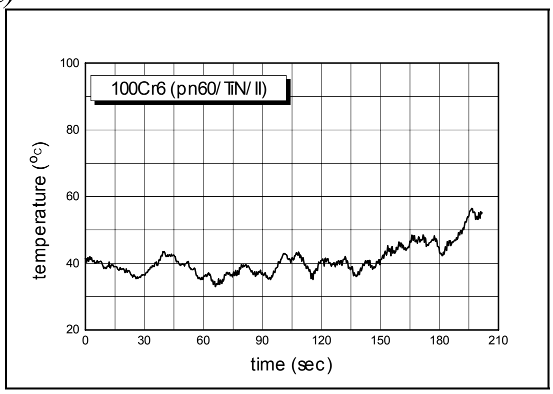

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Figure 1. Friction coefficient and contact temp. vs sliding time, a,b) uncoated, c,d) pn/TiN(PVD)/II.

Table 1. Atomic ratio N/Ti in coating.

	Coating	Ratio N/Ti (atomic)
1	TiN(PVD)	0.98
2	TiN(IBAD)	1.00
3	Pn60/TiN(PVD)/II	0.89

Table 2. Surface microhardness ($HV_{0.03}$)

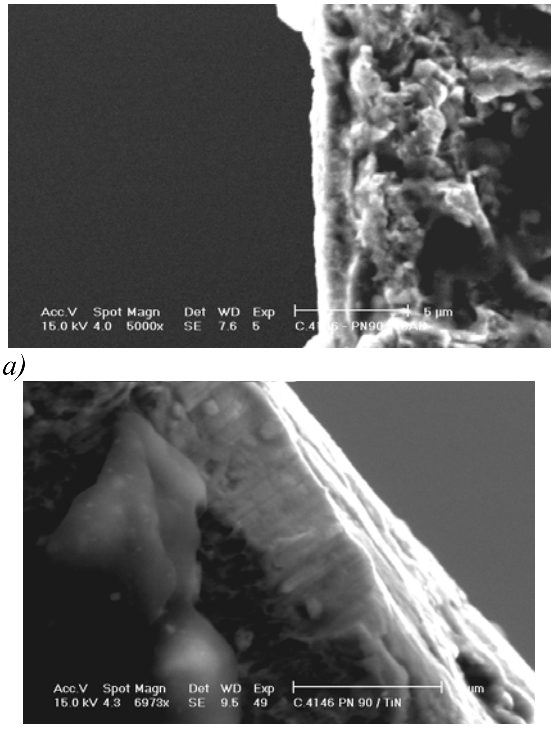
Unco-at.	pn60/ TiN(PVD)	pn60/ TiN(IBAD)	pn60/ TiN(PVD)/II
409	**1975**	**1780**	**2985**

A hardness increase is observed for implanted samples. This can be attributed to iron nitride formation in the near surface regions. The material under study is TiN coating with a thickness of approximately 3μm deposited by PVD and 1μm deposited by IBAD. With smaller load indentation, TiN(IBAD) coating show, irrespective of the coating thickness, the greatest increase in hardness (5135 $HV_{0.005}$).

All the samples with coatings deposited by PVD displayed a same like initial surface roughness. In addition, coatings prepared by IBAD, displayed a small decrease in initial surface roughness. The friction coefficient and contact temperature are presented in Figure 1.

The wear resistance of the TiN coating was obviously improved by the presence of a nitride interlayer. Such an improvements is probably due to the adequate bonding between the nitrided layer and substrate. Energy depressive analyze with X-ray (EDAX), of the transfer layer showed that the transfer layer consists of small amount of counter material (adhesive wear).

The curves of friction coefficient are clearly reproducible and distinctively show a lower rise in temperature and friction coefficient for the composite (pn/TiN) coated specimens and much more for sample with ion implantation. The coating morphology was evaluated using the well-known structure zone model of Thornton. All observed morphologies are believed to be from region of zone I (PVD) and from the border of region zone T (IBAD). It has been suggested, that the transition from open porous coatings with low microhardness and rough surface, often in tensile stress to dense coatings films with greater microhardness, smooth surface occurs at a well-defined critical energy delivered to the growing film. The microstructure of the TiN film, Fig. 2, shows columns in the film.



a)

b)

Figure 2. Fracture cross-section scanning electron micrograph of a)pn/Ti(IBAD) and b)pn/TiN(PVD).

The topography of TiN coatings was investigated on the test steel (Figure 3).

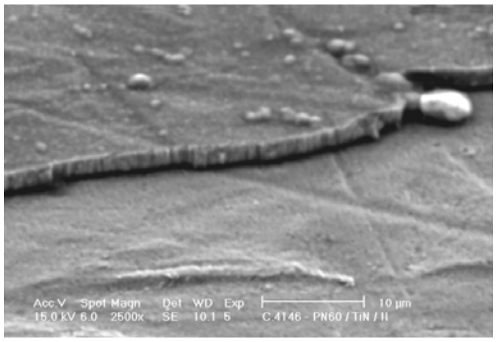


Figure 3. Topography of pn/TiN(PVD)/II coating.

The PVD coating process did not significantly change roughness. For the practical applications of IBAD coatings, it is important to know that the roughness of the surface decreased slightly after deposition (from Ra=0.19 μm to Ra=0.12 μm).

X-ray diffractogram for the coating is shown in Fig.4.

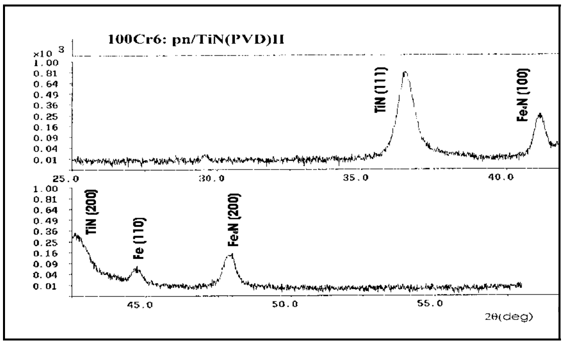


Figure 4. X-ray diffraction spectrum of pn/TiN(IBAD)/II.

For the films deposited by IBAD, the (200) orientation becomes dominated. The ion bombardment is believed to enhance the mobility of the adatoms on the sample surface.

4. CONCLUSIONS

The TiN (IBAD) films which have a (200) texture and which are relatively hard, appears very favorable for wear resistance. This good behavior is linked with low stress level in film. In this case, IBAD technologies produced more were resistance coating than PVD technologies. Ion implantation results in the formation of layered structure in the near-surface region. The present coating method can produce dance structures, high hardness and the high critical load values can be achieved. Tribological tests confirm that these composite coatings are wear resistant and provide very low friction coefficient and contact temperature.

REFERENCES

[1] H. Haufmann, Surface and Coatings Technology, Vol 74-75, (1998), 23-29.

[2] K. Mogensen, N. Thomsen, S. Esikilden, C. Mathiasen and J.Bottiger, Surface and Coatings Technology 99, 140 (1998)

[3] Jones and S. Bull, Surface and Coatings Technology, Vol 83, (1996), 269-274.

[4] B. Škorić and D. Kakaš, Thin Solid Films, Elsevier Science, Oxford, Vol 317, (1998), 486-489.