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INFLUENCE OF A NANOINTERFACE ON TRIBOLOGICAL BEHAVIOR OF TiN COATINGS DEPOSITED BY LOW TEMPERATURE IBAD

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Ion Beam Assisted Deposition (IBAD) has been used for deposition of TiN coatings on carburized steel samples with the aim of sustaining the earlier obtained characteristics of the central region. Special attention has been given to improving adhesion, which usually presents a problem when using low temperature deposition. Ion Beam Mixing (IBM) has been used in order to acquire nanointerfaces within a thickness range of 10-60nm. Tribological characteristics have been analyzed with different equipment and with various loads. An extremely low friction coefficient has been obtained. On the other hand, TiN coatings have somewhat lower hardness than usual. It is our opinion that the obtained data has widened the field of application of TiN coatings deposited onto new types of steel and new types of mechanical parts.

Keywords: low temperature deposition, TiN, low friction coefficient, adhesion

INTRODUCTION

Low temperature deposition is a subject of investigations for around 15 years. There are several deposition methods with various results [1,2]. The main problem is low adhesion of the coating and that is why this technique has not found its place in the modern day industry. IBAD deposition offers the solution for this type of problem, however, only IBAD is not enough since the mail role has the interface between the coating and the substrate [3]. Using Ion Beam Mixing we can achieve intensive mixing of the atoms of the substrate with the atoms of the deposited coating. The thickness of the nanointerlayer can easily be regulated by correction of parameters such as : evaporation, energy of additional bombardment, atom to ion ration, incident angle etc [4]. The deposition of the hard coating can also be strictly controlled with the aim to obtain the preferred orientation of the layer, the wanted thickness of the coating, surface roughness etc. We have published papers about these problems where details about the previous [5,6], but in this paper we wish to explain how this process of low temperature with IBAD and IBM can influence on some tribological phenomena and the adhesion quality.

MATERIALS AND EXPERIMENTAL PROCEDURE

Samples for deposition with a diameter of 20mm and a thickness of 5mm – were produced of carburizing steel with 0.165%C, 0.2%Si, 1.2%Mn and 1%Cr.
Before IBAD deposition the surface of samples was grounded to a surface roughness of 0.035 μm R_a.

IBAD apparatus is consisted of a 5-cm Kaufman ion source, 5 kW electron beam evaporator, residual gas analyzer, quartz thickness monitor, mechanical and cryo pump. Base pressure was $1.5 \cdot 10^{-6}$ mbar. Titanium was evaporated with 720 W power, producing condensation rate of 0.2 nm/s. Growing film was bombarded with argon ion beam. Ion energy was 1 keV, and ion current density 53 $\mu A/cm^2$. Ion incidence angle was between 52º and 53º. During deposition of pure Ti sublayer, operating pressure was $5.6 \cdot 10^{-5}$ mbar, and maximum temperature was 58 °C. For the purpose of TiN deposition, nitrogen was added as a background atmosphere with partial pressure from 1.1 to $1.2 \cdot 10^{-5}$ mbar. Total operating pressure was around $7 \cdot 10^{-5}$ mbar. During deposition, temperature did not exceed 58 °C.

To improve the adhesion of the TiN layer, it was decided that an interface, made using dynamical mixing, as well as an sublayer which consists of Ti should be produced. Thickness of the Ti sublayers is 10-15nm for sample 15, 30-35nm for sample 13 and 50-60nm for sample 14, with the thickness of TiN hard coating was varied from 600nm to 1.2µm.

Wear test results: Equipment: Home made device, Material in contact (counter material): Ball made of hard metal - 3mm, Load: 300 p, Wear length: 2 mm, Speed: 0.015 m/s, Temperature: 22 °C, Humidity: 25%.

RESULTS AND DISCUSSION

During the scratch test measurements we obtained excellent results shown in figures 1 and 2. In figure 1 it can be seen that even when using a maximal load of the diamond prism, the effects of delamination are hardly visible on the end of the channel but not on the sides. At the bottom of the channel tracks of cracking can be seen, however, on the electronic data record , the rise in the friction coefficient is not obvious. During measurements on the equipment in Kragujevac, we have obtained a friction coefficient 0.05, but exactly the same value was measured with the load of 50N on the same sample, shown in figure 2.

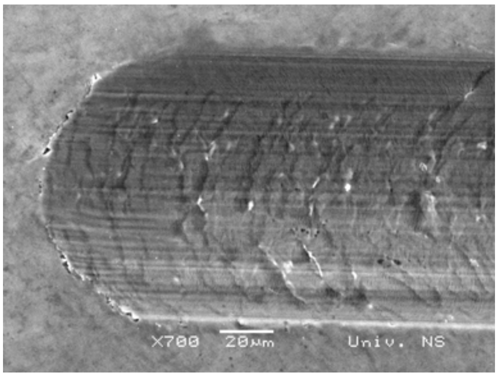


Fig. 1. End of the channel for sample 13

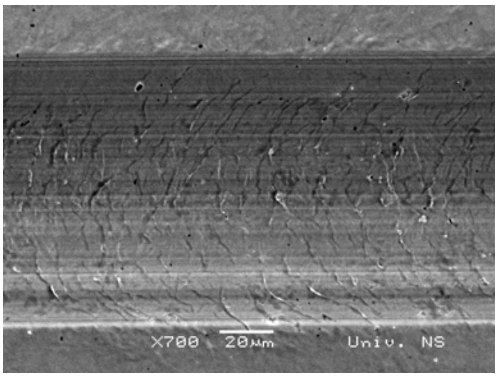


Fig. 2. Sample 13

At the sample 15, at the end of the channel when the load exceeded 90N a significant rise in the friction coefficient from 0.05 to 0.1 can be seen, and failure tracks appeared at the sides and the front simultaneously – figure 3. Measurement results for micro hardness and modulus of elasticity presented in figure 4, show significant dispersion which can not be attributed to the interface thickness change, but more to the certain instability of the process at these low temperatures. The obtained hardness for samples 13 and 14 are relatively satisfying. However, adhesion which has been achieved at the surface of carburized steel can be said that is excellent.

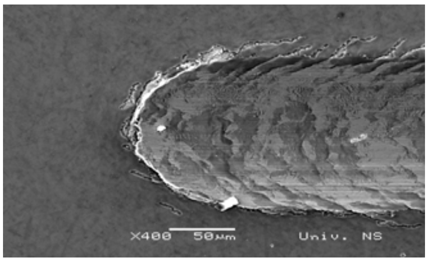


Figure 3. Channel of the

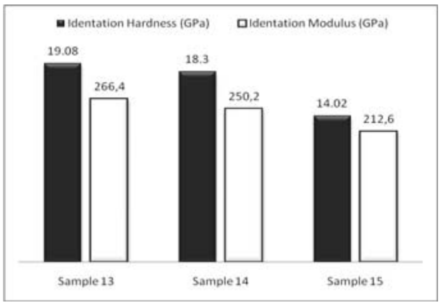


Fig. 4. Hardness -

The difference in hardness of the samples can be explained by the structure shown in figures 5 and 6. For sample 14 something between a columnar and grainy structure is visible. In the structure of the sample 15 columnar structure can not be observed, the structure looks amorphous. Taking into account so many parameters which we have controlled, the difference in these structures could be explained by mutually conjugated parameters effects, which shows that the control process should be upgraded.

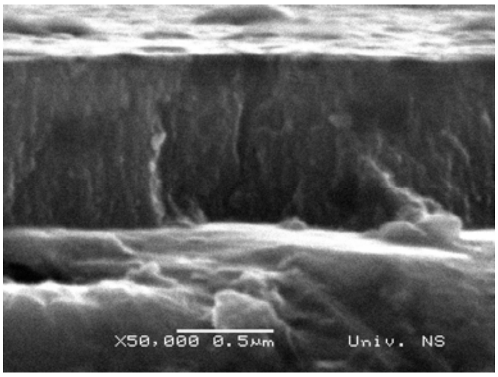


Fig 5. sample 14

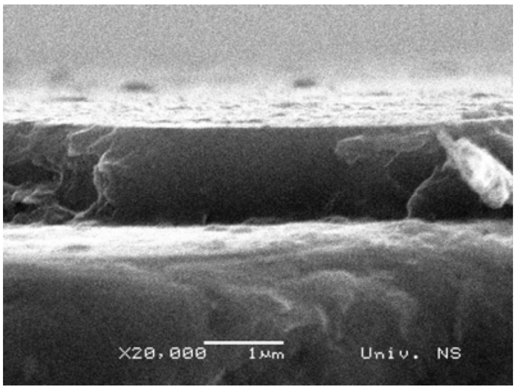


Fig 6. sample 15

Scratch tests were conducted on ST 2000 with a diamond prism – figure 7. An extremely low and slick line of the friction coefficient is obvious, which is in agreement with the visual appearance shown in figures 1 and 2.

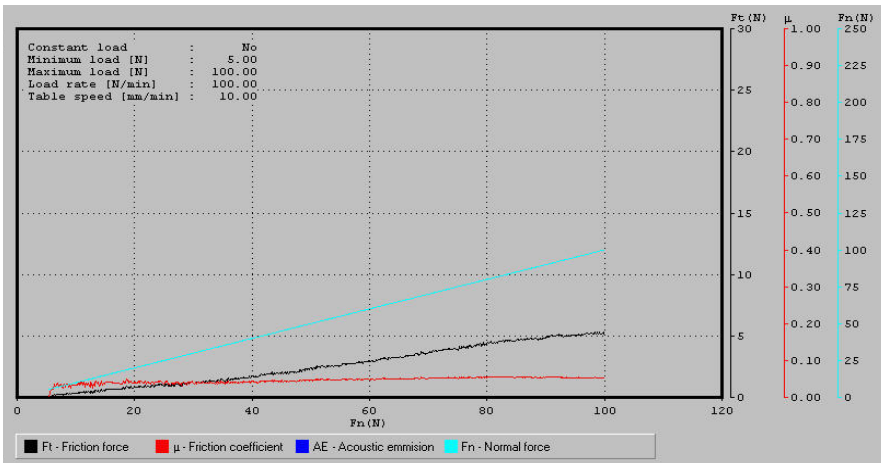
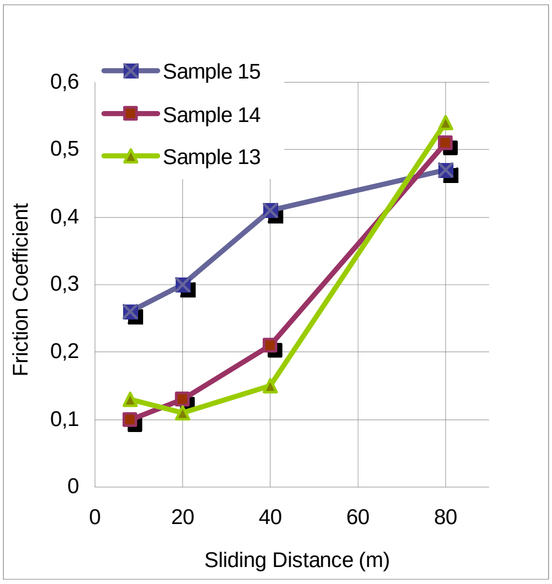
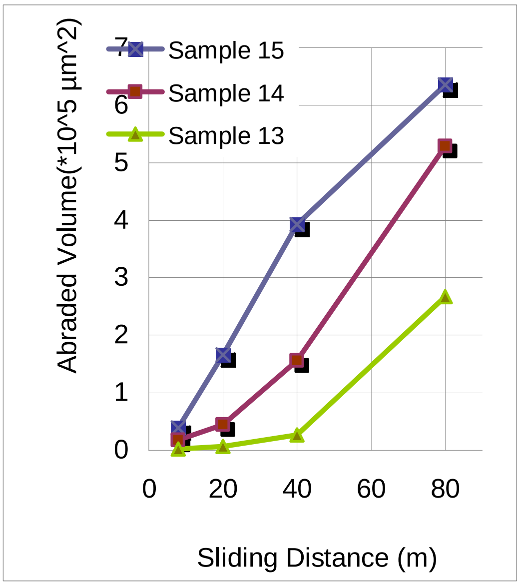


Figure 7. Friction coefficient - Sample 13

By checking the data using the Scopus data base, we haven't found that anybody published results with such low friction coefficient of the TiN coatings, so we decided to check our results in another laboratory – Research centre Rossendorf – using a different test equipment (counter material was a 3mm ball made of hard metal). Obtained results are shown in figure 8, where it can easily be seen that the friction coefficient is approximately 0.1 for the samples 13 and 14. This friction coefficient is higher compared to the results using the ST2000 which can be explained by the different counter material.

Having in mind the difference in structure as well as in hardness of the surface layer we have obtained different wear resistance – figure 9.





CONCLUSION

On the basis of the results obtained by this investigation, it can be concluded that

- it is possible to conduct the low temperature deposition of hard coatings (TiN) using IBAD technology combined with Ion Beam Mixing.
- for the results of the deposition, especially very good adhesion, a special meaning has the presence of the interlayer of 30-60nm. The exact explanation of the thickness effect is in progress, and needs more experiments.
- very low temperatures lead to instability of the deposition process, which is manifested in differences in hardness and structure. However, it should be noted that most samples (most charges) possess relatively low dispersion in the hardness value. However, we suppose that the process control should be improved for industrial application.
- results of this experiment show the possibility of a new field of application of hard coatings like deposition on carburized steel. This substrate material provides high mechanical characteristics and fatigue resistance, but with one micron TiN coating provides also high wear resistance and especially low friction coefficient. This combination makes a very promising material for industrial application.

LITERATURE

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