*Металлофиз. новейшие технол. / Metallofiz. Noveishie Tekhnol.*
2016, т. 38, № 7, сс. 903–909 / DOI: 10.15407/mfint.38.07.0903
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PACS numbers: 62.20.Qp, 68.55.jd, 81.15.Cd, 81.15.Dj, 81.15.Kk, 81.40.Pq, 81.65.Lp

# Effect of MoZrN Coating on a Steel XC100

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The zirconium nitride ZrN coatings are deposited on substrates of XC100 steel using physical vapour deposition (PVD) technique. Coatings based on nitrides of transition metals (Nb, Zr, Ti, V, ...) developed by PVD are known to increase the life of cutting tools, and so they naturally have seen a rapid industrial growth. It is possible to produce ZrN-coatings with variations of nitrogen partial pressure, the residual stresses, the thickness of the thin film, and the friction coefficient depending on the nitrogen content. Usage of nitrogen is a good way to enhance wear resistance and effectiveness in tribological applications.

**Key words:** zirconium nitride, coating, substrate, PVD-technique, tribological applications.

Покриття з нітриду цирконію ZrN наносилися на підложжя зі сталі XC100 з використанням технології вакуумного напорошення (PVD). Покриття на основі нітридів перехідних металів (Nb, Zr, Ti, V, ...), створені з використанням PVD-методи, як відомо, збільшують термін придатности різального інструменту; тому спостерігається швидкий ріст їх промислового виробництва. Наявна можливість виготовлення ZrN-покриттів зі змінними парціальним тиском азоту, залишковими напруженнями, товщиною тонкої плівки та коефіцієнтом тертя залежно від вмісту азоту. Використання азоту є перспективним шляхом підвищення зносостійкости та ефективности в трибології.

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Please cite this article as: A. Abboudi, B. Meddour, B. Chermime, H. Djebaili, and M. Brioua, Effect of MoZrN Coating on a Steel XC100, *Metallofiz. Noveishie Tekhnol.*, **38**, No. 7: 903–909 (2016), DOI: 10.15407/mfint.38.07.0903.

**Ключові слова:** нітрид цирконію, покриття, підкладка, PVD-метод, трибологія.

Покрытия из нитрида циркония ZrN наносились на подложки из стали XC100 с использованием метода вакуумного напыления (PVD). Покрытия на основе нитридов переходных металлов (Nb, Zr, Ti, V, ...), созданные с использованием PVD-технологии, как известно, увеличивают срок службы режущего инструмента; поэтому наблюдается быстрый рост их промышленного производства. Имеется возможность изготавливать ZrN-покрытия с изменяемыми парциальным давлением азота, остаточными напряжениями, толщиной тонкой плёнки и коэффициентом трения в зависимости от содержания азота. Использование азота является перспективным путём повышения износостойкости и эффективности в трибологии.

**Ключевые слова:** нитрид циркония, покрытие, подложка, PVD-метод, трибология.

*(Received April 12, 2016)*

## 1. INTRODUCTION

The use of coatings of the nitride of transition metals has been explored with success in the past decades, due to properties such as high hardness, biocompatibility, wear and corrosion resistance and thermal stability. Titanium nitride is the most studied. However, zirconium, niobium nitrides, and vanadium, among others, also have similar protective properties [1]. Authors agree on the values of hardness of about 25 GPa for TiN [2, 3].

In order to determine the process of forming of these films, depending on the used equipment, a strict control of all deposition parameters is required. Currently, the technique most commonly used is the coating of metal surfaces with reactive nitrides magnetron sputtering which enables the handling of a large number of parameters such as energy deposition (bias), deposition rate (plasma current), residual stresses of the layer thickness and a neutral reagent gas (Rodriguez *et al.*, 1994) showed that CrN compared to TiCN, ZrN, TiN [4] has the wear rate is the lowest.

## 2. MATERIAL AND METHODS

The ZrN and MoZrN deposits are made in ENSAM (Ecole Nationale Supérieure d'Arts et Métiers) of Cluny using System Dual magnetron sputtering (Nordiko 3500) (Fig. 1). We have processed to remove air to create a vacuum of $10^{-6}$ Torr. Thereafter, we have set the desired polarization with Argon fixation and progressive increase of the nitrogen

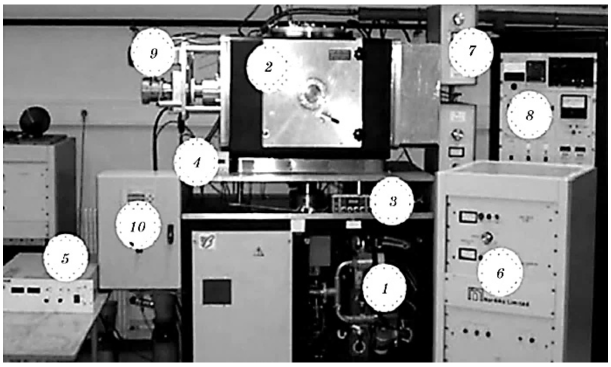

**Fig. 1.** Device for magnetron sputtering: *1*—cryogen secondary pump, *2*—enceinte of deposit, *3*—mass flowmeters, *4*—Baratron capacitance manometer, *5*—DC power supply, *6*—RF generator 13.5 MHz, *7*—impedance adapter, *8*—pumping control system and pressure, *9*—rotation of the motor carrier substrates, *10*—control system of the target caches and substrates.

**TABLE 1.** Chemical composition of the steel XC100.

| XC100 | C | Mn | S, P | Si | Cr | Ni | Cu |
|---|---|---|---|---|---|---|---|
| Percentage | 0.95 | 0.25 | S < 0.025 | 0.15 | 0.15 | 0.2 | 0.2 |

pressure.

XC100 was used as substrate material and polished to a surface roughness of 0.09 mm, after the polishing process, the sample was ultrasonically cleaned in hot alkaline cleaning bath for at least 5 min and then quenched. The target, composed of materials to be sprayed, are connected to a radio frequency (RF) generator (13.56 MHz) power of a variable from 0 to 1250 W), with Mo and Zr target and nitrogen gas as reagent, a substrate XC100. Sources of Zr and Mo were installed on each side of the chamber wall; the distance between the substrate and the targets was fixed around 8 cm. The variation in the percentage of Zirconium (Zr) is made by changing the voltage on the target (Zr) by setting the voltage of the Mo target, a second series of depositions were carried out by setting the voltage of the Zr target and varying the voltage of the Mo target, the deposition time is 100 min. The chemical composition of the steel XC100 is given in the following Table 1.

## 3. RESULTS AND DISCUSSION

### 3.1. Thickness of Films According to the Deposition Time

According to Fig. 2, we see that the deposited thickness is linearly in-

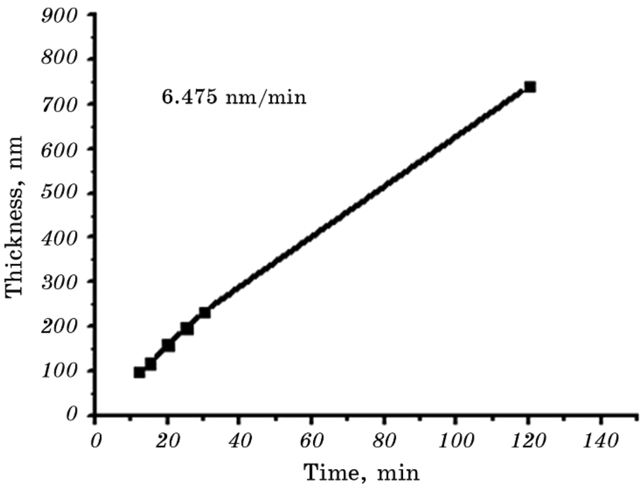

**Fig. 2.** Thickness of films according to the deposition time.

creasing with deposition time. The deposition rate is 6.475 nm/min.

Therefore, the deposited mass per surface area of the substrate is also XC100 linear with the deposition time.

### 3.2. Residual Stresses as a Function of the Thickness

The decrease of the stress when the thickness increase is attributed to relaxation of the layer in surface. It is noted that the stress of ZrN layers (Fig. 3) is not constant with the thickness. It reaches a maximum and then decreases to 100 nm to 250 nm. Such results have been reported for layers of aluminium nitride [5, 6]. The stress peak is due to a change in structure during growth of the layer.

### 3.3. Coefficient of Friction as a Function of the Thickness

The friction coefficient of the XC100 steel with the diamond indenter is between 0.2 and 0.6; so, it is very large compared to that of the carbide inserts.

Figure 4 represents the coefficient of friction of a film according to ZrN thickness; the friction coefficient of mono- and multilayer films on XC100 steel is higher than that of the carbide films. It is between 0.08 and 0.11 and remains very low. For coating, the ZrN and MoZrN coefficient of friction was between 0.2 and 0.3. The application of most of ZrN and produced a collection MoZrN reduction equipment [7].

Moreover, the layers formed by magnetron sputtering to have a high friction coefficient. Layers of CrN deposited on high-speed steel by arc

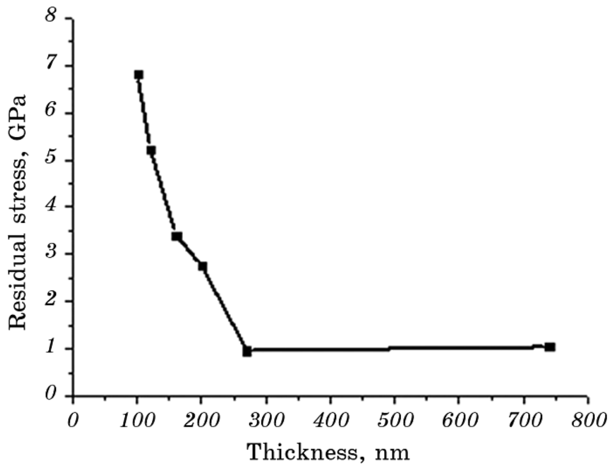

**Fig. 3.** Residual stresses as a function of the thickness.

evaporation and to reduce the coefficient of friction was also obtained by S.-C. Lee, W.-Y. Ho, and D. F. Lai [8].

### 3.4. Deposition Rate as a Function of % Nitrogen

In the studied range of nitrogen, there is a significant variation in the deposition rate as a function of nitrogen (Fig. 5). It is noted that the deposition rate decreases as the nitrogen increases, the decrease of the deposition rate as a function of nitrogen is due to the increase in the

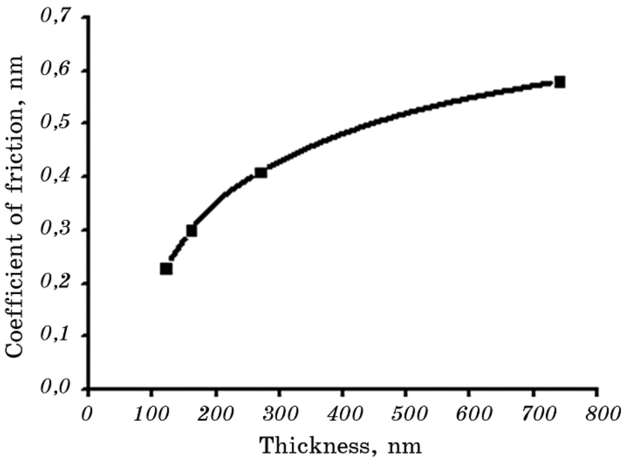

**Fig. 4.** Coefficient of friction as a function of the thickness.

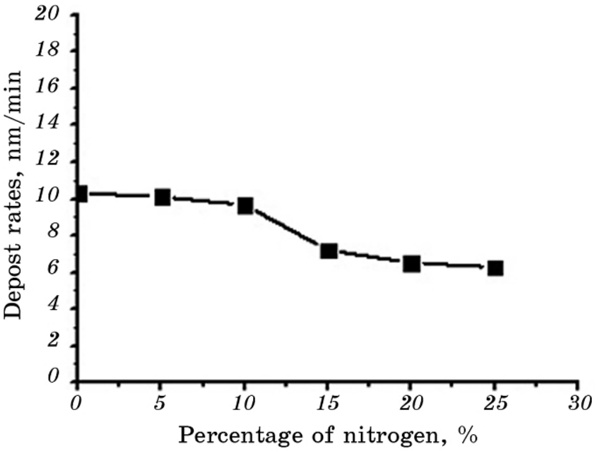

**Fig. 5.** Deposition rate as a function of (% nitrogen).

bias voltage of the target when the power applied generator; inducing higher energy bombarding the target species; is increased.

## 4. CONCLUSION

The present study reflects the influence of various hard coatings on steel XC100.

It appears that the ZrN layer deposited by magnetron sputtering gives better results than the nitriding treatment [9]. Multilayer coatings (MoZrN) and ZrN in all tests resist corrosion. This may be due to a better adhesion of the coating on the substrate and a lower coefficient of friction, which also reduces the cutting forces and the process is more stable with respect to vibration, the thickness of the layer is very significant on the surface.

The authors want to thank especially Prof. Caprian (ENSAM, Cluny–Lyon, France) for has advice and collaboration during this work.

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