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CHARACTERIZATION OF TiAlN COATINGS DEPOSITED BY SPUTTERING USING UNBALANCED MAGNETRON SOURCES AND CATHODE ARC EVAPORATION ON AISI D2 STEEL

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ABSTRACT
The investigation was performed on commercially available tool steel AISI D2 of Uddeholm Company under the trade name Sverker 21, which was a substrate for applying the physical vapour deposition (PVD) TiAlN coatings. The investigated coatings were deposited by sputtering using unbalanced magnetron sources– CC800 (CemeCon) at Jozef Stefan Institute (Ljubljana, Slovenia) and cathode arc evaporation technique (BAI 1200) in Balzers (Kapfenberg, Austria).
The use of hard ceramic coatings deposited by PVD onto tool steels can result in significant improvements in tool life over the uncoated materials. Several fundamental properties of the deposited coatings were investigated. The following laboratory tests were performed: microhardness measuring, nanoindetation test, scratch test, investigation of adhesion, roughness measuring. Results of scanning electron microscopy and glow discharge optical emission spectroscopy (GDOES) depth profile results are included as well.
Keywords: PVD hard ceramic coatings, tool steel

1. INTRODUCTION
Tool steels were developed to resist wear at temperatures of forming and cutting applications. They are divided into six categories: cold work, shock resisting, hot work, high speed, mold and special-purpose tool steels. Cold work tool steels are the most important category because they are used for many types of tools and dies and other applications where high wear resistance and low cost are needed. Surface engineering such as surface treatment, coating and surface modification are employed

to increase the surface hardness and minimise adhesion (reduce friction) and improve wear resistance of tool steel substrates. PVD hard coatings are well known for providing engineering surfaces with high hardness and high tribological properties. It is known that alloying of TiN coatings with additional elements could introduce marked effects on coating properties and performance [1,2,3]. Numerous studies have been carried out to manufacture multicomponent nitride coatings as alternatives to TiN coating for surface protection of cutting and forming tools. For instance, TiAlN coating is a common multicomponent system that yields superior oxidation resistance, and can significantly increase lifetime to cutting tools in comparison with conventional TiN coating [4]. In this paper, we report studies on the deposition, structure, composition and mechanical properties of TiAlN coatings.

2. EXPERIMENTAL

TiAlN coatings were prepared in Balzers BAI 1200 deposition system by cathode arc evaporation technique (coating name: Lumena) and in Jozef Stefan Institute by sputtering using unbalanced magnetron sources– CC800 (CemeCon) (coating name: IJS). Coatings were deposited onto the AISI D2 (1.2379) type tool steel substrates. The steel samples were finely ground, ultrasonically cleaned and sputter cleaned prior to coating deposition in order to obtain optimum adhesion between coating and substrate. In order to correlate the coating properties to the tool performance in exploitation, the samples were heat treated and coated together with the functional tooling parts and their properties were examined. The final macrohardness of tool steel AISI D2 after the heat treatment was 61 HRC in agreement with the tempering graphs, Figure 1. The thickness of hard coatings was determined by the Kalotest technique and from SEM fracture cross-sections. Surface roughness of the deposited coatings was measured on the Taylor-Hobson Talysurf 2 profilometer. The parameter R_a (µm) was assumed as a quantity describing the surface roughness. Vickers microhardness HV was determined by microindentation (Fischerscope H100C). Structure and composition were investigated with SEM (JEOL JSM 5800) and GDOES (LECO SPECTRUMAT-750) depth profiling. The coating adhesion was evaluated with a scratch tester equipped with a 200 µm radius Rockwell C diamond stylus (CSEM REVETEST, table speed 10 mm/min, loading rate 200 N/min, loading scale 0-200 N and scratch length 10 mm).

3. RESULTS AND DISCUSSION

The chemical composition of the investigated tool steel is presented in Table 1.

Table 1. Chemical composition of the tool steel in wt %.

%					
C	Mn	Si	Cr	V	Mo
1.55	0.40	0.30	11.80	0.80	0.80

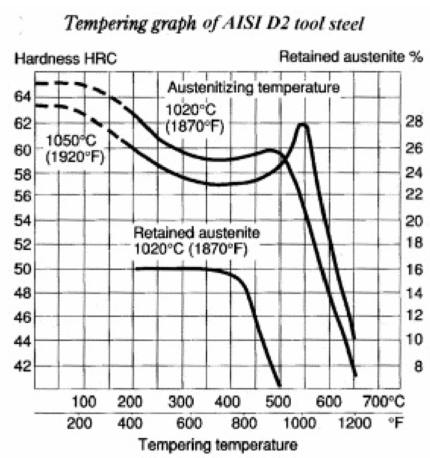

Figure 1. Tempering graph of AISI D2 tool steel [5].

Typical SEM micrographs illustrating the cross-section views of TiAlN coating deposited by cathode arc evaporation technique (coating name: Lumena) are shown in Fig. 2 A, B and TiAlN coating deposited by sputtering using unbalanced magnetron sources– CC800 (CemeCon) (coating name: IJS) are shown in Fig. 2 C, D. The interface between the coating and the substrate is sharp and without irregularities (Fig. 2). The microstructure is slightly columnar; but it is not clearly expressed. Coating thickness of Lumena and IJS were 9.2±0.4 μm and 2.8±0.2, respectively. The surface roughness of TiAlN coatings for Lumena and IJS were 0.20±0.02 μm and 0.21±0.02 μm, respectively.

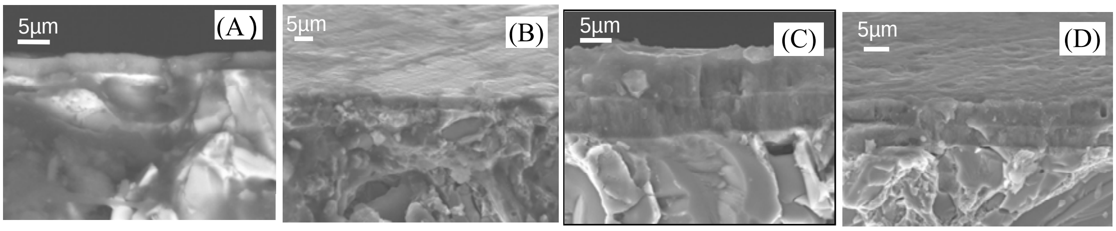

Figure 2. SEM fracture cross-sections of TiAlN coating-IJS (A, B) and TiAlN coating-Lumen (C, D).

The scratch test gives much more information among which five critical loads were considered for evaluation: Lc_3 (flaking at the scratch edge), Lc_4 (partial delamination of the coating), Lc_5 (total delamination of the coating), Lc(AE) (onset of acoustic emission) and $Lc(F_t)$ (scratching force jump). The Lc_3, Lc_4, Lc_5, Lc(AE) and $Lc(F_t)$ correspond within a few Newtons. These Lc values indicate good adhesion of both coatings, in good agreement with the Rockwell test. The critical loads obtained from scratch tests are shown in Table 2 and Figure 3. In Figure 4 the micrographs of the scratch track of investigated TiAlN coatings are shown.

Table 2. The mechanical properties of TiAlN PVD hard coatings deposited on AISI D2 (1.2379) tool steel

Coating name	**Coating composition**	**Substrate**	**$HV_{0.01}$**	**$E/(1-\nu^2)$ (GPa)**	**Scratch. coeff.**	**Lc_5 (N)**	**Rockwell test**
Lumena	TiAlN	1.2379	3150±150	389±9	0.056±0.007	96±5	acceptable
IJS	TiAlN	1.2379	3200±150	335±9	0.089±0.007	94±5	excellent

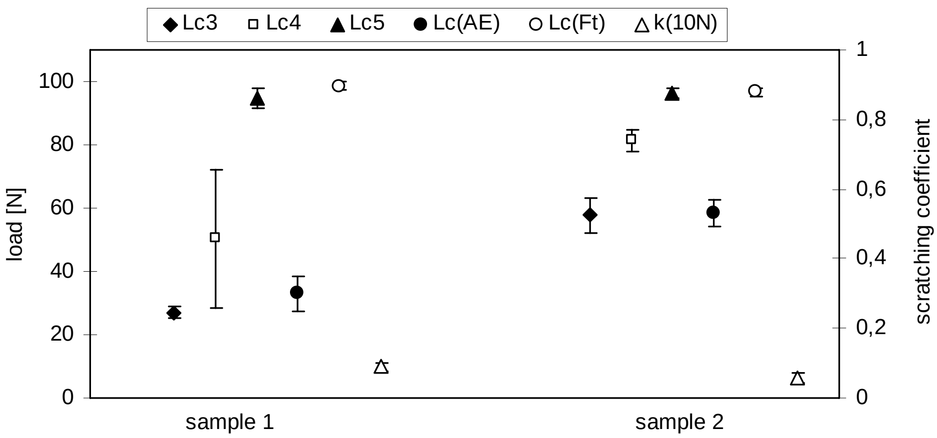

Figure 3. The critical loads and scratching coefficients obtained from scratch tests for sample 1 - TiAlN coating - IJS and sample 2 - TiAlN coating – Lumen.

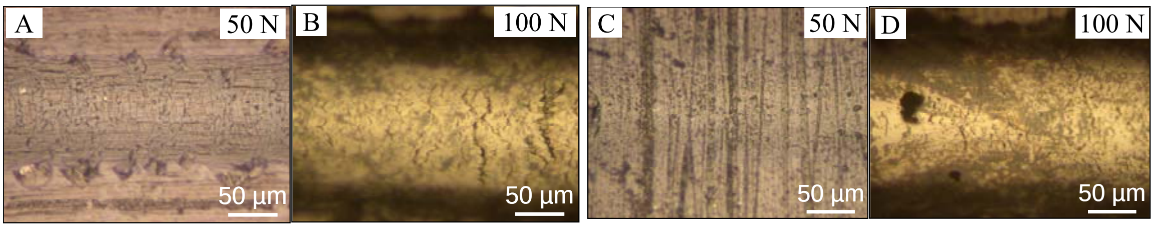

Figure 4. Scratch tracks for the TiAlN coating-IJS (A, B) and for the TiAlN coating-Lumena (C, D) under the loads of 50 and 100 N.

4. CONCLUSION

No significant differences are observed in surface roughness, $E/(1-\nu^2)$ and Lc values. At 100 mN hardness was obtained for TiAlN coating - IJS (3200 HV), which was very close to the TiAlN coating -Lumena. Lc values indicate good adhesion of both coatings, in good agreement with the Rockwell test.

5. REFERENCES

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