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Characterization of Hardness and Microstructure of TiAlN and TiCN/Al_2O_3 Coatings Deposited Via LARC Deposition

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***Abstract* - In the present work, we investigate the hardness and microstructure of TiAlN and TiCN/Al_2O_3 coatings deposited using the lateral rotating cathodes (LARC) technology. The deposited coatings are characterized for microvicker's hardness testing, x-ray diffraction analysis, and scanning electron microscopy (SEM) imaging. Our results reveal that the TiCN/Al_2O_3 TiAlN coatings exhibit the highest hardness of 25 GPa. The x-ray diffraction pattern of the TiCN/Al_2O_3 coatings exhibits a strong crystalline phases of hexahedral structure which contributes to higher hardness. The microstructure of TiAlN coatings reveal several porous sites.**

Keywords – Microstructure; TiAlN; TiCN/Al_2O_3 Coatings; Lateral Rotating Cathodes (LARC) Technology; Physical Vapor Deposition (PVD)

I. INTRODUCTION

High productivity and precision in finished products are the needs of today's metal working industries. This demand emphasizes the need of cutting tools with high wear resistance and service life. There are several classes of cutting tools available in today's market. However, the WC-Co (cemented carbide) and Coated WC-Co are extensively used in high-speed machining and in machining of "hard – to – cut" materials. The refractory ceramic oxides are known for their excellent wear and thermal resistance properties. Alumina Oxide (Al_2O_3) is the most commonly used refractory oxide coatings in many applications which demand wear resistance. When Al is combined with other materials such as Ti, Zr, Cr etc. its properties are further improved [1-4]. TiAlN coatings are known for their superior hardness (>25GPa) and wear resistance upto high temperatures of 1000ºC. Several studies have been carried out to understand the behaviour of TiAlN system of coatings. A comparative study made on nano AlTiN and multilayered TiAlN/TiSiN+CrN in dry machining of AISI 3430 steel showed that nano crytalline coatings exhibited higher hardness. The high hardness of nano crystalline coatings can be attributed to its high hardness (>30GPa). Similarly, Liew et al. have demonstrated that nano crystalline TiAlN coated tool produces a good surface finish with minimum lubricants. Multilayered coatings also possess superior properties and can be effectively used in high-speed machining applications. In the present work we investigate the microstructure and hardness of TiAlN and TiCN/Al_2O_3 coatings [5-8].

II. MATERIALS AND METHODS

In this study, the hardness and microstructure of TiAlN and TiCN/Al_2O_3 coatings are deposited using the lateral rotating cathodes (LARC) technology. The coating process was carried out in an industrial coating unit called PLATIT π – 80.

Commercially available cemented carbide substrates with TNMG 160404 specifications were chosen for coating. Prior to coating, the inserts are cleaned with deionized water and dried in an oven at 100°C. The coating chamber comprises two lateral rotating cathodes and a carousel where the inserts are mounted. The chamber is maintained at a working pressure of 1 – 1.5 Pa with a flow of Nitrogen and Argon gases. The substrate is biased with a voltage of -70 to -75V, while the cathodes (targets) are biased with a voltage of -20V. The current between the cathodes ranges from 80 to 100 amperes.

A magnetic system is employed to guide the arc plasma backward, allowing large particles to deposit on the walls and clean the impurities on the target. Without interrupting the arc, the magnetic system then redirects the plasma toward the substrate. The choice of target materials depends on the desired coating type. For TiAlN coating, one block of Ti and one block of Al are used. For TiCN-Al_2O_3 coating, one block of TiCN and another block of Al_2O_3 were used.The schematic of the coating chamber is as shown in figure 1.

During deposition, both the carousel and inserts continuously rotate about their vertical axis at a speed of 10 rpm. The entire process is programmed to deposit 3µm of coatings in one cycle time. The current between the cathodes is continuously controlled to maintain the desired ratio of elements in the coatings.

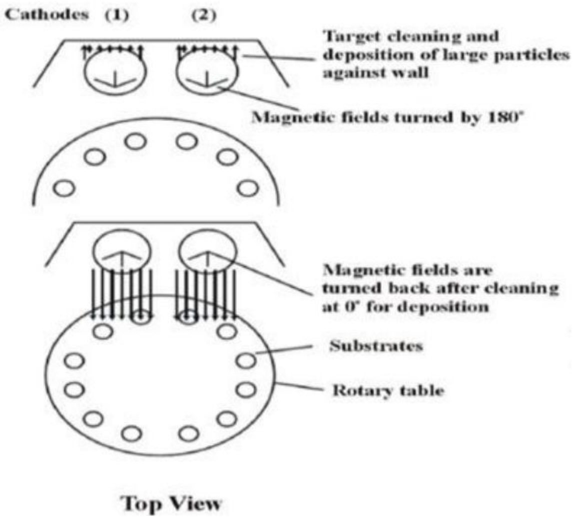


Figure 1. Schematic of the LARC process

To assess the hardness of the deposited coatings, Matsuzawa MMT-X7 microhardness tester is utilized. The tester employs a diamond pyramid indenter and the indentation left behind is measured and displayed on an LCD interface. The machine has a load range of 1gf – 1000gf. A load of 500gf is applied to all samples with a dwell time of 15 seconds.

Scanning Electron Microscopy (SEM) was used to capture images of the coating surface. Phenom desktop scanning electron microscope was utilized for this purpose. Additionally, X-ray diffraction (XRD) studies were conducted to study the elemental phases present in the TiAlN and TiCN/Al_2O_3 coatings. Bruker's D8 advanced X-ray diffractometer was utilized for XRD studies.

III. Results and Discussions

A. Hardness

The hardness results for the TiAlN and TiCN/Al_2O_3 coatings are presented in Table 1. It is observed that the hardness of the TiCN/Al_2O_3 coating was higher compared to the TiAlN coating. High hardness of the coating can be attributed to its bilayered structure. This also indicates the presence of a strong interface between TiCN and Al_2O_3 layer. Moreover, the interfacial bond between the amorphous and crystalline phases enhances the strength of the coating and restricts the movement of dislocations, leading to improved oxidation and wear resistance. The obtained hardness values in this study are comparable to hardness found in other related works. However, it should be noted that the hardness values did not reach the super hardness state.

Types of Coating	Colour	Microvickers Hardness (in GPa)
TiAlN	Grey	15
TiCN/Al_2O_3	Black	25

Table1. Hardness values of as deposited coatings

B. Scanning Electron Microscopy and X –ray diffraction

The SEM images presented below depict the microstructure of the TiAlN and TiCN-Al_2O_3 coatings. The TiAlN coating exhibits a slightly porous morphology with some unmelted particles. These porous sites can lead to reduction in the hardness of the coatings. There were no cracks, or any other large voids present on the surface of the coating.
Similarly, the TiCN-Al_2O_3 coating also displays a relatively smooth surface morphology. The coating does not have any porous sites or micro cracks. Further no unmelted particles were observed.

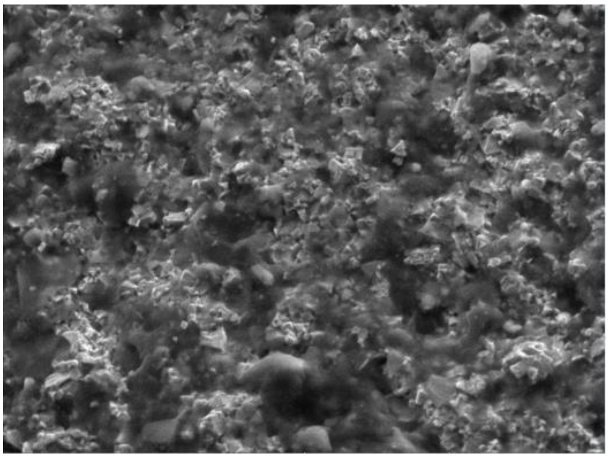


Figure 2. SEM image of TiAlN coating.

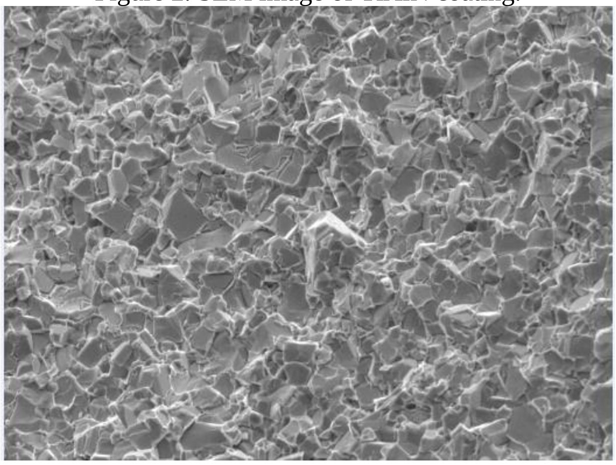
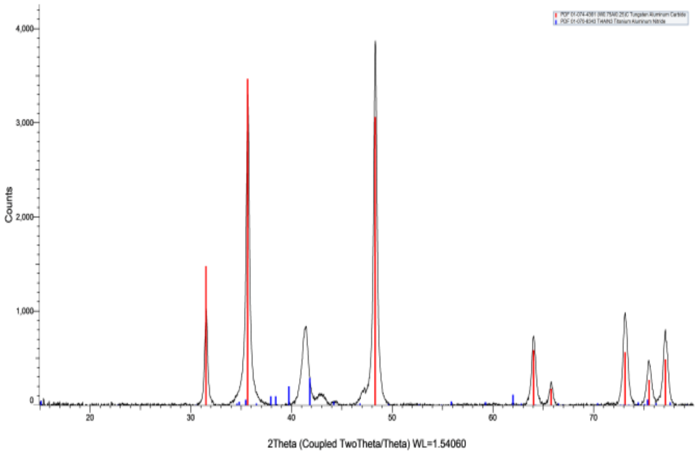


Figure 3. SEM image of TiCN/Al_2O_3 coating.

C. X – Ray Diffraction Studies

The XRD analysis revealed information regarding the crystal structures of the TiAlN and TiCN/Al_2O_3 coatings. The TiAlN coating showed the presence of Ti_4AlN_3 phase in low intensity. A strong peak for tungsten aluminum carbide is observed. The crystallinity of the coating is reduced when compared with TiCN/Al_2O_3coating. In the case of TiCN/Al_2O_3 coating the presence of Al2O3 in rhombohedral structure has contributed to its high hardness.

Figure 5. XRD pattern of TiCN/Al_2O_3 coating



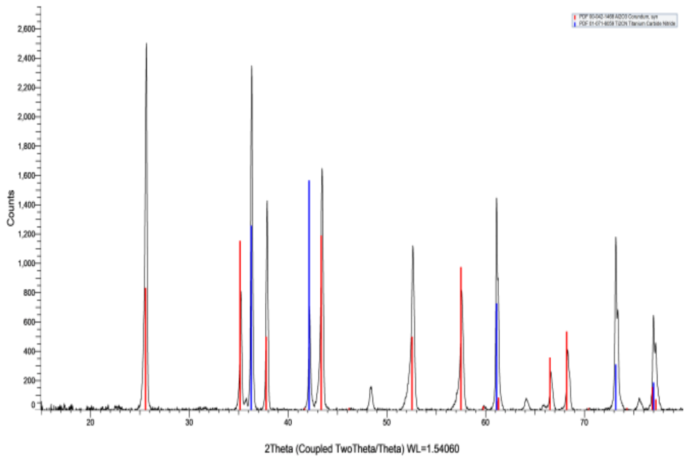


Figure 4. XRD pattern of TiAlN coating

IV. CONCLUSIONS

All the coatings, including TiAlN and TiCN-Al_2O_3, underwent characterization of surface morphology and mechanical properties. It was observed that the TiAlN coating demonstrated higher hardness compared to the TiCN/Al_2O_3 coating. High hardness can be attributed to the presence of strong crystalline structures of TiCN and Al_2O_3. Further studies on wear resistance are to be investigated in future.

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