EVALUATION AND CHARACTERIZATION OF THIN FILM COATINGS

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ABSTRACT

Recent advancement in cutting tool materials and PVD (physical Vapour Deposition) surface coatings are making high-speed dry machining an increasingly viable machining operation in commercial manufacturing sectors. High oxidation resistant coatings, such as TiAlN, are used extensively in global manufacturing for reducing production costs and improving productivity in such aggressive metal-cutting operations. In this investigation, the characterization of different types of coatings (TiN, TiAlN, TiN+TiAlN, TiN+AlCrN) assessed by Coating’s thickness, surface roughness, hardness and SEM with EDS have been evaluated. Cutting tools coated with materials capable of enhanced tribological and resistance properties. A heat-treated monolayer coating, competitive with other coatings. The film made out of TiN+AlCrN (aluminum–chromium–nitride) showed good characterization compared to other monolayer coatings.

KEYWORDS: Thin Film Coatings, PVD

INTRODUCTION

The recent advances in modern manufacturing technologies demand coating solution with high mechanical hardness, wear resistance and corrosion resistance [1–3]. Coated tools have compound material structure, consisting of the substrate covered with a hard, anti-friction, chemically inert and thermally isolating layer, approximately one to few micrometers thick. As such, coated tools compared to uncoated ones, offer better protection against mechanical and thermal loads, diminish friction and interactions between tool and chip and improve wear resistance in a wide cutting temperature range.

COATING DEPOSITION TECHNIQUES FOR CUTTING TOOLS

Physical vapour deposition (PVD) covers a broad family of vacuum coating processes in which the employed material is physically removed from a source by evaporation or sputtering. Then, it is transported by the energy of the vapour particles, and condensed as a film on the surfaces of appropriately placed parts under vacuum. Chemical compounds are deposited by either using a similar source of material, or by introducing reactive gases (nitrogen, oxygen, or simple hydrocarbons) containing the desired reactants, thus reacting with metal(s) from the PVD source. Chemical vapour deposition (CVD), unlike PVD vacuum processes, is a heat-activated process based on the reaction of gaseous chemical compounds with suitably heated and prepared substrates.

Primary reactive vapours can be metal halides (chloride, bromide, iodide, or fluoride) or metal carbonyls, M (CO), as well as hydrides and organometallic compounds. To decompose or reduce the metal compound, a transfer of heat energy is involved, and the substrate is usually held at a substantially higher temperature than any other part of the system. For this reason, the reaction chamber may present more of a high-temperature problem than any other part of the system.
Most reactions are also conducted in an anhydrous and anaerobic environment, and frequently at sub-atmospheric pressures. Typical deposition temperatures range from 800 to 1200°C. The ability to provide uniformly thick coatings with refined grain is also influenced by the deposition temperature. In both cases, low-temperature processing is frequently desirable, although a compromise in the rate of deposition must often be made. The figure 1 shows various coating deposition techniques for cutting tools.

In our study coating was carried out on TNMG160404 carbide inserts and DIN6535K carbide twist drill bits using four different types of material by cathodic Arc Process. 1) TiN coating 2) TiAlN coating 3) TiN coating first layer and AlCrN on the outer layer 4) TiN+TiAlN coating.

**Coating Conditions**

<table>
<thead>
<tr>
<th>TiN</th>
<th>TiAlN</th>
<th>TiN+TiAlN</th>
<th>TiN+AlCrN</th>
</tr>
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<tbody>
<tr>
<td>Golden Yellow</td>
<td>Black violet</td>
<td>Red violet</td>
<td>Grey blue</td>
</tr>
<tr>
<td>1.5 microns</td>
<td>1.5 microns</td>
<td>3.3-3.4 microns</td>
<td>3.3-3.4 microns</td>
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<tr>
<td>500°C</td>
<td>500°C</td>
<td>500°C</td>
<td>500°C</td>
</tr>
<tr>
<td>Monolayer</td>
<td>Monolayer</td>
<td>Multilayer</td>
<td>Multilayer</td>
</tr>
<tr>
<td>&lt;800°C</td>
<td>&lt;800°C</td>
<td>&lt;800°C</td>
<td>&lt;1100°C</td>
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**EVALUATION OF COATING CHARACTERISTICS**

The evaluation of coating characteristics was performed through following tests 1) Microhardness Test 2) Surface Roughness 3) SEM and EDS analysis

**Micro Hardness Test:** Micro hardness test was conducted to determine the hardness of each coating using Metatech Hardness Tester at HV0.05 scale. The hardness test can be carried out in various methods. Vickers micro hardness (HV) is calculated by measuring the diagonal lengths of an indent left by introducing a diamond pyramid indenter with a given load into the sample material.

The size of the indent is read optically in order to determine the hardness. The hardness value can be obtained from table or formula after determining the mean value of the two measured diagonal lengths the Vickers scale ranges from 10gm to 1Kg. This test is important as hardness changes due to thin film coatings. The indentation was carried out on each coating, for TiN hardness was found to be 2400 (figure 1), for TiAlN the hardness was found to be 3200 (figure 2) and for TiN+AlCrN coating the hardness was found to be 3300 (figure 3) and for TiN+TiAlN coating the hardness was found to be 3200 (figure 4).
Figure 1: Image of Indentation Made on TiN

Figure 2: Image of Indentation Made for TiAlN

Figure 3: Image of Indentation Made on AlCrN

Figure 4: Image of Indentation on TiN+TiAlN
Surface Roughness

Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. For measuring the surface roughness different methods and parameters are used. Ra is the most commonly used method (average roughness or absolute roughness). Ra is the arithmetic average of the absolute values of the profile height deviation from the mean line, recorded within the evaluation length. The Ra test was performed on each coating to determine the surface roughness of each coating. It was performed using Taysurf-series 2 machine. For TiN it was found to be 0.5206 micrometer (figure 4) for TiAlN it was found to be 0.2702 micrometer (figure 5) for TiN+AlCrN coating it was found to be 0.5618 micrometer (figure 6).

Figure 5: Ra of TiN

Figure 6: Ra of TiAlN
SEM and EDS Analysis

EDS analysis was carried out to determine the elemental composition of coating and SEM analysis was carried out to study the surface morphology of the coating. From the SEM images it is observed that at 100micrometer scale and 250x magnification the surface of TiN appears to be very smooth without much of cracks present but if we focus at 2micrometer scale and 5000x magnification it is observed that the hair line cracks present on the surface. But the coating does not propagate the cracks during the machining operations this effect is known gargling effect. [5]
From the SEM images of TiAlN it has been observed that there are some amount particles like structure present on the surface. It is because of presence of the aluminium with titanium which forms the uneven surface and this increases the hardness of coating and the oxidation resistance of the coating will also be increased. From the SEM images of TiN+AlCrN it has been observed that the coating is not much even or smooth surface compared to TiN and TiAlN. It is because of presence of AlCrN as the outer layer of the coating. The chromium is one of the hard material which reacts with the aluminium in the presence of nitrogen atmosphere which results in uneven surface and the presence on TiN as the inner also adds to it. Al based coatings provide chemical inertness, hardness and good wear resistance due to the formation of \( \text{Al}_2\text{O}_3 \) layer on the tool surface at high temperatures. In TiN+TiAlN coating TiN helps in reducing propagation of cracks. TiN and TiAlN films starts to oxidize at temperatures of 550\(^\circ\)c and 800\(^\circ\)c. Nitride with high amounts of aluminium with excellent properties at high temperatures, excellent anti oxidation characteristics as well as anti-spalling and debris removal properties for the contact interface.
Figure 11: SEM Image of TiAlN

Figure 12: SEM Image of TiAlN

Figure 13: SEM Image of TiN+TiAlN
Figure 14: SEM Image of TiN+TiAlN

Figure 15: SEM Image of TiN+AlCrN

Figure 16: SEM Image of TiN+AlCrN
EDS Analysis of TiN Coating

![EDS Analysis of TiN Coating](image1.png)

**Figure 17**

EDS Analysis of TiAlN Coating

![EDS Analysis of TiAlN Coating](image2.png)

**Figure 18**
EDS Analysis of TiN+AlCrN Coating

<table>
<thead>
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<td>Cr K</td>
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EDS Analysis of TiN+TiAIN Coating

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<td>Al K</td>
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<tr>
<td>Ti K</td>
<td>20.31</td>
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<tr>
<td>Totals</td>
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CONCLUDING REMARKS

In the present investigation it was observed that the hardness of TiN coating was low compared to TiAlN coating, TiN+TiAlN coating and TiN+AlCrN coating. The surface roughness of TiN+AlCrN and TiN+TiAlN both coatings have more Ra value because of multilayer coating.

From the SEM and EDS analysis it has been observed that the presence of Aluminium in TiAlN coating increases the oxidation resistance which will increase the wear resistance and the presence of Chromium and Aluminium in TiN+AlCrN coating will increase the hardness of coating and the oxidation resistance will also be increased. From the above characterization study it is clear that the TiN+AlCrN coating deposited by the PVD process showed better physical properties which can be utilized for wide range of applications.

The structural analysis shows that the heat treatment of TiN+AlCrN coating allows recrystallization and crystal growth, enhancing its wear behavior. These characteristics make the coated tools better for cutting applications. Based on the high oxidation resistance and improved tribological interaction of the coatings. Order of preference of coatings can be mentioned as TiN, TiAlN, TiN+TiAlN, TiN+AlCrN.
REFERENCES


