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Modern coatings in high performance cutting applications

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Abstract

Modern, state-of-the-art, PVD coatings are required to fulfill a variety of different applications. Each metal cutting operation requires an optimal combination of various film parameters to achieve a high end cutting performance. Especially, Al-based coatings such as AlTiN- and AlCrN-coatings show very good results in high performance metal cutting applications.

Wear resistance, thermal stability such as oxidation resistance and hardness at elevated temperatures are key issues within these cutting operations. In this paper the influence of these properties on Al-based nitride coatings in relation to metal cutting tests such as milling and drilling will be discussed.

Keywords: PVD; Hard coatings; AlCrN; TiAlN; Cutting tools

1. Introduction

The keyword for manufacturers of cutting tools and coatings for cutting tools is productivity: a 30% reduction of tool costs, or a 50% increase in tool lifetime results only in a 1% reduction of manufacturing costs. But an increase in cutting data by 20% reduces manufacturing costs by 15%. In order to achieve higher productivity different approaches – high performance cutting (HPC) and high speed cutting (HSC) [1] can be chosen.

Advances in manufacturing technologies (increased cutting speeds, dry machining, etc.) triggered the fast commercial growth of PVD coatings for cutting tools. On the other hand, technological improvements in coating technologies (TiAlN, AlTiN, AlCrN and nanocomposite coatings) enabled these advances in manufacturing technologies.

Twenty five years ago TiN started the success story of PVD coatings in cutting tool applications. Recently, a new generation of coatings were introduced, based on the Al–Cr–N system. This system is characterized by superior abrasive wear resistance and improved oxidation resistance – promising results in cutting tool application have been reported [2,3].

This paper reports the results of a comparative investigation of state-of-the-art coatings and high-aluminum AlCrN coatings, particularly relative to high temperature behavior. Oxidation tests at elevated temperatures have been performed to rate their chemical stability in a high temperature environment. These are then related to coated tool performance in several metal cutting tests.

2. Experimental

Standard Balzers coatings were used for the comparisons of the various nitride films. All coatings were deposited by a standard Balzers RCS cathodic arc coating machine. A schematic view of this coating system is shown in Fig. 1. The coatings were done by using pure Ti-targets for TiCN, TiAl-targets with two different compositions for (Ti,Al)N-coatings and high aluminum content (Al,Cr)-targets for AlCrN-coatings.

Prior to deposition the substrates were chemically cleaned, heated and plasma etched using an Argon-ion-etching process. In the cases of (Ti,Al)N and CrAlN, a pure

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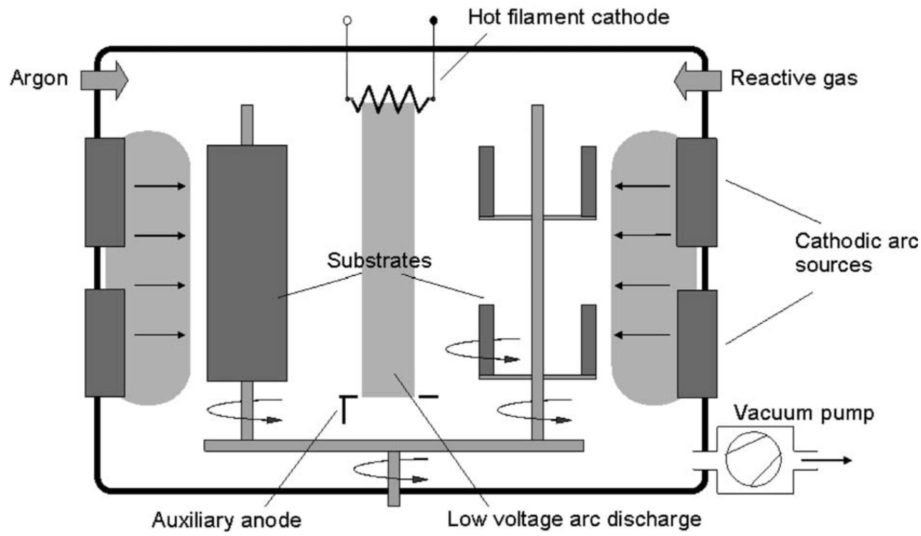

Fig. 1. Schematic illustration of the coating device used for the film deposition.

reactive nitrogen atmosphere was used while for TiCN a mixture of nitrogen and acetylene was used during the deposition. The pressure during deposition was in the range of 0.5–3.5 Pa at a temperature of approximately 500 °C. For all coatings the DC-substrate bias voltage was in the range of −50 to −150 V. The thicknesses of the coatings were in the range of 4–5 μm for the evaluation of mechanical properties and 2–3 μm for the oxidation tests. The thicknesses for the cutting tests were in the range of 3.5–4.5 μm.

The coatings deposited onto cemented carbide inserts were characterized using standard scanning electron microscopy (LEO 1530). The X-ray diffraction measurements were carried out using a Siemens Diffractometer D500 equipped with a Cu Kα X-ray source. Here, the glancing incidence (GI) mode was used. A Fischerscope H100C was used for measuring the Vickers microhardness. For this measurement the load was varied from 0.4 mN to 1 N. The load for the hardness measurements was held at 50 mN.

The abrasive wear test is comparable to a standard calotte wear test. A suspension is used to grind a spherical crater into the coating. From measurements of the ball wear scar the wear volume can be calculated. This volume is taken as a measure of resistance against abrasive wear behavior of the coating [4].

The annealing experiments for the hardness measurements were performed in a high-vacuum furnace PVA MOV 64 (Pfeiffer GmbH, Germany) using Al_2O_3 crucibles. After evacuation of the furnace to a pressure of $P_{vac} < 2 \times 10^{-6}$ mbar the temperature was increased to the required temperature at a heating rate of 50 °C/min in a protective argon atmosphere by increasing the argon pressure from 100 to 400 mbar. A constant argon pressure of $P_{Ar} = 400$ mbar was kept during the whole annealing time. After annealing for 2 h, the sample was cooled down in argon atmosphere to room temperature at a cooling rate of 50 °C/min. The oxidation experiments were performed in a programmable furnace PEO-601.This furnace can be heated up to 1100 °C in vacuum, air or other atmospheres. The oxidation tests were performed at several temperatures in air for duration of 30 min. After heating, the samples were continuously cooled down to a temperature of 100 °C before they were taken out of the furnace. The cutting tests were performed either in the Balzers internal cutting laboratory using a MIKRON VCP600 CNC milling machine or at external customers' machine shops.

3. Results and discussion

3.1. Comparison of coating properties

In Fig. 2a the *abrasive wear* coefficient of the various coatings is shown. The abrasion resistance of TiAlN- and AlTiN-coatings was in the range of 3–5. In comparison to the TiAl-based hard coatings the abrasion resistance of the harder and more brittle TiCN-coating was better by a factor two of while that of the AlCrN-coating was

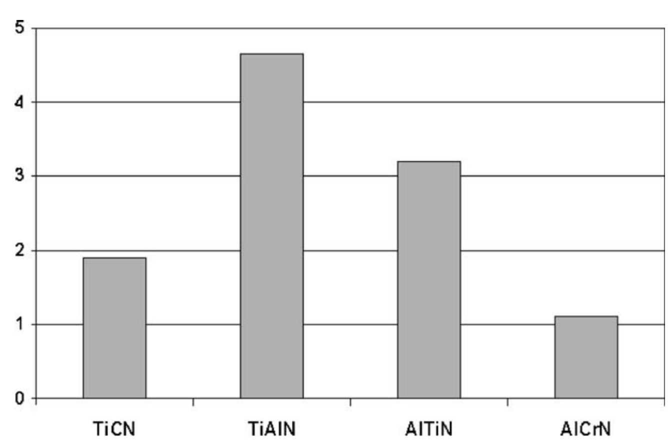

Fig. 2a. Abrasive wear resistance of TiCN, TiAlN, AlCrN coatings measured by calo wear test.