Phase transition in $Cr_xAl_{(1-x)}N$ coating at high temperatures

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Abstract

In this work, Al doped CrN superhard coatings are studied for their thermal stability. Surface and cross sectional morphology of the coating was investigated using Scanning Electron Microscopy (SEM) equipped with Energy Dispersive Spectroscopy (EDS) detector. Synchrotron radiation X-diffraction (Powder Diffraction) beamline was used to investigate the microstructure and phase transition of the coating layers within the temperature range of 25 °C - 700 °C in steps of 100 °C. SEM study revealed interesting elemental distribution over the coating layers. Results indicated that CrN and Cr,T, are the main structural phases at 25 °C and 700 °C respectively. Dominant structural changes during annealing results in the gradual transformation of cubic CrN phase to the hexagonal Cr,T,N phase. In addition, the recrystallization of CrN and Cr,T,N phases with preferential growth directions were observed. As the temperature increased the width of the peaks were reduced while their increased intensity indicate the grain growth in the coating layers. These CrAlNs have the potential to be used in cutting, milling and screw-threading tools due to their better thermal stability, corrosion and wear resistances.

Introduction

The use of modern coating materials and modern methods of coating deposition has allowed manufacturers to produce composite structures that withstand aggressive environments and harsh working conditions. Transition metal nitrides (TiN and CrN) have been widely applied in industrial applications as they provide wear protection, high temperature and corrosion resistance, good adhesion and a high level of hardness. Recently, CrN has been used as a coating in cutting, milling and screw-threading tools due to its better thermal stability, corrosion and wear resistances. The ever growing demand on better tool properties led to the development of ternary coatings like Cr,T,Al,N. Al doping improves hardness, oxidation resistance and thermal stability of binary nitrides [1].

Table 1. Cr and Al Atomic percentage in the coating film

<table>
<thead>
<tr>
<th>Element</th>
<th>Atom (at %)</th>
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<tbody>
<tr>
<td>Cr</td>
<td>81.83</td>
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<tr>
<td>Al</td>
<td>18.17</td>
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</table>

Fig. 1. (a) SEM image of a typical Cr,T,Al,N, (b), (c) and (d) distribution of Fe, Cr and Al, respectively

Since certain crystal structures and phase transformations at high temperature have detrimental effects on the properties of hard coatings [2,3], it is essential to investigate the stable structures at the working temperature up to 1000 °C.

Experimental details

$Cr_xAl_{(1-x)}N$ coating film were deposited on AISI M2 High speed using a TEER UDP 650/4 closed field unbalanced Magnetron Sputtering technique. A JEOL JSM-6000 SEM equipped with EDS was used to investigate the coating microstructure and chemical compositions (Fig. 2 and 3). In situ crystal structural studies were done at the Australian Synchrotron Powder Diffraction (PD) beamline facility (X-ray radiation I=0.8289 Å). Samples were heated from temperature T=25 °C to 700 °C in several steps.

![Synchrotron diffraction patterns for Cr,T,Al,N hard coatings in the range 2θ =15°-60°](image)

Fig. 2. Synchrotron diffraction patterns for Cr,T,Al,N hard coatings in the range 2θ =15°-60°

(a) T=25 °C, 200 °C, 500 °C, 600 °C & 700 °C and (b) different phases at T=25 °C & 700 °C

Results and Discussion

Fig. 2 is the diffraction patterns of Cr,T,Al,N coating, over different 2θ ranges, at 25 °C and 700 °C. At 25 °C, Cr,T,Al,N exhibited several intense peaks belonging to Cr,N-Cr,N phases. Dominant structural alteration at higher temperatures is the gradual transformation of c-Cr,N phase to the hexagonal Cr,T,N phase. As the temperature increase the width of the peaks reduces and the intensity increases indicating increase in grain size. Cr,T,Al,N sample showed highest intensity of Cr,N at 700 °C with peaks from (101), (110), (112) and (300). In addition to the intense peaks from Cr,N and Cr,T,N, there are small traces of Chromium oxide (Cr2O3) at 700 °C [4]. However, formation of Cr2O3 was expected at higher temperature annealing [2].

Conclusion

Results showed interesting structural evaluation and chemical characterization of Cr,T,Al,N coating with high precision. Powder diffraction Patterns of Cr,T,Al,N coating showed significant phase changes in the coating. Recrystallization of Cr,N and Cr,T,N phases, with preferential growth directions, were observed with excellent resolution using Synchrotron beamline compared to literature laboratory XRD results. Results from SEM in combination with EDS, for Cr,T,Al,N, provides an insight of the element distribution of the coating film.

References


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