Crystalline-to-amorphous structure transitions in TiNBN coatings during short-time oxidation

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Abstract

In this work, two types of magnetron sputtered TiNBN coatings with different Ti/Nb atomic ratios were studied using X-ray diffraction (XRD), scanning electron microscope (SEM), transmission electron microscope (TEM) and nano-indentation. Aided by the CALPHAD approach, the variations in chemical composition, microstructure and properties in the as-deposited and as-oxidized (at 500 °C up to 300 s) coatings were systematically analyzed to explore their composition-structure-property relationships.

Background

High temperature nitride coatings are widely used for surface protection of critical components in harsh environments because of their excellent mechanical properties, high melting point, high thermal stability and high temperature oxidation resistance.

Methodology

In this work, two types of magnetron sputtered TiNBN coatings with different Ti/Nb atomic ratios were studied using X-ray diffraction (XRD), scanning electron microscope (SEM), transmission electron microscope (TEM) and nano-indentation. Aided by the CALPHAD approach, the variations in chemical composition, microstructure and properties in the as-deposited and as-oxidized (at 500 °C up to 300 s) coatings were systematically analyzed to explore their composition-structure-property relationships.

Results

Microstructure and mechanical properties

The surface of TiN coatings is denser than that of TiN coating.

Conclusions

In this work, the variations in phase composition and structure of the Ti0.9Nb0.1N and Ti0.8Nb0.2N coatings prior to and after the short-time oxidation (at 500 °C up to 300 s) were systematically studied.

The crystalline-amorphous structure transitions are more obvious with a higher Nb/Ti atomic ratio.

The hardness of the TiNBN coatings increases with the precipitation of nanocrystals.

The formation of a mixed structure consisting of nanocrystals embedded in an amorphous matrix may be beneficial to the enhancement of coatings’ hardness.

Expectations

Future work will focus on the following two aspects:

1. Clarify the crystalline-amorphous evolution process of the short-time oxidized TiNBN coatings aided by CALPHAD approach.
2. Study the friction and wear properties of the nanocrystalline and fully amorphous TiNBN coatings.

Acknowledgments

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Table 1. Composition of coatings (at.%).

<table>
<thead>
<tr>
<th>Films</th>
<th>Ti</th>
<th>Nb</th>
<th>N</th>
</tr>
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<tbody>
<tr>
<td>Ti0.9Nb0.1N</td>
<td>17.89</td>
<td>15.73</td>
<td>66.38</td>
</tr>
<tr>
<td>Ti0.8Nb0.2N</td>
<td>38.05</td>
<td>8.92</td>
<td>53.03</td>
</tr>
</tbody>
</table>

Fig. 1. Applications of nitride coatings.

Fig. 2. Workflow chart.

Fig. 3. Surface and cross-sectional morphologies of Ti0.9Nb0.1N and Ti0.8Nb0.2N coatings.

Fig. 4. XRD patterns of the coatings in the as-deposited condition and after oxidation at 500 °C for 30, 120 and 300s.

(a) Ti0.9Nb0.1N and (b) Ti0.8Nb0.2N.

Fig. 5. Hardness of the as-deposited coating and the coatings oxidized at 500 °C for 120 and 300s.

(a) TIN (111) 0.25 nm 
(b) TIN (300) 0.22 nm

TiN (111) 0.25 nm

Fig. 5. Fast Fourier transform (FFT) derived diffraction patterns of Ti0.9Nb0.1N coating oxidized at 500°C for 120 s and high-resolution (HR) TEM image.