MECHANICAL AND TRIBOLOGICAL PROPERTIES OF TA-CNx FILMS PREPARED BY FILTERED ARC DEPOSITION

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ABSTRACT
Tetrahedral amorphous carbon nitride (Ta-CNx) films with different nitrogen contents have been deposited in a filtered cathodic vacuum arc system with a T-shaped magnetic filter. Hardness, Young’s modulus, thickness and roughness were studied to represent the mechanical properties. Ta-CNx film coated ball sliding against S55C disk in oil lubrication condition were performed. Friction coefficients and special wear rates of ta-CNx films were compared. Ta-CNx deposited by TFAD shows high hardness around 35.4 GPa, roughness around 14.8nm, thickness around 277nm in the wide range of nitrogen contents (0-0.12%). With the increasing of nitrogen content, both hardness and Young’s modulus decreased, special wear rate dramatically decreased.

Keywords: Ta-CNx, TFAD, friction coefficient, special wear rate.

INTRODUCTION
Carbon nitride (CNx) films have a great potential for various industrial applications owing to their high hardness, high wear resistance and low friction. Until now numbers of groups have attempted to synthesis CNx by various methods. CNx with a high fraction of sp$^3$, referred to as ta-CNx, have extreme properties as thin protective coatings which can approach those of diamond. Among all the methods, TFAD is effective with highly ionized plasma of energetic carbon ions (Polo, 2000). Previous studies have tried to analyze the properties of CNx from different perspectives: Fernández reviewed an exhaustive characterization by XPS, EELS, IR, XAS and NMR to study the microstructure (Fernández, 2003). Yamamoto demonstrated the relationship between tribological properties and sp$^3$/sp$^2$ structure of CNx (Yamamoto, 2012), and argued that the structural change of CNx could affect plastic/elastic properties which resulted in tribological change (Yamamoto, 2014). However, those studies mainly focused on the tribological properties of CNx deposited on Si substrate under air condition.

In this study, using different N$_2$/Ar flow rate, ta-C and ta-CNx films were deposited on SUJ2 ball substrates in a TFAD system which incorporates a T-shaped magnetic filter. The mechanical properties and tribological behavior in oil lubrication of ta-CNx were investigated.

RESULTS AND CONCLUSIONS
Table 1 list the nitrogen contents, hardness, Young’s modulus, thickness and roughness of the ta-C and ta-CNx. ta-CNx deposited by TFAD shows high hardness, low roughness. Hardness and Young’s modulus both decrease with the increase of nitrogen content. The friction
coefficient and wear rate of ta-CNx with different nitrogen content are shown in Fig. 1 and Fig. 2 respectively. It exhibits low friction and ultra-low wear in the PAO lubrication friction test. Friction coefficients have no obvious relationship with nitrogen content. However, as the nitrogen content increases, special wear rate has a tendency decreasing, which suggests higher wear resistance.

Table 1 - Mechanical properties of the ta-C and ta-CNx

<table>
<thead>
<tr>
<th>Film</th>
<th>Nitrogen partial pressure, Pa</th>
<th>Nitrogen content, at%</th>
<th>Hardness, GPa</th>
<th>Young's modulus, GPa</th>
<th>Thickness, nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>ta-C</td>
<td>0</td>
<td>0.0</td>
<td>45.0</td>
<td>986.0</td>
<td>220.2</td>
</tr>
<tr>
<td>ta-CNx</td>
<td>0.018</td>
<td>4.0</td>
<td>39.5</td>
<td>610.4</td>
<td>290.2</td>
</tr>
<tr>
<td>ta-CNx</td>
<td>0.035</td>
<td>5.9</td>
<td>31.1</td>
<td>429.2</td>
<td>286.8</td>
</tr>
<tr>
<td>ta-CNx</td>
<td>0.069</td>
<td>9.8</td>
<td>31.0</td>
<td>360.9</td>
<td>276.5</td>
</tr>
<tr>
<td>ta-CNx</td>
<td>0.098</td>
<td>13.1</td>
<td>-</td>
<td>-</td>
<td>238.6</td>
</tr>
<tr>
<td>ta-CNx</td>
<td>0.12</td>
<td>15.6</td>
<td>25.3</td>
<td>268.2</td>
<td>354.6</td>
</tr>
</tbody>
</table>

ta-CNx deposited by TFAD shows high hardness, low friction and high wear resistance. The results point out that the softer ta-CNx with higher resistance. One hypothesis may be the soft ta-CNx facilitates the smooth friction interface. Further tests of the morphology and structure change will be conducted. And friction tests with changing sliding speed will be performed to confirm if it is boundary lubrication.

REFERENCES