Tribological properties and thermal stability of TiAlCN coatings deposited by ICP-assisted sputtering

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Abstract: In this study, the tribological and thermal properties of TiAlCN coatings were investigated to evaluate their feasibility in automobile applications. TiAlCN coatings with carbon compositions between 25 and 65 at.% were prepared by inductively coupled plasma (ICP) assisted sputtering and were annealed at 400, 500, and 600 °C in air.

1. Introduction

In automobile or cutting tool applications in which flash temperatures can reach as high as 700 °C, it is essential that wear-resistant coatings maintain their improved tribological properties at elevated temperatures. Typically, hard coating materials are carbon-based or are binary metal nitrides, carbides, borides or oxides which are fabricated by physical or chemical vapor deposition (PVD or CVD) processes. With growing demands on higher tribological performance and thermal stability, successive studies are introducing additional elements to the binary compounds and are conducting more sophisticated processes to introduce new properties or to enhance the performance of existing coatings. TiAlCN coating is an example of a quaternary compound which originated from binary titanium nitride (TiN) coatings.

2. Results and discussion

The XRD results revealed no distinct crystal structures in TiAlCN coatings with a carbon composition > 53 at.%, however, the presence of TiAlN grains was confirmed by Raman spectroscopy and TEM diffraction results. The TiAlCN coatings with high carbon contents maintained hardness values > 15 GPa, even after high-temperature annealing, in contrast to the low hardness (< 10 GPa) of a typical DLC coating after a similar heat treatment. It was found that the TiAlN grains in the amorphous carbon phase are responsible for the high hardness of the TiAlCN coatings. The wear rates and friction coefficients of the TiAlCN coatings decreased with an increase in the annealing temperature, which was also not found in the DLC coatings. For the coating consisting 58 at.% C, the friction coefficient of 0.166 at room temperature dropped to 0.146 after it had been annealed at 600 °C. The Raman spectrum indicated that the sp^2 to sp^3 ratios in the amorphous carbon phase increased > 3.0 after annealing. The transformation of sp^3 to sp^2 bonds during the annealing process appeared to have supplied more lubrication between the counterparts, resulting in lower friction coefficients.

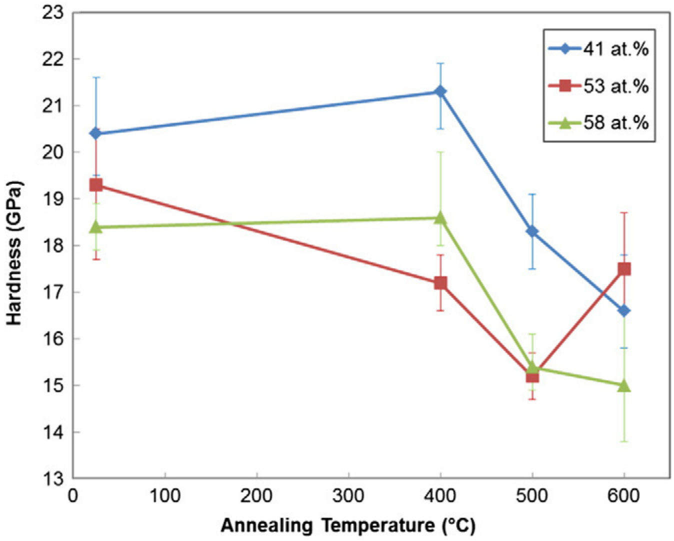

Fig. 1. Micro-hardness of amorphous TiAlCN coatings as a function of the annealing temperature.

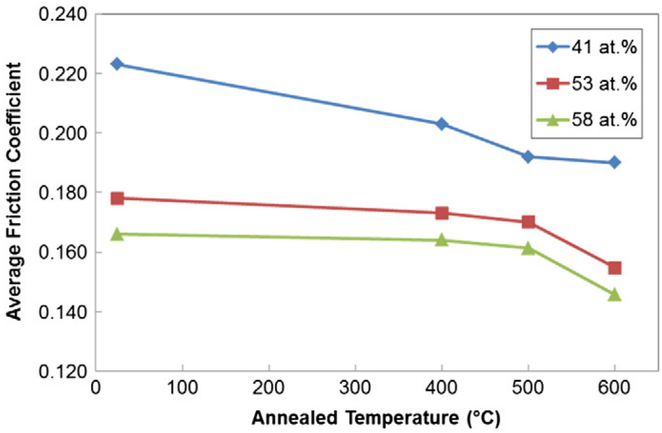

Fig. 2. Average friction coefficients of amorphous TiAlCN coatings as a function of the annleaing temperature.

3. Conclusions

The coating hardness decreased slightly after high-temperature annealing due to graphitization in the amorphous carbon phase, however, the friction coefficients and wear rates were reduced with the annealing temperature. The relatively high coating hardness (> 15 GPa) and low friction coefficient (0.146) of the TiAlCN coatings with thermal stability may present an alternative coating to the commercialized carbon- or nitride-based coatings for automobile parts.

References

[1] H. Ronkainen, in, 2001, pp. 2.52.
[2] J. Musil, Surf. Coat. Technol. 125 (2000) 322.
[3] H. Holleck, J. VAC, Sci. Technol. A. 4 (1986) 2661.
[4] N. Moolsradoo, S. Abe, S. Watanabe, Adv. Mater. Sci. Eng. 2011 (2011) 1.7.