Corrosion and Tribological properties of ta-C: Ta coatings

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ABSTRACT

Multilayer tetrahedral amorphous carbon/ tantalum-doped tetrahedral amorphous carbon (ta-C/ta-C: Ta) coatings with varying total thicknesses (300, 600, and 1000 nm) and layer thickness ratios (1:0.5, 1:1, and 1:2) between the ta-C layer and ta-C: Ta layer were prepared. The study investigated the static corrosion resistance and tribological properties of the coatings in the NaCl solution. The static corrosion resistance positive correlation depended on the coating surface's Ta-O/Ta-C ratio. The lowest wear rate of 7×10^{-8} mm^3/Nm was obtained from the coating with a total thickness of 300 nm due to the highest corrosion resistance of the wear scar. A decreased sp^2/sp^3 ratio and the formation of tantalum oxide on the wear scar contributed to the lowest corrosion current, corrosive defect density, and wear rate.

Keywords: tantalum doped, multilayer, corrosion resistance, corrosive wear.

INTRODUCTION

Humanity transition to environmentally friendly power sources, such as batteries, hydrogen, ammonia, and biodiesel, for automotive propulsion in the future [1]. While cost-effective ammonia is expected to be a promising power source due to concerns about the depletion of precious metals in batteries, there are worries about potential corrosion when utilized in internal combustion engines. The corrosive response can generate pinholes or cracks on the surface, decreasing the wear resistance of the component surfaces. Diamond-like carbon (DLC) coating is a promising protective material used in engines because it garnered attention for its mechanical properties (high hardness and low friction coefficient). However, research on DLC coatings, which possess high hardness, low friction, and high corrosion resistance, is still in the early stages. ta-C type [2] is one of the keys to achieving high hardness via a high amount of sp^3, even if the coating includes some metal atoms. Tantalum (Ta) is considered a highly corrosion-resistant element. Therefore, our research group worked on developing a new Ta-containing coating [3]. The multilayer design of tantalum-doped carbon coatings determines their corrosion resistance and tribological properties.

In this paper, we conducted fundamental static corrosion and tribological tests in NaCl solution on multilayer ta-C/ta-C: Ta coating with various total thicknesses and layer thickness ratios. We investigated the effect of surface chemical bonding on the corrosion properties, the impact of NaCl solution and structural graphitization transformation on the friction properties, and the synergistic effect of carbon structure and tantalum oxide formation contributing to the corrosive wear resistance.

RESULTS AND CONCLUSIONS

The static corrosion resistance of ta-C/ta-C: Ta coatings with various total thicknesses and layer thickness ratios were analyzed using the potentiodynamic polarization test. A lower Log i acts with a higher corrosion resistance. Specifically, for the ta-C coating, the high content of the C-C sp^3 bond suppresses the diffusion of corrosion media to the substrate. However, as shown in Fig. 1(a), no positive correlation between the sp^2/sp^3 ratio and Log i. Thus, it is essential to consider the effect of tantalum on corrosion resistance. The oxide film acts as an intense barrier action against the penetration of corrosive ions. A higher oxide peak area ratio (from the XPS deconvoluted spectra) corresponds to a denser oxide film formed on the surface. As shown in Fig. 1(a), the ratio of

Ta-O/Ta-C exhibits a negative correlation to Log i. The highest Ta-O/Ta-C value corresponds to the lowest corrosion current (Log i), indicating the highest corrosion resistance. For the wear properties of the coatings, the interaction of corrosion also plays a role in the wear of the coatings. The relationship between corrosive defect density and wear rate is illustrated in Fig.1(b). The corrosive defect density of the wear scar shows a positive correlation to the wear rate, indicating that the wear rate depends on the interaction of corrosion. The coating with a total thickness of 300 nm exhibits the lowest corrosive defect density, corresponding to the lowest wear rate in the NaCl solution. To analyze the mechanism of the corrosive defect, as shown in Fig.1(c), Log i of the wear scar shows a clear positive correlation with the corrosive defect density, indicating that the corrosion resistance of the wear scar is positively correlated with the corrosive defect density. Besides, Fig.1(d) illustrates that the Ta-O/Ta-C ratio negatively correlates with Log i. The wear scar on the coating with a total thickness of 300 nm, which has the highest Ta-O/Ta-C ratio, corresponds to the lowest Log i, resulting in the lowest corrosive defect density.

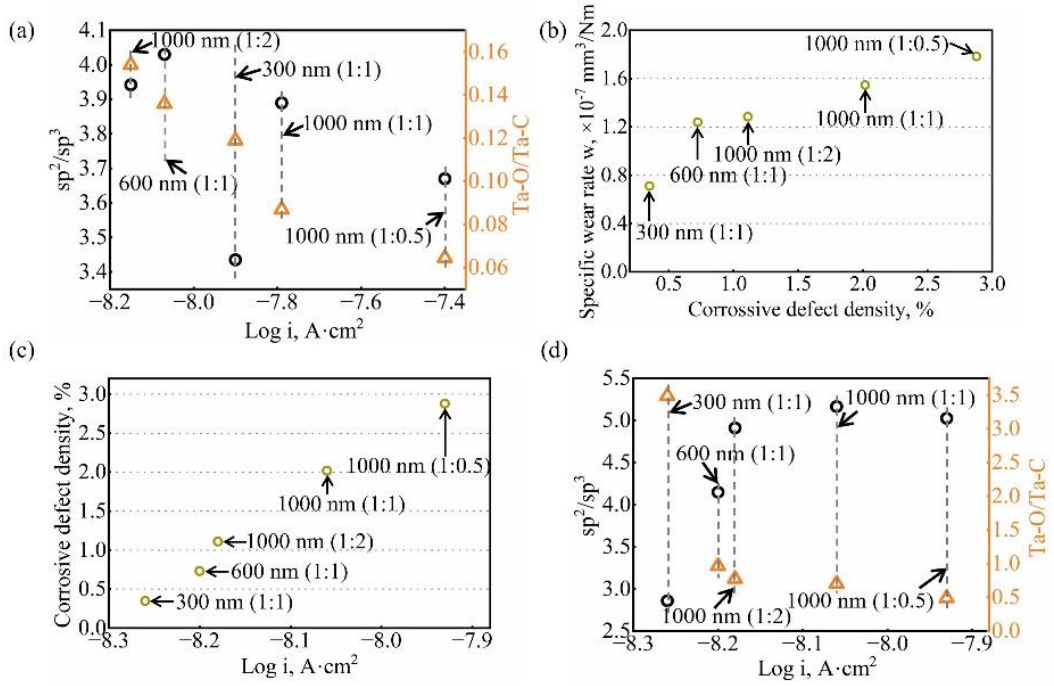

Fig. 1 (a) Surface chemical bond of as-deposited coatings, (b) Relationship of sp2/sp3 of wear scar and friction coefficient, (c) Relationship of corrosive defect density and wear rate, (d) Relationship of Log i and corrosive defect density.

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