Applied Surface Science 464 (2019) 88–98

Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

Full Length Article

Microstructure and tribological properties of plasma sprayed TiCN-Mo based composite coatings

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ARTICLE INFO

Keywords:
Reactive plasma spraying
TiCN
Ceramic coatings
Microstructures
Tribological properties

ABSTRACT

In the present work, TiCN-Mo composite coatings were fabricated by using reactive plasma spraying with the mixture of Ti-graphite aggregates and metal Mo powders under N_2 condition. Results showed that metal Mo strips homogeneously dispersed in lamellar TiCN matrix to generate nearly alternate ceramic-metal composite coatings. Good interface bond were achieved between metal Mo strips and ceramic matrix due to the formation of rim structure. The Mo addition slightly decreased hardness of composite coatings. The hardness distribution uniformity of composite coatings also decreased as Mo content increased (> 10 wt.%). TiCN-Mo composite coatings showed higher friction coefficient than coatings without Mo. TiCN-Mo composite coatings showed improved wear resistance with lower wear rate. Under present sliding wear condition, worn surfaces of TiCN based coatings were covered by thick iron and titanium oxide layer and wear debris contained large amount of oxides, indicating severe adhesive wear accompanied with oxidative wear.

1. Introduction

TiCN based cerment are reported to possess favorable properties including superior chemical stability, high hardness, excellent resistance to wear and good toughness [1–3]. These make TiCN a promising hard protective coating for metal surfaces [4,5]. However, due to the intrinsic brittleness, TiCN cerments are still vulnerable to degeneration under severe conditions required wear resistance [6,7]. Recent studies reveal that the addition of metallic binders (Ni, Co, Fe, Mo, Ni–Co and Ni–Mo) and carbides contributes to the improvement of mechanical properties and wear performance of TiC and TiCN cermets [8–12]. These provide a route to prepare TiCN-metal composite coatings with enhanced toughness and strength.

The addition of transition metal binders into cerments could bring two advantages. As a binder, the wetting behavior of transition metals is favor to improve the bonding strength of cerments. Furthermore, transition metals usually have ductile nature and some strength, which provide toughness for cerments. However, the strength and wear resistance of cerment-metal composites are mainly contributed by the hard cerment phase [13]. Various kinds of metal binders lead to different mechanical properties of cerments [14]. Fe-based alloy binders have low cost but inferior corrosion resistance [2]. Metal Co binder is most often used in WC based cerments, resulting in good mechanical properties. But the Co addition has high cost [15]. As for Ni binder, it shows poor wettability with TiC or TiCN grains, thus resulting in high porosity and low mechanical properties. In addition, the hardness and strength of TiC cerment with Ni binder is lower than that with Co binder. Thus, it is necessary to explore proper metal binders for cerments according to practical requirements.

Several researches [16–19] have found that the introducing of Mo or Mo_2C can not only improve the wettability between metallic binder and ceramic phase, but also refine the TiC or TiCN grains, thus leading to full densification and improved fracture toughness and strength of transverse rupture for cerments. However, the excess addition of Mo is reported to decrease the hardness because of the formation of (Ti, Mo)(CN) when the content exceeds 10 wt.% [16,20]. Thus, the particle size and volume fraction of the Mo addition need to be considered.

The fabrication of bulk cerment-metal composites also gives insight to prepare cerment-metal composite coatings. Metal Mo is reported to increase the scuffing resistance to abrasive wear and decrease the

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https://doi.org/10.1016/j.apsusc.2018.09.063
Received 7 April 2018; Received in revised form 6 July 2018; Accepted 7 September 2018
Available online 08 September 2018

friction coefficient during sliding wear. Thus, Mo could be a proper addition to improve mechanical properties for coatings [21–23]. In this study, metal Mo was adopted for producing TiCN-Mo composite coatings.

TiCN coatings can be produced by using several techniques including magnetron sputtering [24,25], arc ion deposition [26,27] and chemical vapor deposition. Nevertheless, these methods usually produce thin TiCN films. Owing to the simple deposition condition, high deposition rate and enhanced cohesion strength, reactive plasma spraying (RPS) is most suitable to produce thick TiCN based coatings with high performance [28,29]. In our previous study, nanostructured TiCN coatings ($TiC_{0.2}N_{0.8}$) are successfully fabricated by using RPS with Ti feedstock under the mixed gas condition (N_2-C_2H_2) [30]. Recently, nanostructured TiCN coatings with high C content phase ($TiC_{0.7}N_{0.3}$) are also obtained by using RPS technique with Ti-graphite aggregates under N_2 condition [31,32]. It is reported that the addition of Cr is lead to enhancing the mechanical properties of plasma sprayed TiCN coatings [33]. Since Mo shows better wettability and strength than Cr, the addition of Mo in plasma sprayed TiCN coatings is expected to have enhanced mechanical properties.

In this work, Ti-graphite aggregates are used for fabricating TiCN coatings by using RPS technique. Metal Mo powders are mixed with Ti-graphite aggregates to produce TiCN-Mo composite coatings. The microstructures and tribological properties of composite coatings with different Mo additions are investigated.

2. Experimental details

2.1. Raw materials and process for coatings

As-received powders are commercial Ti powder (30–45 μm, Fig. 1a), graphite powder (5 μm, Fig. 1b) and Mo powder (30–45 μm, Fig. 1c). Firstly, Ti and graphite powders were added into deionized water with the ratio of 4:1, then mixed by using electro motion blender to get the slurry. Polyvinyl alcohol and carboxymethylcellulose sodium were introduced into slurry as dispersing agent and binder, respectively. Then, the spray drying method was employed to the mixed slurry to obtain Ti-graphite aggregates with spherical feature (Fig. 1d). Secondly, Mo powders with different weight fraction (10 wt.%, 20 wt.% and 30 wt.%) were mixed with Ti-graphite powders by using ball milling. Finally, the homogeneous (Ti-graphite) + Mo feedstock was obtained by milling process with Al_2O_3 balls (4 mm in diameter) for 24 h.

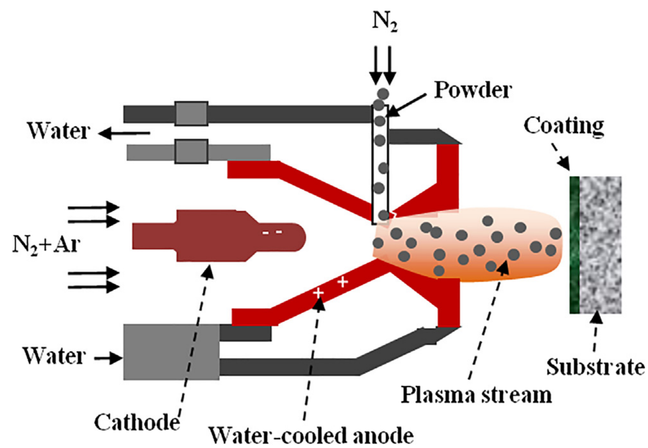

Fig. 2. The illustration of the work process for reactive plasma spraying (RPS).

The work process for reactive plasma spraying was illustrated in Fig. 2. The substrate materials are mild steels (10 mm × 10 mm × 10 mm), which were degreased by using grit blasting treatments before spraying. A Ni-10 wt.% Al bond coating (~100 μm thickness) was deposited onto the surface of steel substrates. The spraying process was conducted by using the GP-80B spray equipment. The reactive spraying system comprised a reactive gas tunnel and plasma-spray torch (BT-G3). The (Ti-graphite) + Mo feedstock were introduced into plasma jet and reacted with N_2 in gas tunnel. Table 1 summarized the detailed processing parameters.

2.2. Characterization

X-ray diffraction (Rigaku D/max 2500, Japan) with Cu-Kα radiation (λ = 0.15406 nm) was used to examine the phase structure of feedstock and as-obtained coatings. X-ray photoelectron spectroscopy (XPS, PHI 5700 ESCA System) was employed to analyze the chemical bond of TiCN-Mo coatings. Scanning electron microscopy (SEM, JSM-7100F, JEOL Ltd.) with the energy dispersive X-ray spectrometer (EDS) was

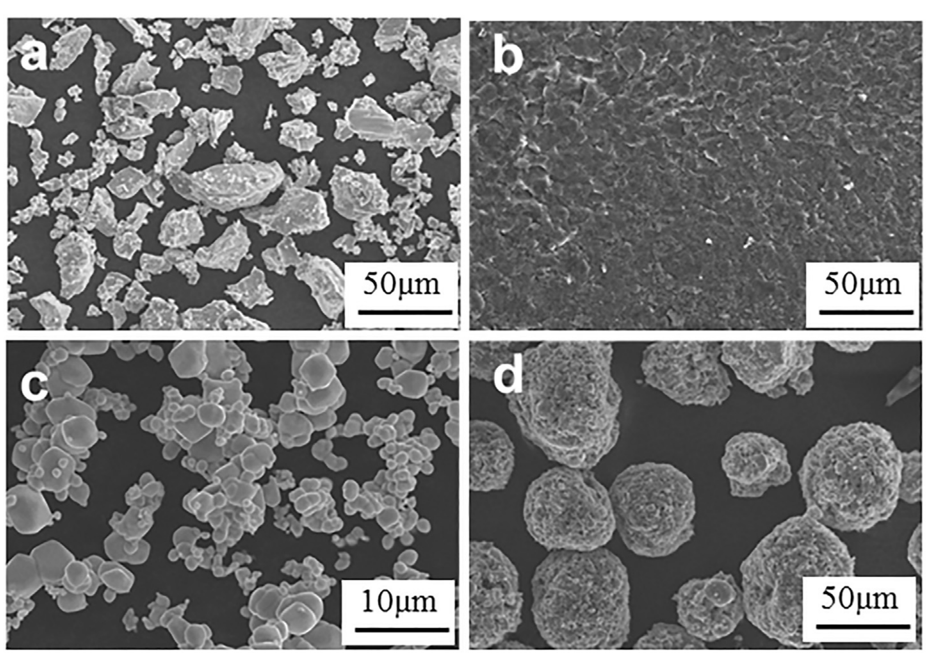

Fig. 1. SEM observations of (a) Ti powders, (b) graphite powders (c) Mo powders and (d) Ti-graphite aggregates.