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Microstructures and mechanical properties of Ti−Cr−N/Al−Ti−Cr based coatings prepared by plasma nitriding 5083 Al alloys co-deposited with Ti−Cr films

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ABSTRACT

A duplex treatment involving sputtering Ti−Cr film followed with plasma nitriding was employed to in-situ fabricate multilayer coatings on the surface of 5083 Al alloys. Ti−Cr films with different Cr addition were firstly sputtered on 5083 Al alloys by using magnetron sputtering, then nitrided at 460 °C under the N_2−H_2 gas condition. Results showed that the as-obtained coatings were composed of the outside (Ti, Cr)$N_{0.3}$ or (Ti,Cr)N layer and the inside Al_{18}(Ti,Cr)$_2$$Mg_3$ layer. With increasing Cr content in the Ti−Cr film, (Ti,Cr)N phase was inclined to form in the outside layer and the Al_{18}(Ti,Cr)$_2$$Mg_3$ layer increased the thickness. Meanwhile, the surface hardness of multilayer coatings was enhanced and reached the maximum value of ~1020 HV. Specimens with outside (Ti,Cr)N layer showed better wear resistance than specimens with outside (Ti,Cr)$N_{0.3}$ layer. The nitrided specimens exhibited mainly adhesive wear and abrasive wear accompanied with oxidation wear.

1. Introduction

Transition metal nitride coatings, such as TiN, CrN, TiAlN and TiCrN have been widely studied because of their high hardness, wear resistance and thermal stability [1–4]. However, these hard ceramics usually show brittle nature and large elastic properties mismatch with the substrates. As for single-layer ceramic coatings, cracks often generate from the surface and spread beneath the interface throughout the coatings, thus leading to the breakage of ceramic layer [5,6]. Various studies prove that multilayer architecture is the best approach to improve the fracture resistance of coatings in contrast to single-layer coatings [7–10]. The multilayer structure could act as a crack inhibitor, thus improve the tribological properties of coatings.

In recent studies, multilayer structure has drawn increasing attention in preparation of hard nitride coatings. Various kinds of ceramic/metal and ceramic/ceramic multilayer coatings including TiN/Ti, TiN/TiCN, TiAlN/CrN, CrN/MoN, CrN/DLC,etc. have been intensively studied [1,7,11–14]. The Ti layer has lower hardness than ceramics and could be identified as a solid lubricant during wear, leading to the reduced coefficient of friction [15]. In addition, the ceramic/ceramic multilayer coatings are often designed as superlattice structure, resulting in the super high harness of multilayer coatings. Furthermore, the ternary nitride coating such as TiCrN(40 GPa), TiAlN(25–35 GPa), CrTiN(16 GPa), TiZrN (23–29 GPa) and CrAlN(~17 GPa) are reported to show enhanced mechanical properties [16–19]. Especially, TiCrN attracts more attention due to high hardness and low friction coefficient (0.3) [4]. Thus, the mechanical properties of ceramic coatings could be further tailored by combination of multicomponent and multilayer architecture design.

Actually, these hard nitride coatings are usually deposited on the steel substrates by using magnetron sputtering. The coatings show ultrahigh hardness but have thin thickness of several microns. In addition, the coating/substrate interface remains mechanical bonding. The nitride based multilayer coatings might be not appropriate to deposited on the soft Al alloy substrates with ceramic interlayers. Actually, the soft Al alloy surfaces could be also strengthened by hard coatings by using plasma nitriding, physical chemical deposition, plasma electrolytic oxidation, ion implantation and so on [20–23]. However, these methods usually produce single ceramic coatings. Thus, it is necessary to explore a proper transition layer for the ceramic coating and the substrate. As reported in the previous studies [24–26], the nitride/aluminide multilayer structures were prepared by plasma nitriding pure

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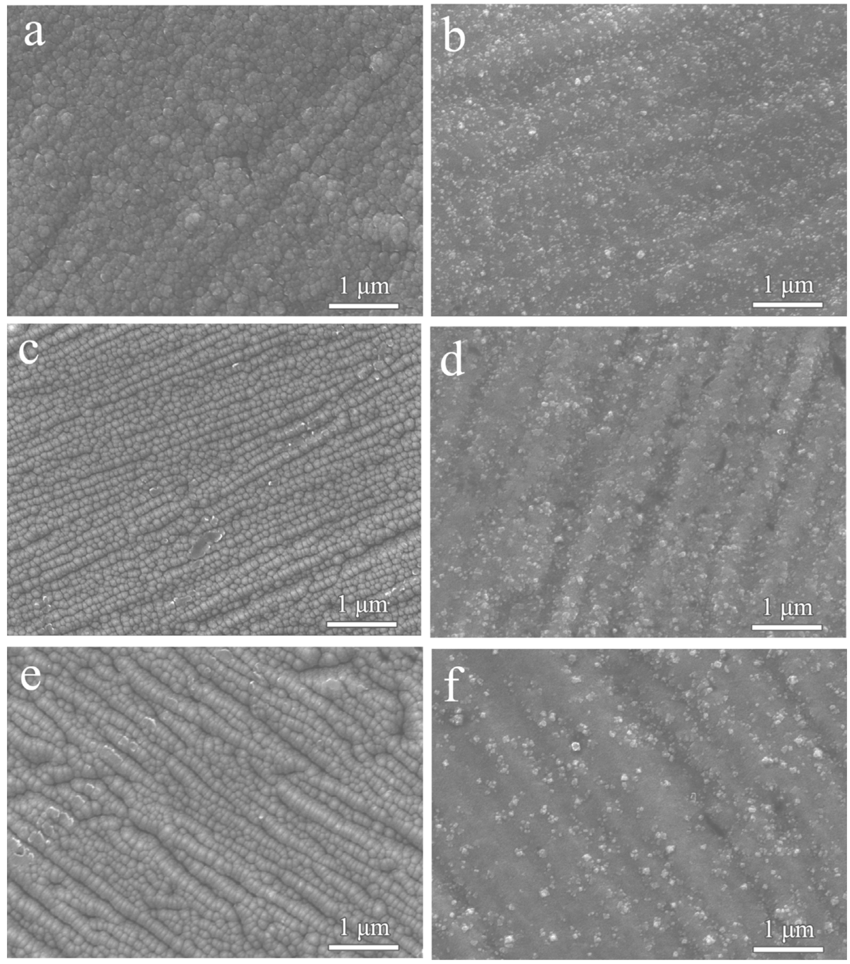

Fig. 1. SEM images of surface for 5083 Al alloys coated with Ti–Cr films before and after nitrided at 460 °C for 8 h: (a) D1 film, (b) D2 film, (c) D3 film, (d) P1 coating, (e) P2 coating and(d) P3 coating.

Table 1
The EDS results on the surfaces of Ti–Cr alloy films and the nitrided coatings.

Sample	Ti (At. %)	Cr (At. %)	Al (At. %)	N (At. %)	Fe (At. %)
D1 film	87.27	10.27	2.56	–	–
D2 film	72.49	25.56	1.95	–	–
D3 film	59.48	39.74	0.78	–	–
P1 coating	73.28	8.63	–	16.58	1.51
P2 coating	39.73	16.43	–	42.13	1.71
P3 coating	27.20	20.77	–	49.83	2.19

Ti coated Al alloys. $TiN_{0.30}$ layer with nano grains and aluminide layer were in-situ fabricated due to the thermo-diffusion during plasma nitriding. Especially, the Ti–Al diffusion led to metallurgical bonding between the coating and substrate.

The ternary metal nitride TiCrN shows better mechanical properties than binary TiN or CrN, which is usually deposited by magnetron sputtering. In this study, different Ti–Cr alloy films were firstly deposited on 5083 Al alloy substrates. Then, plasma nitriding were conducted on the Ti–Cr coated 5083 Al alloys to simultaneously fabricate the Ti–Cr–N/Al–Ti–Cr based intermetallic layers. Microstructures and

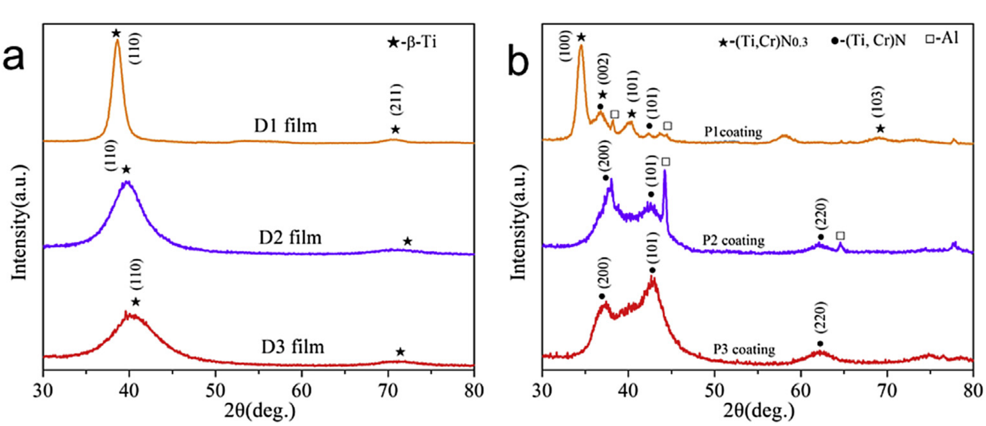

Fig. 2. XRD spectrums of 5083 Al alloys coated with Ti–Cr films: (a) before nitriding and (b) after plasma nitrided at 460 °C for 8 h.