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Friction and Wear Studies of Uncoated and TiZrN Coated Brass Substrates

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Abstract

Objectives: Investigation of enhancement in tribological properties of TiZrN coated brass substrate. **Methods/Statistical Analysis**: The magnetron sputtering was used to develop TiZrN coating on brass substrate by varying titanium (Ti) target power. X-ray diffraction (XRD) and Scanning Electron Microscopy (SEM) was used to do structural characterization of TiZrN coatings. Tribological properties of TiZrN coatings such as friction and wear were investigated by a pin on disc tribometer. **Findings**: The evolution of well intense (200) and (311) peaks of TiZrN coatings was observed with rise in power of titanium target. Increase of titanium power has a negligible effect on average crystallite size of TiZrN coatings and average crystallite size is around 4-5nm. TiZrN coatings are uniform, smooth and crack free as observed from SEM images for all samples. Tribological properties of TiZrN coatings were examined with testing parameters such as load and sliding distance. **Application/Improvements:** This coating may be useful for applications where low friction and wear is required such as gears, bearings, and electrical applications.

Keywords: Friction, Sputtering, TiZrN, Tribology, Wear

1. Introduction

Modern developments in coating technologies now make possible the deposition of coating with enhanced tribological properties, which were not possible a decade ago. These modern deposition methods motivates the people to use different materials with improved surface properties[1]. There are several reports about the effects of metal ion implantation on the wear, friction and microstructure of TiN coatings with many implanted ions such as Zr, W, Ti, Al[2–4]. However, similarly to titanium, its tribological properties might limit its application. For this cause, several studies have been performed to develop wear-resistant zirconium and titanium-based alloys[5]. It was found that researchers attracted towards use of ZrN coatings for cryogenic thermometers, hard coatings, decorative film, diffusion barrier, improved mechanical properties, better wear, corrosion resistance and attractive golden colour as compared to TiN films. During drilling test Zirconium Nitride deposited tools have good performance over Titanium Nitride coated tools[6]. The characterization of samples was done by scanning electron microscope and X-ray diffraction method[7,8].

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ZrN is a natural choice because it is closely related to TiN and it has a high hardness at high temperatures[9]. Since last decade, modern deposition technics make possible to develop hard coating materials with enhanced properties for the various industrial appliances. We found only a few work on multicomponent coatings have been carried out[10]. So the objective of this research work is to develop multicomponent coatings of titanium zirconium nitride (TiZrN). In this paper, we have deposited TiZrN coatings using reactive magnetron sputtering technique. The effect of titanium (Ti) target power variation on structure, surface morphology and tribological properties of TiZrN coatings are investigated.

2. Experimental Details

Ternary Titanium Zirconium Nitride (TiZrN) coatings were sputter deposited in a cylindrical chamber manufactured by Excel Instruments, Mumbai. Titanium (Ti) and zirconium (Zr) targets (99.99% purity, 50.8mm × 6.5mm) were used for the sputtering process. The chamber was initially evacuated to around 5 $x10^{-4}$ Pa using a turbo molecular pump backed by a rotary pump. Thereafter Ar and N_2 gas of high purity (99.99%) were injected into the chamber. The flow of gases was kept constant and controlled by Mass Flow controller (MFC), (ALICAT instruments, USA). The flow rate of argon and nitrogen were kept constant at 32 sccm and 8 sccm respectively whereas sputtering pressure was set at 1.5Pa for all cases. The substrates were kept at a temperature of 500°C, deposition time was 60minutes and target to substrate distance was kept constant at 50mm for all depositions. The constant Zr target power was maintained at 275W whereas the power of Ti target was varied from 275W, 350W, 400W, and 450W. The corresponding sample names deposited at these Ti target power variations are indicated as 275W, 350W, 400W and 450W accordingly.

D2 Phaser/X-ray Diffraction was used to examine the structure characterization of TiZrN coatings. To study the shape & structure of coating, Scanning Electron microscope (EVO-18, Make: ZEISS) was used. Pin on disc (Ducom) tribometer with pins of 12mm diameter and 30mm in height and disc with a diameter of 165mm and height of 8mm was used for measuring wear and friction. The material used in the contact pair was uncoated and TiZrN coated brass pins and discs made of En-31steel (hardened to 60HRc). The normal load applied were 10N, 20N, 30N and 40N and sliding distance values were 625m, 707m, and 785m.

3. Results and Discussion

Shows Figure 1 X-ray diffraction graphs of Titanium Zirconium Nitride coatings deposited at various titanium target power of 275W, 350W, 400W, and 450W. It is observed from XRD graphs that deposited TiZrN coatings exhibit cubic TiZrN phase with preferred (200) orientation for all samples. The intensity of (200) orientation rises with an increase in Ti target power from 275W to 450W. Chinsakolthanakorn et al. observed XRD pattern change with increase Ti target power. The consider orientation change from (111) to (200) is due to the highly-energetic ion bombardment. Moreover, the peaks intensity increases with an increase in titanium target deposition current[11].

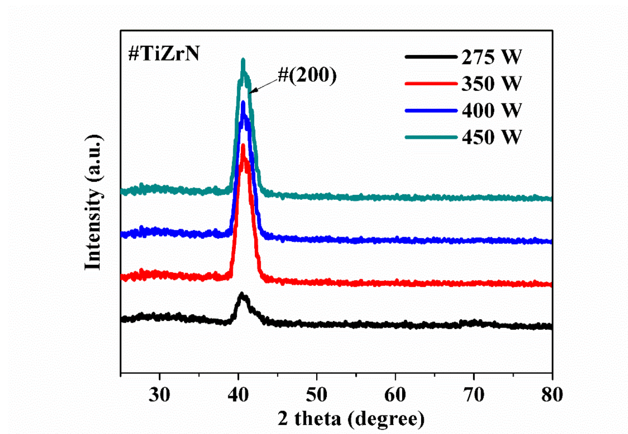

Figure 1. XRD patterns of TiZrN coatings deposited at different Titanium (Ti) power.

Park et al. have reported magnetron sputtered film, the pattern variations from (111) to (200) with an increase in bias voltage[12]. Wang et al. observed that TiZrN (111) and (200) peaks decreased as bias voltages were varried from -55 to -105V. The TiZrN lattice turns distorted at a high bias voltage. Peak broadening at higher bias voltages was evident resulting from an increase in residual stresses of TiZrN[13]. We were able to develop TiZrN coatings with preferred single (200) orientation even at low target titanium power of 275W.

The average crystallite size (d) of TiZrN coatings as calculated by Scherrer formula is represented in Figure 2. It was observed that increase of Ti power has a negligible effect on average crystallite size of TiZrN coatings and average crystallite size is around ~4-5nm.

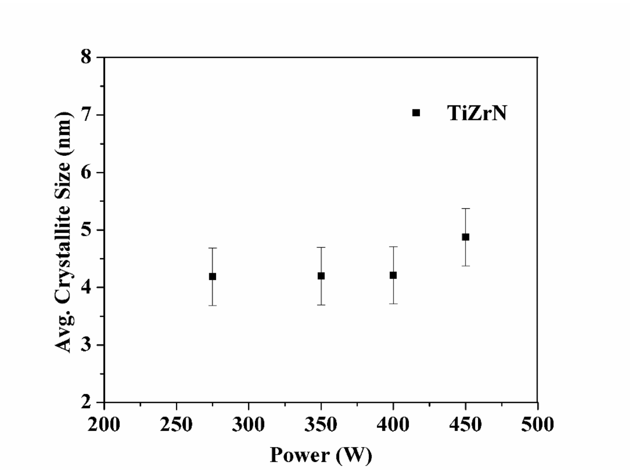

Figure 2. Average crystallite size of TiZrN coatings deposited at different Titanium (Ti) power.

The morphology of TiZrN coatings deposited at various Ti target power is shown in Figure 3. TiZrN coatings are uniform, smooth, crack free and have almost same average crystallite size as observed from SEM images for all samples. In many research work it is concluded that as the Ti columnar width changes proportionally as the target power increases, and which leads to higher grain size[11]. Grimberg et.al. Studied microstructure of (Ti,Zr)N coating deposited at a nitrogen pressure of 0.67 and 1.33Pa. The coating substrate interface is smooth and without noticeable microcracks[14].

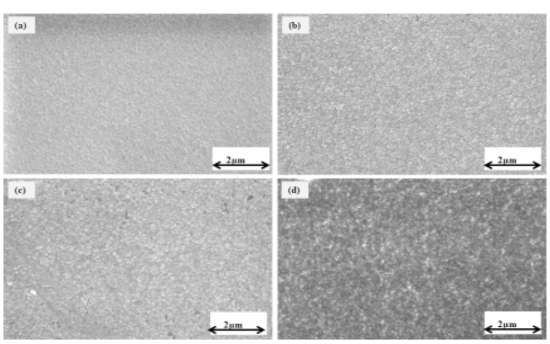

Figure 3. SEM images of TiZrN coatings deposited at different Titanium (Ti) power of: (a) 275W (b) 350W (c) 400W and (d) 450W.

Figure 4(a) and 4(b) shows the effect of load and sliding distance on wear rate of uncoated and TiZrN coated brass pins deposited at different Ti power of 350W and 450W. It is clearly seen that wear rate of the uncoated brass pin is higher than that of TiZrN coated brass pin. The wear rate of uncoated and TiZrN coated brass pins deposited at different Ti power of 350W and 450W are in the range of 2.5×10^{-3} to 5.87×10^{-3} mm^3/Nm depending on load and sliding distance. As shown in Figure 4(a), when load is increased from 10N to 40N, the wear rate of uncoated brass pin increases from 3.51×10^{-3} to 5.87×10^{-3} mm^3/Nm, for TiZrN coated brass pins deposited at Ti power of 450W coating it increases from 2.74×10^{-3} to 5.38×10^{-3} mm^3/Nm and for TiZrN coated brass pins deposited at Ti power of 350W coating it increases from 2.5×10^{-3} to 5.23×10^{-3} mm^3/Nm. As shown in Figure 4(b) with increase of sliding distance, the wear rate of uncoated brass pin increases from 3.51×10^{-3} to 1.19×10^{-2} mm^3/Nm, TiZrN coated brass pin at Ti power of 450W increases from 2.74×10^{-3} to 8.81×10^{-3} mm^3/Nm and of TiZrN coated brass pin at Ti power of 350W increases from 2.5×10^{-3} to 8.8×10^{-3} mm^3/Nm. It is reported that TiN and ZrN have almost identical microhardness whereas ZrTiN films have the highest microhardness[10]. Jianxin et al. observed that ZrN coatings, coefficient of friction was depended on load and sliding distance[1].

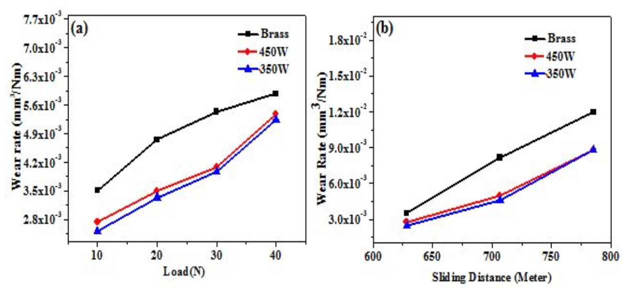

Figure 4. Wear rate for uncoated and TiZrN coated brass pins deposited at different Ti power of 350W and 450W at different values of (a) load and (b) sliding distance.

Figure 5(a) and Figure 5(b) shows the consequence of load and sliding distance on the coefficient of friction(COF) of uncoated and TiZrN coated brass pins prepared at different Ti power of 350W and 450W. From Figure 5(a) it is observed that the coefficients of friction decrease generally with increase in load. The coefficients of friction for uncoated brass decreased from 0.287 to 0.22 with increased load from 10 to 40N.

As for TiZrN coated brass pins prepared at various Ti power of 350W and 450W the coefficients of friction decreased linearly from approximately 0.215 to 0.169 with increase in load. Figure 5(b) shows a variation of friction coefficient with sliding distance under a load of 10N. The curves show coefficients of friction for uncoated brass, TiZrN coatings deposited at Ti power of 350W and 450W increases with increase in sliding distance. The coefficients of friction for uncoated brass pin increases from 0.287 to 0.321 with an increase in sliding distance. As for TiZrN coatings deposited at Ti power of 350W and 450W friction coefficient increases linearly from approximately 0.215 to 0.278 with increase in sliding distance. It is observed that friction coefficients of TiZrN coating are lower than that of uncoated brass after run-in period. Deng et al. Observed ZrN coatings, friction coefficient was also depended on load and sliding distance[1].

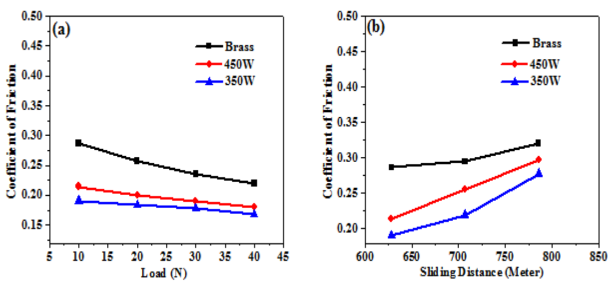

Figure 5. Coefficient Of Friction (COF) for uncoated and TiZrN coated brass pins deposited at different Ti power of 350W and 450W at different values of (a) load and (b) sliding distance.

4. Conclusion

Ternary TiZrN coatings were effectively sputter deposited on brass substrates. It was found that coefficient of friction and wear rate were clearly related to Ti power, load, and sliding distance. TiZrN coating shows a friction coefficient of 0.169 to 0.278 at room temperature, depending on load and sliding distance. The wear rate of uncoated brass is larger than those of TiZrN coatings. The wear rate of TiZrN coating and brass are located in the range of 2.5×10^{-3} to 1.19×10^{-2} mm^3/Nm, depending on load and sliding distance. The wear rate of coated brass is improved due to TiZrN coatings high hardness.

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