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Study of Wear & Corrosion Resistance of Cr Based Nitride and Carbide Thin Films

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ABSTRACT

Present work focus on developing various combinations of Chromium based nitride and Carbide thin films. These films deposited in the form of monolayer and nano-structured Bilayers thin film using advance cathodic arc process to produce coatings that have flexibility to modify the surface properties as per the need of application. Coatings produced exhibit a smooth surface suitable for most industrial applications such as Protective, cutting tools, Antireflective or decorative coating. Coatings on industrial equipment such as drills bits, fasteners, stampings and other parts and pieces that would go into heavy-duty applications. The monolayer/nano-structured Bilayer coatings of CrN, CrC and CrN/CrC is deposited. Coatings were deposited by varying coating parameters to obtain specific mechanical properties such as very high corrosion resistance, wear coefficient, toughness & hardness etc. this coating is use to coat on milling tools, round shank tools, trim tooling, plastic molds, punches and brazed carbide tooling. The Detailed investigation of this coating is by Adhesion Test, Wear Measurement and corrosion resistance measurement by potentiostat.

Keywords: cathodic arc process, monolayer, nano-structured Bilayer coatings.

INTRODUCTION

In metals, there is actual material loss either by dissolution (corrosion) or by the formation of nonmetallic scale or film (oxidation). Corrosion problem play a vital role in global economic, a huge percentage of an industrialized nation's income is spent on corrosion prevention and the maintenance or replacement of products lost or contaminated.

Stainless steels are highly resistant to corrosion it contain atleast 11% of chromium, which minimizes the formation of rust. Stainless steel are also susceptible to corrosion in some aggressive & corrosive environments and therefore type of environment may strongly reduce their mechanical and tribological properties. To prevent corrosion, a protective layer is coated on the surface of the metal that constantly comes in contact with moisture and oxygen in the atmosphere.

Few study shows hard coating–substrate systems also suffer a severe corrosion attack due to the defects in the coating structure (pores, pinholes) resulting from the PVD-typical film morphology [1,2] while our earlier study shows Hard and Hard layer combination shows improved tribological and morphology properties as compare to Hard and Soft layer combination.[3] C Liu,A Leyland et.al. were investigated in comparison with the columnar structure of TiN coatings, the dense structure with fine equiaxed crystallites made CrN coatings less permeable to the corrosive medium. Corrosion resistance improvement is not only attributed to the increase in thickness, but also to the internal microstructure and phase composition. [4] Douglas E. Wolfe, Brian M. Gabriel et.al. were investigated the erosion resistance of the (Ti,Cr)N coating the higher Cr content, lowest number of nanolayers and interfacial size had the best erosion performance.[5] In several industrial applications such as milling and forming processes coatings are required to have high hardness and elasticity, high oxidation resistance, which enables such coatings to be employed even under higher temperatures [6]. Meng-Tsun Lin et.al. results showed that the TiN/ZrN coating with a nano-composite structure improved the corrosion resistance about 243 and six times, respectively, as compared with uncoated Ti and SS304 in the O2-rich environment with F-ions and acid. [7] Hermann A. Jehn and Manfred E. Baumgartner studied Corrosion behavior hard coating with substrate systems. Their experimental result reflect the electrochemical properties of the coating and the influence of the underlying substrate when micropores, pinholes and other defects are present. [8].

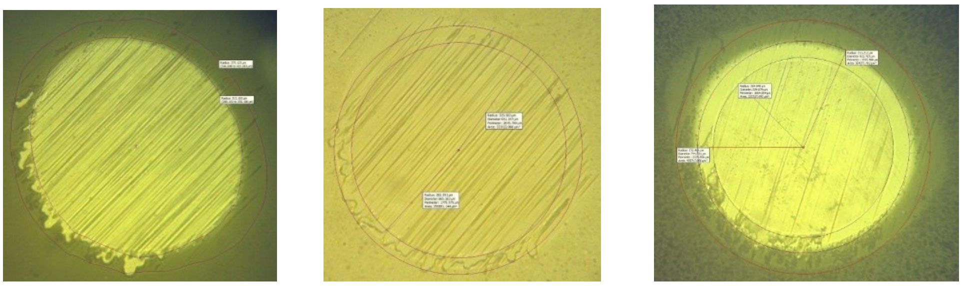
Only limited studies exist on the corrosion behaviour of hard coating substrate systems. Therefore our main aim is to investigate the tribological behaviours of coatings with focus on their corrosion and wear mechanism. This paper attempts to improve the corrosion resistance by interlayers and multilayered coating structures.

METHODOLOGY

Coatings were deposited on mirror polished HSS or soft SS 304 coupons with diameter 22 mm and thickness 6 mm. Several samples of CrN, CrC, CrN/CrC coatings were prepared by first cleaning chemically by organic solvents and then heated to high temperature for removal of any impurity. These films will be subjected for different instrumentation methods such as coating thickness is measured using Ball crater, Roughness Measurements by Roughness tester, Mercedes test using Rockwell C Hardness instrument, Coating Wear Measurement is done by Calotest, and corrosion resistance measurement by potentiostat.

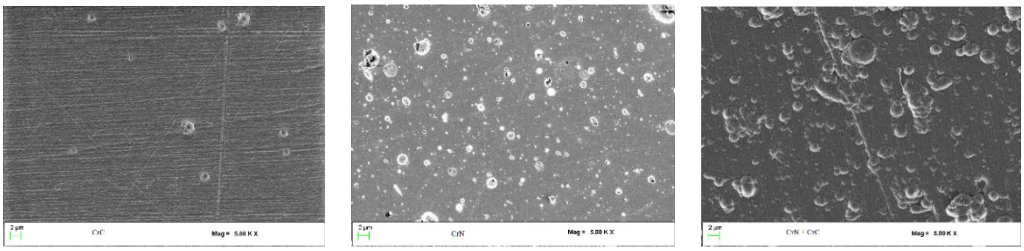
RESULTS AND DISCUSSION

Coating thickness is measured using Ball crater shows 1.30 µm, 2.06 µm and 3.49 µm for CrN, CrC and CrN/CrC coatings respectively [Fig.1]. Calo-wear test has been carried out to evaluate Wear coefficient of the CrN, CrC & CrN/CrC coating was 8.30×10^{-14} m^2/N, 1.51×10^{-13} m^2/N and 1.38×10^{-13} m^2/N respectively. Coating structures like CrN/CrC having duplex surface layer is essential in extending the wear life. Such a multicomponenent coating permit additional functionality in practical applications. example, some layers may provide superior friction and wear properties, while other layer may provide high resistance to corrosion.



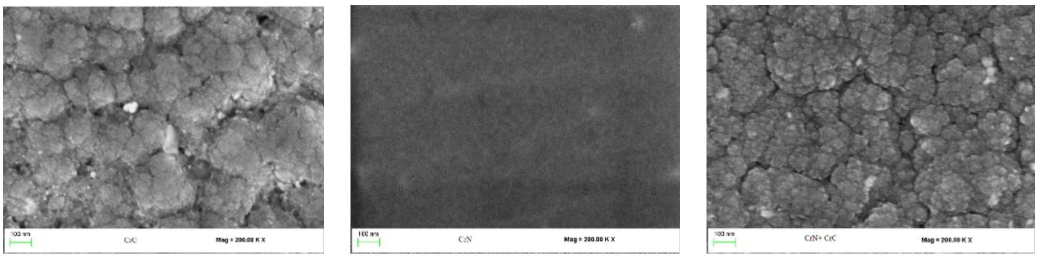
(a) (b) (c)

FIGURE 1. Ball crater images for (a) CrC (b) CrN and (c) CrN/CrC



(a) (b) (c)

FIGURE 2. SEM images at magnification 5 KX for (a) CrC (b) CrN and (c) CrN/CrC



(a) (b) (c)

FIGURE 3. SEM images at magnification 200 KX for (a) CrC (b) CrN and (c) CrN/CrC

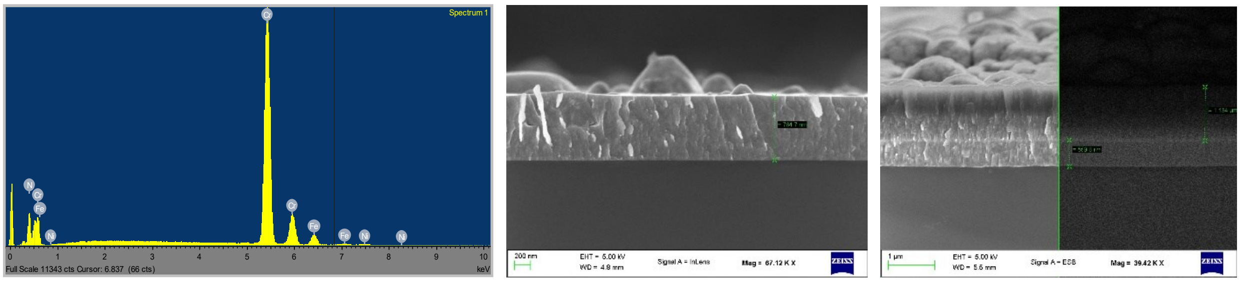
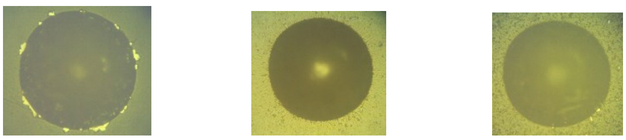


FIGURE 4. (a) EDS measurements for CrN Sample, (b) SEM cross-section image of (i) CrN & (ii) CrN/CrC

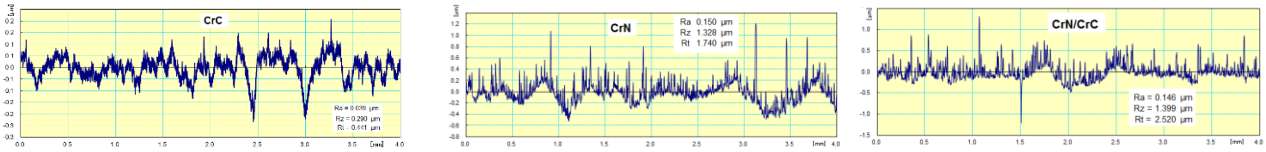


(a) (b) (c)

FIGURE 5. Rockwell C indentation of (a) CrC (b) CrN and (c) CrN/CrC

(a) (b) (c)

FIGURE 6. Corrosion resistance by potentiostat of (a) CrC (b) CrN and (c) CrN/CrC



(a) (b) (c)

FIGURE 7. Surface roughness by Mitutoya profilometer of (a) CrC (b) CrN and (c) CrN/CrC

SEM images at magnification 5KX Fig.2 shows the SEM surface morphologies of CrN, CrC and CrN/CrC coatings, the CrC coating exhibited a very smooth surface while the surface of the CrN and CrN/CrC coating was rough with much micro-drops with granular deposition and pitting defects. chromium-depleted zone adjacent to the grain boundary, is highly susceptible to corrosion and it is called as Intergranular corrosion.

However, SEM images in fig.3 at magnification 200 KX shows small islands start coalescing with each other. The tendency is to form bigger islands is termed agglomeration. The structure of the films at this stage changes from discontinuous island type completely continuous film.

From these SEM images in fig.3 clearly shows that coating structure of CrC and CrN/CrC is island type which is also called as Volmer-Weber (VW) type and CrN coating structure is of layer type which is also called as called Frank-Van der Merwe (FV) type. The EDS measurements for CrN Sample in Fig.4 (a) confirm the composition of under-layer with a ratio of chromium & nitrogen is 51.45 & 44.98 respectively. The main contaminant was Fe and Ni with a content 3.35 & 0.25 atomic% which is because of SS 304 substrate. From the cross-section SEM image in Fig.4 (b) thickness of the CrN & CrN/CrC coating was estimated as 784.7 nm & 559.8/1134 nm respectively. The under-layer of CrN & CrN/CrC is clearly visible on the Si substrate.

Adhesion and coating toughness was evaluated by the Rockwell C indentation method as shown in Fig.5, CrC & CrN/CrC coating shows peel-off but incase of CrC the adhesion failures is more. In CrN coating there is no sign of spalling or adhesion failure.

Corrosion resistance is measured using potentiostat instrument of CrN, CrC & CrN/CrC coating was 2.349 X 10^{-2} mm/yr, 1.497 X 10^{-1} mm/yr and 6.737 X 10^{-3} mm/yr respectively. Standard 1 Molar HCl solution is used to calculate corrosion rate. Corrosion penetration rate is the thickness loss of material per unit of time. Corrosion rate is proportional to the current density associated with the electrochemical reaction. The corrosion rate of a reaction is limited by polarization, Polarization data are plotted as potential versus the logarithm of current density.

Coating surface roughness was measured by Mitutoya profilometer for CrC, CrN & CrN/CrC coating was having roughness (Ra) of 0.039 µm, 0.150 µm and 0.146 µm respectively.

CONCLUSION

Our studies also shows a clear evidences of improvement of the corrosion resistance of Chromium based nitride and Carbide thin films to oxidizing acids over a wide range of concentrations and temperatures. Common acids in this category are nitric acid, hydrochloric acid, perchloric, and hypochlorous acids.

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Conflicts of interest: The authors stated that no conflicts of interest.

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