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A STUDY ON WEAR AND CORROSION RESISTANCE OF CrN_x FILMS BY CATHODIC ARC ION PLATING PROCESS

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ABSTRACT

CrN_X films were deposited on SKD61 and S45C by cathodic arc ion plating process. In this study, the microstructure, microhardness, adhesion, wear and corrosion properties of the CrNx films were studied for various nitrogen partial pressures and the results were compared with those from the electroplated hard Cr. The crystal structure of the films was characterized by X-ray diffraction. Wear tests were performed under no lubricant condition at atmosphere by ball-on-disc type tribotester. Corrosion resistance of the films were studied by electrochemical corrosion test, measuring current demsity-potential curves. The results indicated that the CrN_X films formed using ion plation method showed higer hardness and lower current density, friction coefficient than electroplated hard Cr. Consequently, the application of the CrNx coationgs by ion plating which is free of environmental pollution, is expected to improve lifetime of components in industrial practice.

INTRODUCTION

There have been increasing the applications of plasma techniques in thin film deposition to control film properties such as hardness, wear resistance, adhesion and so on. One of the most developed processes is ion plating[1, 2]. It is generally acknowledged that the ion-plated films have good adhesion and are very dense. Since 1991 the CrN_x coatings have been produced to inprove and protect the surfaces of tools and machining parts or to avoid adhesive wear in contact with loqiod me tals e. g. in the die casting of Al or Al alloys[3]. Their high adhesive resistance, low friction coefficient and low tendency to weld the workpiece due to their low metallic character and high thermal stability protect the tools on which such coatings are deposited. Chromium nitride coatings have been developed by various physical vapor deposition processes, including hollow acthode discharage[4, 5], maganetron sputtering[6, 7], cathodic arc ion plating[3, 8, 9]. The coatings have also been successfully used for protecting tools in metal forming and non-ferrous metal machining.

Electroplated hard Cr coatings are often used for wear and corrosion resistance byt sometimes their performance is not good enough and their use is limited by the following shortcomings of the electroplated process; i) a falling-off in corrosion resistance due to microcracks, ii) hydrogen embrittlement, iii) low deposition rate and poor throwing power, especially iv) pollution problems associated with the plating bath[10, 11]. To avoid such problems physical vapor deposition processes can be considered for the production of better coating properties. The purpose of the present work is to study the microstructure and mechanical properties of CrN_x films deposited with various conditions and to compare the characteristics of electroplated hard Cr.

EXPERIMENTAL PROCEDURE

SKD61 disc spectimens of a diameter of 25 ㎜ and 50㎜ with a thickness of 5㎜ were machined for microstructural analysis and for wear test respectively. THe surface of each disk was polished to a finish Ra ≤0.08㎛. CrN_x coatings of various composition were prepared by the cathodic arc ion plating process which has four chromium targets using d. c substrate bias. All the substrates were precleaned at -700V by metal ions and an intermediate layer by Cr was used. The processing conditions were varied as a function of nitrogen partial pressure. Typical properties of CrNx films are given in Table 1.

The film thickness were determined by examining the fractured sections using scanning electron microscope. Adhesion of film-substrate were observed by optical micrographs of indentation after Rockwell indentation test. Ball-on-disc type wear test was performed and corrosion resistance of the coated specimens was evaluated by the potentiodynamic polarization test in 3.5% deaerated NaCl solution.

Table 1. Typical properties of CrN_x films

properties	result
substrate coating temp	300~370℃
deposition rate	~30mm/min
thickness	2~3㎛
crystal structure	CrM(200),(220)and Cr(110)
microhardness	1,800~2,100Hk(50gf)
oxidation resistance	≤800℃

RESULT AND DISCUSSION

XRD

The X-ray diffraction patterns of CrNx films deposited at various nitrogen pressures are shown in Fig. 1. It was found that as the nitrogen partial pressure increased from 8×10^{-4} torr to 2×10^{-2} torr, the (220) diffraction peak intensity of CrNx films became increasing while CrN(200) peak intensity became decreasing from 5×10^{-3} torr.

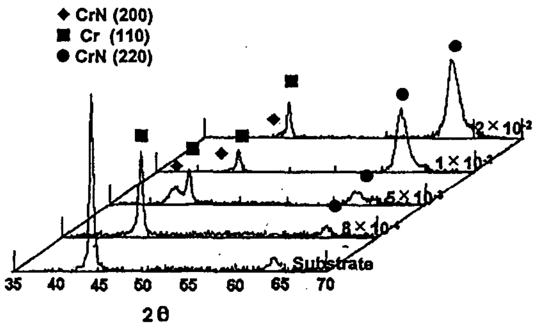

Fig. 1 X-ray diffraction of CrNx films deposited with N_2 partial pressure.

Microhardness

The micro Knoop hardness of CrNx films (thickness:2~3㎛) and electroplated hard Cr (thickness:25㎛) synthesized on SKD61 was measured under the applied load of 25gf and 50gf.

Fig. 2 shows that the microhardness of the electroplated hard Cr on SKD61 was approximaely 900Hk value, while the highest value of the microhardness of CrHx films of about 2,100Hk(50gf) was obtained under the nitrogen partial pressure of 1×10^{-2} torr. Generally, as the nitrogen partial pressure increase, the microhardness values of films increase, showing the maximum microhardness under nitrogen partial pressure of 1×10^{-2} torr.

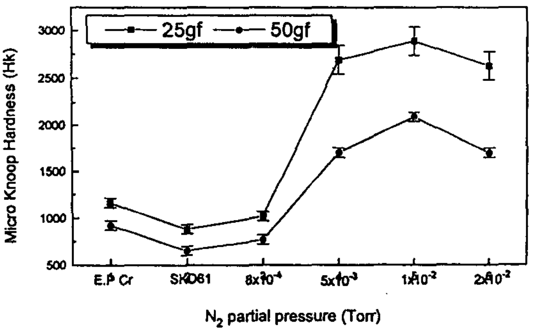

Fig. 2 Microhardness variation in electrolpated hard Cr and CrNx films on SKD 61.

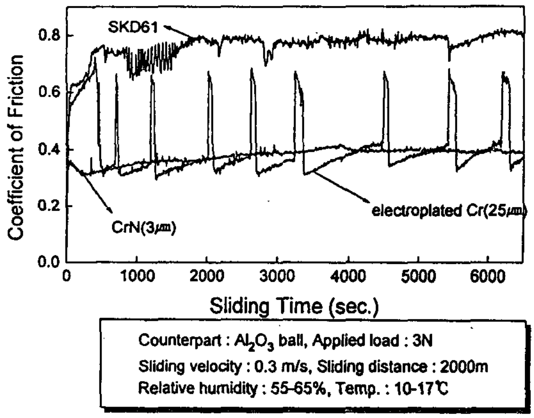

Fig. 3 Variation of dynamic friction coefficient of CrN film and electroplated hard Cr on SKD61.

Wear test

CrNx films showed very low friction coefficient of about 0.38 after wear testing using the tribotester of ball-on-disc type against Al_2O_3 ball under no lubricant condition at atmosphere. However the electroplated hard Cr showed an repetitive abrupt increase in the friction coefficient as shown in Fig. 3. This abrupt behavior was attributed to continuous failures of electroplated Cr, creating microcracks across track in wear scar, as shown in Fig. 3.

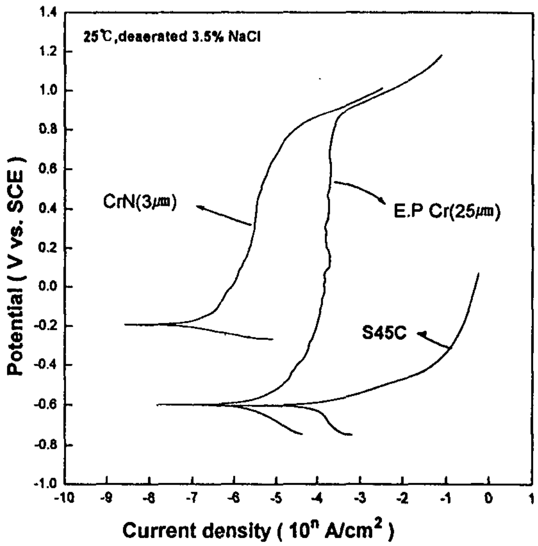

Fig. 4 Current density-potential curves of electroplated hard Cr. and crux films on S45C.

Corrosion test

The dense and chemically stable CrNx films were reported to protect SKD61 substrates from corrosion more effectively than the electroplated Cr coatings with micropores and microcracks. Typical polarization curves were presented in Fig. 4. The current density of passivation for CrNx film was lower than those of the electroplated Cr and substrate.

But the pitting potential of the CrN was similar to that of the elelctroplated Cr.

Adhesion test

Compared with TiN and the other hard coatings, CrNx films could be deposited as thick and dense coatings of up to several decades ㎛ due to very good toughness. Therefore CrN film of about 10㎛ thickness was synthesized and compared with electroplated hard Cr of 25㎛ by Rockwell C indentation test as shown in Fig. 5. For electroplatedhard Cr, a number of cracks around the indentation cavity were propagated through microcracks which formed during plating pro-cess. But for CrN coating, only fime cracks radiat-

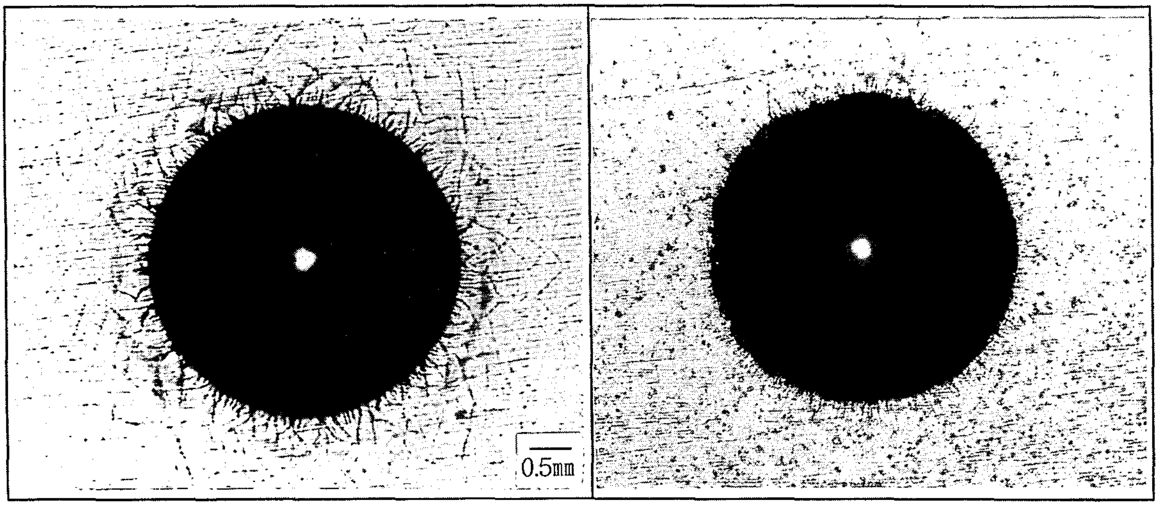

Fig. 5 Optical micrographs of deformed electroplated Cr (thickness : 25μm) and CrN (P_{N2}: 1×10^{-2}torr, thickness: 10μm) after Rockwell C indentation at 150kgf load

ing from the surroundings of the indentation can be detected. Therefore CrN coatings are believed to be capable of absorbing high loads in engineering applications.

CONCLUSIONS

The CrNx films were successfully synthesized by using the cathodic arc ion plating on the SKD61 and S45C. The results obtained in this studies are summarized as follows : (1) CrN(220) peak became dominant, as the nitrogen partial pressure increased. (2) Microhardness of CrNx films were measured to be up to~2,100Hk(50gf) ; which is two to three of those from SKD61 substrate and electroplated hard Cr. (3) The CrN film synthesized under nitrogen partial pressure of 1×10^{-2} torr showed very low friction coefficient of 0.38 against Al_2O_3 counterpart. test., CrN film was more stable chemically than electroplated hard Cr.

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