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Influence of film thickness and Ar−N_2 plasma gas on the structure and performance of sputtered vanadium nitride coatings

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ABSTRACT

We investigated the effect of film thickness on the structure and properties of V−N coatings deposited by magnetron sputtering in an argon and nitrogen atmosphere. The nitrogen percentage was changed between 10 and 20%. Firstly, structural and morphological properties of V−N films were observed, analyzed and subsequently followed by a detailed investigation on the mechanical and tribological properties of these coatings.

It has been shown that film structure, hardness and wear resistance significantly changed with varying the film thickness and the nitrogen percentage. In the case of films deposited under 10%N_2, the presence of V_2N phase was evident. With increasing nitrogen ratio in the deposition chamber from 10 to 20%, the structure was changed from (hc)V_2N to multi phases of V_2N and (fcc) VN (formation of different vanadium nitrides). The thick films containing more nitrogen were slightly dense compared to the thinner ones presenting rough surface and columnar morphology.

Nanoindentation measurements showed that film mechanical behavior depends on its thickness, nitrogen percentage and microstructural features. The film hardness first increased with its thickness and then decreased. The highest hardness of 26.2 GPa was obtained for the film deposited under 20%N_2, which is correlated with its dense structure and film stoichiometry.

The film thickness has a significant effect on the tribological properties of V−N films. The minimum friction coefficient of 0.4 was found for the thickest film of 2500 nm. The wear rate gradually decreased with increasing the film thickness, due to the high hardness, presence of VN phase and the strong adhesion between film and substrate.

1. Introduction

The improvement of surface hardness and wear resistance of parts made of steel would significantly increase the use of these materials. One of the possibilities of enhancing the mechanical properties of steel is to deposit hard coatings with CVD and PVD techniques [1]. The nitrogen with metals has very promising physical characteristics due to its high chemical and physical stability. The good properties of metallic nitrides allow to be used in many applications under several service conditions [2].

Among the sputtered nitride films, vanadium nitrides offer excellent properties and present high corrosive resistance against aggressive media, and good oxidation resistance in ambient air at high temperature [3–6]. In addition, the V−N films were known to show a decrease in the friction coefficient with an increase in temperature due to the formation and melting of V_2O_5 on the wear track during friction process [6,7]. This condition is favorable for cutting tools under high speed machining without lubrication that makes it a suitable compound for many uses [8–10].

The mechanical properties of the films are essentially influenced by the crystallographic structure, which is established during the film deposition. V−N films with an almost stoichiometric composition exhibit cubic or hexagonal structures and hence present higher hardness values than the other nitrides films [11–14].

Depending on the deposition conditions, the sputtered V−N coatings could be deposited with nanometric particles, displaying very high hardness values (up to 30 GPa) and a low coefficient of friction (0.4) compared to any other binary compounds [15,16].

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