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Study of Ti(C,N) coatings deposited by magnetron sputtering

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ABSTRACT

In this work, Ti(C,N) coating have been deposited by RF reactive magnetron sputtering (13.56 MHz). We've been studied the effect of the nitrogen partial pressure and the substrate bias voltage on the properties of titanium carbonitride coatings prepared by RF reactive magnetron sputtering. The deposited coatings were characterized by atomic force microscopy (AFM) and micro-indentation.

KEYWORDS

Ti(C,N);
Magnetron Sputtering;
Hardness.

INTRODUCTION

In recent years, significant attention of the researchers is given to multicomponent interstitial compounds of titanium (carbonitrides, carboxides, and oxynitrides). This is explained by the fact that their physicomechanical properties are better than the properties of binary compounds[1]. Titanium carbonitride (TiCN) coatings are very interesting coatings that combine the high hardness and low friction coefficient of the TiC phases and the high toughness of the TiN phases[2-7]. These unique properties make TiCN coatings a good solution for the applications requiring high abrasion and wear resistance.

The deposition of TiCN coatings by sputtering has important specific advantages such as low levels of impurities and easy control of deposition rate. This method also enables the production of thin coatings of various morphology and crystallographic structure. When a sputtering technique is used for depositing TiCN coatings, the coatings properties are widely changed by the variation of the sputtering conditions, such as reactive gas pressure, total pressure, and substrate bias voltage. Therefore, it is interesting to study the effects of the deposition parameters on TiCN coatings.

In this work, Ti(C,N) coating have been deposited by RF reactive magnetron sputtering (13.56 MHz). We've been studied the effect of the partial pressure and the substrate bias voltage on the properties of titanium carbonitride coatings prepared by RF reactive magnetron sputtering. The deposited coatings were characterized by ellipsometry, atomic force microscopy (AFM) and micro-indentation.

EXPERIMENTAL DETAILS

The TiCN coatings were deposited by R.F.(13,56MHz) reactive planar magnetron sputtering from a high purity Ti (99,999%) target onto Si (100) and steel.

The deposition chamber consists of a cylindrical stainless steel reactor of 230mm diameter and 250mm high. In the chamber, all substrates are mounted at the midpoint of a circle planetary substrate holder (diameter 100mm).

The distance between the target Ti and the substrate holder is about 30mm. The sputtering cathode was thick pure titanium target and was continuously water cooled.. The pressure control device consists of a penning and a baratron gauges.

The gases used are high-purity argon (99,99990%) as the working gas and nitrogen (99,99990%) as the reactive gas. Before introducing the gases into the chamber, the reactor is pumped down to 10^{-6} mbar using secondary diffusion pump.

The coatings were deposited onto substrates, which were previously polished and ultrasonically cleaned in alcohol and acetone. In all the runs, the substrate was not heated.

RESULTS& DISCUSSIONS

The surface structure was found to be very smooth and dense when the coating was deposited at lower working pressure and higher bias voltage compared to higher working pressure and lower bias.

For the lowest CH_4 partial pressures, the TiCN are polycrystalline, with a structure similar to that of TiC, becoming amorphous with the increase of the CH_4 partial pressure above 5mTorr.

TABLE 1 : Roughness of TiCN coatings as function substrate bias and partial pressure

Substrate Bias (volts)	Roughness (nm)	
	Ra	Rq
0	1.42	1.70
50	0.42	0.53
75	0.45	0.57
Pressure (mTorr)	**Roughness (nm)**	
	Ra	**Rq**
10	0.30	0.40
20	0.42	0.53
30	1.80	1.50

According to the data of ellipsometric measurements, the thickness of the coatings was 160-220 nm and the refractive index was 2.1–2.3 depending on experimental conditions (Figure 1& 2).

The refractive index increase with increasing the substrate bias, and decrease when the pressure increases. These values of the refractive index are indicative of a high density of the coatings. For the thickness, it's de-

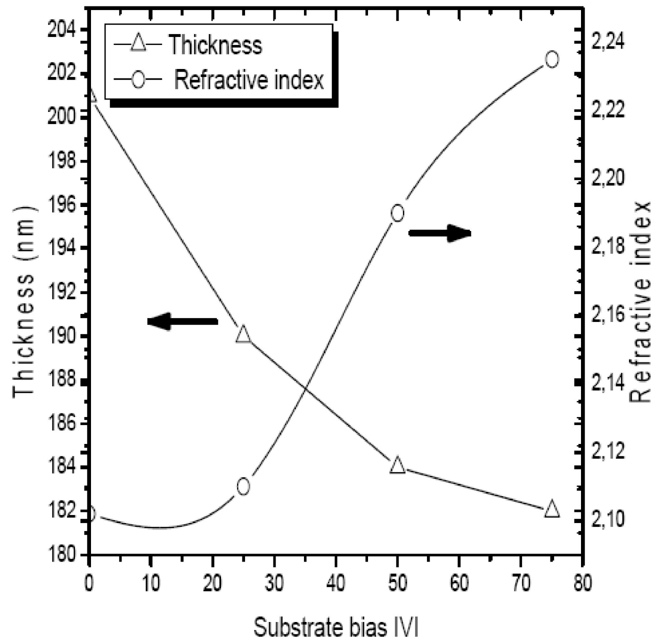

Figure 1 : Thickness & refractive index vs substrate bias

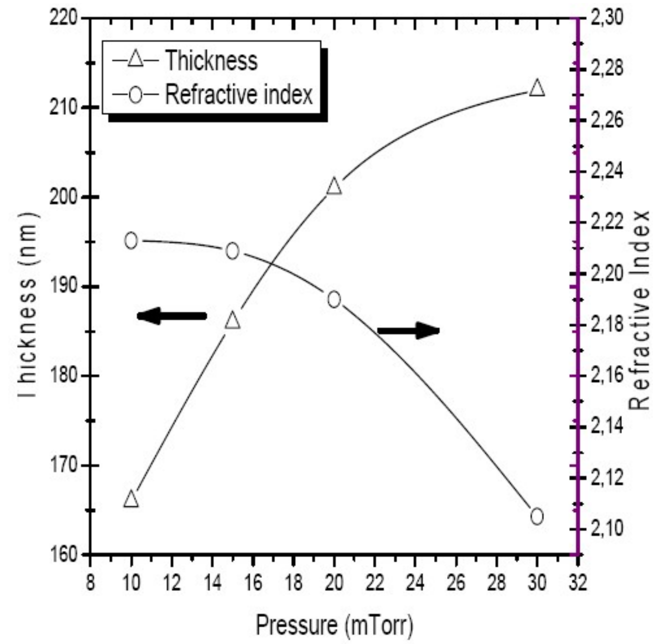

Figure 2 : Thickness & refractive index vs substrate bias

pending on the substrate bias and pressure, its increase with the pressure and decrease with the substrate bias.

Concerning the hardness when the pressure increases the hardness increase, to maximal value of 40GPa for partial pressure of 8mtorr and decrease to the value of 34GPa. These values are in good agreement with other works of literature[8-10].

The excellent performance against wear of protective coatings can be foreseen from the hardness (H) to

Young modulus (E) ratios, a parameter commonly used to evaluate the wear resistance of the coatings[11]. This is the so called elastic strain to failure, which has been proposed and consistently used [12,13] to evaluate the resistance to plastic deformation of thin film coatings and to predict their resistance to wear. Thus, a high H^3/E^2 ratio indicates a high resistance of the coating to plastic deformation and, presumably, a high wear resistance as well, besides low stiffness. TiCN does indeed display very attractive H^3/E^2 as seen on Figure 4.

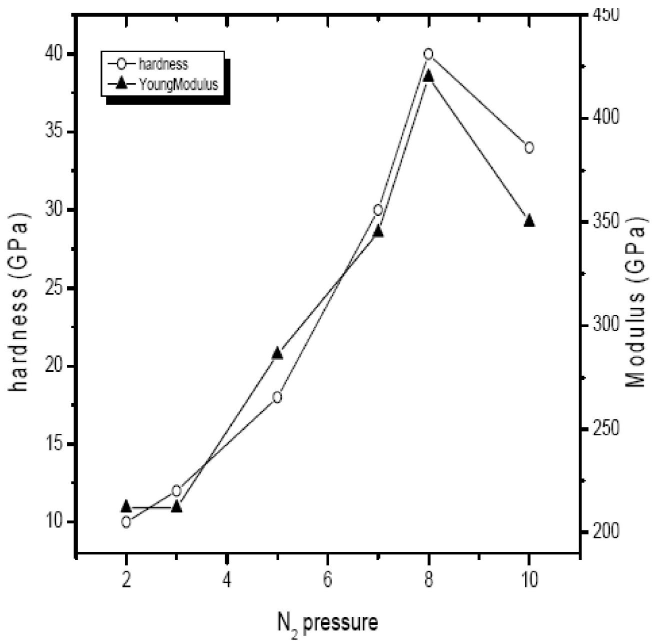

Figure 3 : Hardness and Young modulus as function of partial pressure of nitrogen

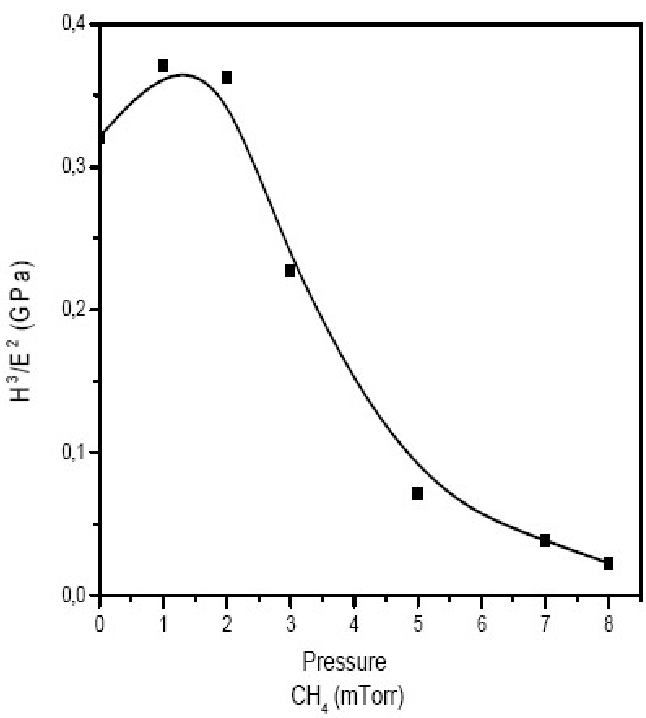

Figure 4 : H^3/E^2 ratios versus methane pressure for TiCN

CONCLUSION

The deposition of titanium carbonitride on silicon and steel by the RF magnetron sputtering using a mixture gas methane, nitrogen and argon has been successfully done. The refractive index of titanium carbonitride increase with increasing the substrate bias, and decrease when the pressure increases.

Titanium carbonitride coating has a good effect on the hardness of the steel surface. It was clearly seen that the concentration of N_2 and CH_4 in the gas mixture has a strong influence on the hardness. The experimental H^3/E^2 figures indicate a pronounced wear resistance increase for the lower CH_4 pressure.

In conclusion, we can say that stoichiometric, crystalline, and very dense films can produce excellent protective TiCN coatings concerning wear Resistance.

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