FAKULTA APLIKOVANÝCH VĚD ZÁPADOČESKÉ UNIVERZITY V PLZNI
STUDENTSKÁ VĚDECKÁ KONFERENCE 2017

Effect of energy on physical and mechanical properties of hard $Ti(Al,V)N_x$ films prepared by magnetron sputtering

Martin Jaroš[1], Jindřich Musil[2], Radomír Čerstvý[3], Stanislav Haviar[4]

Introduction

It is well known that properties of thin films are determined by their elemental and phase composition (crystalline phase, amorphous phase or mixture of crystalline and amorphous phase), structure (size of grains and their crystallographic orientation), and microstructure (porous/columnar, dense/voids-free). Up to now, the properties of the thin film are controlled by different deposition parameters. The problem in this approach is the fact that a correct combination of the deposition parameters necessary to form the film with prescribed properties is unknown. Different combinations of deposition parameters result in different energy $\mathcal{E}$ delivered to the growing film what is difficult to predict. It means that the main parameter which really controls the film properties is the energy $\mathcal{E}$ and thereby the correlations between the properties of the film and the energy $\mathcal{E}$ are of a key importance (J. Musil (2015)). Therefore, an opposite approach in the development of new films should be used. At first, correlations between the film properties and the energy $\mathcal{E}$ should be found. Then, based on this knowledge the necessary deposition parameters which ensure the formation of the films with prescribed properties should be determined.

In the simplest case of a collision-less, fully ionized plasma the energy of ion bombardment $\mathcal{E}_{bi}$ can be expressed in the following form

$$\mathcal{E}_{bi}\ [\mathrm{J/cm^3}] \approx \frac{|U_s| \times i_s}{a_D} \qquad (1)$$

Here, U_s is the substrate bias, i_s is the substrate ion current density and a_D is the deposition rate of film.

This presentation shows the effect of the energy $\mathcal{E}$ delivered to the growing $Ti(Al,V)N_x$ film on its preferred crystallographic orientation (texture) of grains, microstructure, physical and mechanical properties, and resistance to cracking in detail. A great attention is devoted also to (i) the control of the structure and microstructure of film by the energy $\mathcal{E}$ delivered to the film during its growth in the DC and pulsed magnetron discharges, (ii) the energy $\mathcal{E}$ delivered to the film held at different substrate biases U_s and (iii) the energy $\mathcal{E}$ delivered to the film by fast neutrals.

[1] student doktorského studijního programu Aplikované vědy a informatika, obor Fyzika plazmatu a tenkých vrstev, e-mail: jarosm@kfy.zcu.cz
[2] vědecko-výzkumný pracovník, NTIS, VP4, Fakulta aplikovaných věd, Západočeská univerzita v Plzni, e-mail: musil@kfy.zcu.cz
[3] vědecko-výzkumný pracovník, NTIS, VP4, Fakulta aplikovaných věd, Západočeská univerzita v Plzni, e-mail: cerstvy@kfy.zcu.cz
[4] vědecko-výzkumný pracovník, NTIS, VP4, Fakulta aplikovaných věd, Západočeská univerzita v Plzni, e-mail: haviar@kfy.zcu.cz

Results and Discussion

The presentation reports on a detailed investigation of the interrelationships between the energy $\mathcal{E}_{bi}$ and $\mathcal{E}_{fn}$ delivered to the $Ti(Al,V)N_x$ film by bombarding ions and fast neutrals, respectively, and its structure, microstructure, mechanical properties, and resistance to cracking. Main issues of this study can be summarized as follows

1. The texture of $Ti(Al,V)N_x$ film varies from TiN(200) to TiN(220) with increasing energy $\mathcal{E}_{bi}$ or $\mathcal{E}_{fn}$.

2. The $Ti(Al,V)N_x$ films sputtered at low energies $\mathcal{E}_{bi} < 1.7$ MJ/cm^3 and high sputtering gas pressures $p_T > 0.7$ Pa are characterized by the TiN(200) reflection and low resistance to cracking. On the other hand, the $Ti(Al,V)N_x$ films sputtered at high energies $\mathcal{E}_{bi} \geq 1.7$ MJ/cm^3 and low pressures $p_T < 0.7$ Pa exhibit no TiN(200) reflection but an enhanced resistance to cracking. It indicates that the absence of the TiN(200) reflection in XRD pattern can be used as an indicator that the $Ti(Al,V)N_x$ film with enhanced resistance to cracking is formed.

3. The $Ti(Al,V)N_x$ film with high ratio $H/E^* \geq 0.1$, high elastic recovery $W_e \geq 60\%$, dense, voids-free non-columnar microstructure and compressive macrostress ($\sigma < 0$) exhibit an enhanced resistance to cracking.

4. In sputtering of the $Ti(Al,V)N_x$ film with enhanced resistance to cracking the energy $\mathcal{E}_{bi}$ can be fully substituted by the energy $\mathcal{E}_{fn}$. This finding is of a general validity. Moreover, the use of the energy $\mathcal{E}_{fn}$ in deposition of films makes it possible to sputter nanocrystalline and crystalline films on electrically insulating substrates without their heating and arcing on their surfaces.

5. The energy $\mathcal{E}$ is a key parameter controlling physical and mechanical properties of sputtered films including their resistance to cracking and enabling their production in a reproducible way.

Acknowledgments

This work was supported by the project LO1506 of the Czech Ministry of Education, Youth and Sports under the program NPU I.

References

Musil, J., 2015. *Flexible hard nanocomposite coatings*, RSC Advances, Vol. 5. pp 60482-60495.