Structure and tribological properties of magnetron sputtered quaternary (Ti,Zr)1-xAlxN and (Ti,Zr)1-xSixN films

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Abstract

Hard coatings based on transition metal nitrides are widely used to increase the wear and corrosion resistance of the technological tools and products. Their structural and phase state as well as mechanical properties can be modified by a variation of elemental composition. In particular, nanocomposite structure formation is possible. In the present work we investigate the structural and phase transformations in (Ti,Zr)1-xAlxN and (Ti,Zr)1-xSixN films depending on Al and Si content, respectively. The friction coefficient measurements and wear track analysis were performed to test the tribological properties of these films.
(Ti,Zr)1-xAlxN and (Ti,Zr)1-xSixN films with thickness of 300 nm have been deposited onto Si (001) wafers by a reactive unbalanced magnetron sputtering method. Titanium, zirconium and aluminum or silicon targets were co-sputtered under mixed Ar+N2 plasma discharges (working pressure p = 0.19 Pa). Varying the RF power of the Al target from 20 to 200 W resulted in aluminum concentration, xAl, to increase from 2.6 to 36.4 at.% in (Ti,Zr)1-xAlxN films. Changing the RF power of the Si target from 60 to 200 W provided the rise of the silicon concentration, xSi, from 6.5 to 22.6 at.% in (Ti,Zr)1-xSixN films. And the Ti:Zr concentration ratio was kept constant to ˜1.0. The tribological behaviour was investigated by reciprocating dry-sliding tests on a ISPF tribometer.

Results of the XRD analysis on as-deposited (Ti,Zr)1-xAlxN films indicate that with rising Al concentration the structure changes from single-phase cubic TiZr(Al)N solid solution to dual-phase nanocomposite and then it turns into the amorphous state. This structural evolution is accompanied with a transition from (111) to (200) texture at low Al concentrations.

The synthesized (Ti,Zr)1-xSixN films are the multiphase systems consisting of (Ti,Zr)N nanocrystals with (200) preferred orientation surrounded by X-ray amorphous SiNy matrix. Transformation of nanocrystalline structure of the films into X-ray amorphous state is observed when Si concentration reaches the value of 22.6 t.%.
In the case of (Ti,Zr)1-xAlxN films, the lowest values of the friction coefficient are registered at the Al concentration $0 < xAl < 7.1$ at.%. When xAl ˜13.8 at.%, the deterioration of the tribological properties takes place. The best tribological properties are observed in the

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case of (Ti,Zr)1-xSixN films: the friction coefficient is in the range of 0.15-0.26. There is a clear tendency of wear resistance increase for (Ti,Zr)1-xSixN films with xSi rise. Correlation of the tribological properties of the coatings with their structural state is discussed.

Keywords: Hard coating, reactive magnetron sputtering, phase formation