СВОЙСТВА, ДИАГНОСТИКА И ПРИМЕНЕНИЕ ПОЛУПРОВОДНИКОВЫХ МАТЕРИАЛОВ И СТРУКТУР НА ИХ ОСНОВЕ

ELECTROPHYSICAL PROPERTIES OF TiAlN COATINGS PREPARED USING CONTROLLED REACTIVE MAGNETRON SPUTTERING

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INTRODUCTION

Titanium-aluminium nitrides are technologically important for different application fields such as wear-resistant and optical coatings. The structure of TiAlN coatings depends strongly on the deposition parameters, in particular, reactive and transport gases, substrate temperature, etc. In this work, a study on the influence of deposition parameters on the structure and electrophysical properties of TiAlN coatings is presented.

The optical properties of ‘Ti’-based nitride coatings can be tailored by controlling the stoichiometry, which affects the density of free electrons in the Ti d band [1, 2]. Incorporation of additional elements (such as Al) in the TiN matrix changes the bonding structure. The change in the bonding structure results in variations in the electrical resistivity and the optical properties of TiAlN [3].

In the present study, TiAlN coatings were prepared by reactive magnetron sputtering. The algorithm of the optical control of the nitrogen flow for the processes of the magnetron deposition of the TiAlN films is used [4]. The results of the determination of the optical characteristics and of the elemental composition of the films are considered.

EXPERIMENTAL DETAILS

Prior to deposition substrates were cleaned by ion etching in argon plasma at a pressure of 6.0·10-2 Pa. The parameters of deposition procedure were: discharge current I = 20 mA; discharge voltage U = 2.4 kV; cleaning time t = 5 min.

TiAlN coating was prepared from the reactive magnetron sputtering of Ti–Al composite target in argon–nitrogen plasma at a pressure of 0.71 Pa. The TiAlN films were deposited on Si, SiO_2, C and glass substrates at different values of reactivity α [4]. The value of reactivity α = 1 corresponds to fully nitride or “poisoned” target (fully nitrated deposition process) and the value of reactivity α = 0 corresponds to deposition process in inert gas – argon. Deposition parameters of TiAlN coatings are shown in Table 1.

RESULTS AND DISCUSSION

The elemental composition of the as deposited samples was measured by Rutherford backscattering spectroscopy (RBS). RBS experiments were performed using a 1.2 MeV He^+ beam. Results of RBS measurements shown in Table 2.

Table 1

Deposition parameters of TiAlN coatings

	α	Bias voltage, V	Deposition temperature, °C
TiAlN1	0.65 excess of nitrogen	- 90	450
TiAlN2	0.58 stoichiometry	- 90	450
TiAlN3	0.53 deficiency of nitrogen	- 90	450

According to Table 2 oxygen is located in the surface layer. Since thickness of oxide is small (~ 30), it can be concluded that the film surface is oxidized by the influence of environment after unloading from the vacuum chamber.

Table 2

Elemental composition of the TiAlN coatings produced at different nitrogen deposition pressures

α	Depth$\cdot 10^{-15}$ at/cm^2	Ti, %	Al, %	N, %	O, %	Al/Ti	N/(Al+Ti)
0.53	350	33	17	11	39	0.51	0.22
	2850	33	17	50	0	0.51	1
0.58	400	31	19	10	40	0.61	0.2
	2650	31	19	50	0	0.61	1

SEM images illustrating the microstructure and surface morphology of the TiAlN coatings deposited at different α are shown in Fig. 1 and Fig. 2.

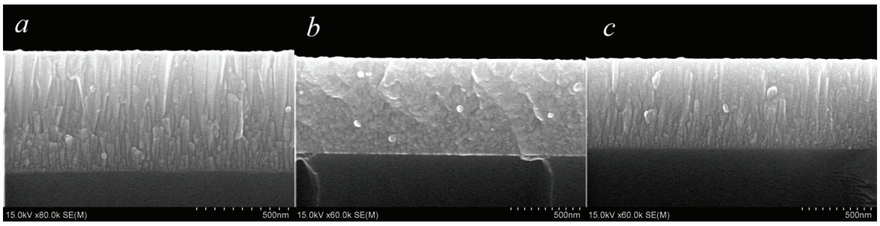

Fig. 1. The cross-section morphology of TiAlN films with different α
a – α = 0.65, *b* – α = 0.58, *c* – α = 0.53

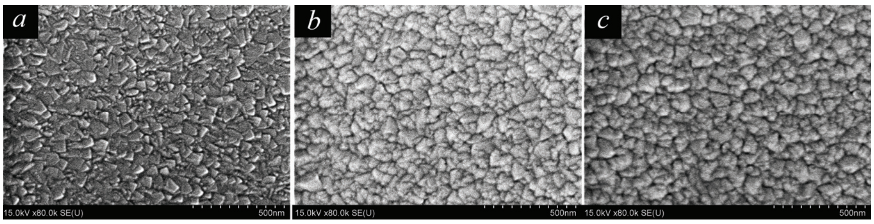

Fig. 2. SEM micrographs of the TiAlN coatings produced at different α:
a – α = 0.65, *b* – α = 0.58, *c* – α = 0.53

Typical cross-sectional SEM images obtained from the samples TiAlN1, $TiAlN_2$ and TiAlN3 are shown in Fig.1 a, b and c, respectively. Columnar microstructure is observed in the TiAlN1 and TiAlN3 films. It contains a well-defined columnar microstructure with an average columnar diameter of 80-90 nm. In the case of TiAlN2 film microstructure is globular. Dense fine grained microstructure was obtained on all samples (Fig. 2). The grain size becomes smaller and the grain boundaries become sharper with increasing the N2 flow. Microstructural changes can be explained as a decrease in atomic mobility with increasing nitrogen flow and change of the chemical potential on the growing film surface [5].

Optical measurements of the reflection coefficient from thin TiAlN film deposited samples were made in the spectral range from 350 to 1000 μm.

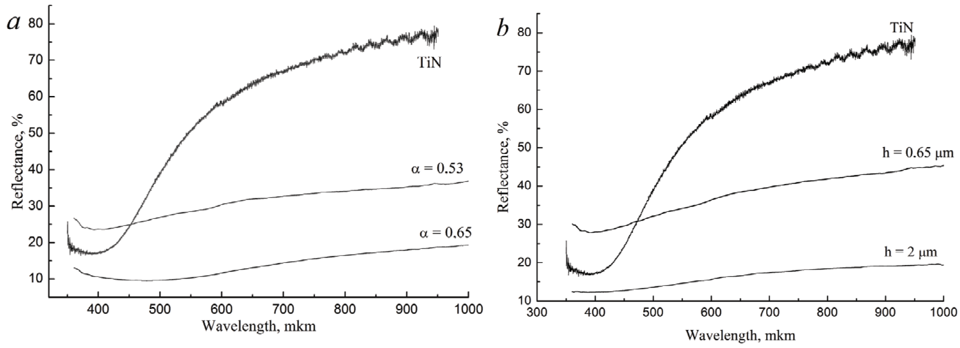

Fig. 3. The relative reflectance of TiAlN coatings *a* - with different α; *b*- with different thicknesses

Reflectance measurements of samples with different α (Fig. 3a) show a decrease in reflectance with increasing nitrogen in the sample for different wavelengths, as expected. The reflection coefficient also decreases with increasing of the thickness of the sample (see Fig. 3b).

The resistivity values of TiAlN coatings obtained for the various flow of nitrogen are shown in Table 3. This table shows that the minimum resistivity corresponded to the stoichiometric composition of the films with α = 0.58.

Table 3

The resistivity values of coatings produced at different nitrogen deposition pressures

	TiAlN			TiN
α	0.65	0.58	0.53	0.58
ρ, μOm·cm	440	100	350	40

CONCLUSIONS

The investigations of RBS and SEM of TiAlN coatings deposited at different value of reactivity allow us to find the elemental composition and morphology of coatings in dependence on the deposition process. Reflection measurements have shown optical properties of films. Electrophysical properties of films were determined.

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DEVICE-PROCESS SIMULATION OF SILICON DIODE STRUCTURES BY VARIOUS PARAMETERS OF EPITAXIAL FILM

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INTRODUCTION

At present various diodes types [1] are widely used as in the capacity of discrete devices so in the capacity of different integrated circuit components. The new semiconductor devices design requires device-process simulation of such ones very often because the simulation allows to reduce costs on experimental samples making. The device construction and its technological fabrication process are unknown very often and it's necessary to realize device-process simulation for specific manufacturing environment. Therefore the simulation of semiconductor devices [2] including diodes is the important stage in its production process.

The aim of this work was the simulation of the silicon diode structure with area of 4 μm x 1 μm = 4 μm^2 at its formation in next epitaxial film types: 1) 17.0SEPh2.0; 2) 25.0SEPh6.0; 3) 25.0SEPh20.0. The simulation of diode technological fabrication process and the electric characteristics was performed with the help of the software package of the company Synopsys [3] which is the instrument for such aims.

SELECTION AND SIMULATION OF THE PROCESS CHART FOR DIODE FORMATION

The short technological fabrication process of simulated diode includes next operations:

1. Selection of substrate type: 100SESb0,01 (silicon doped antimony Sb of the electron type conductivity with the diameter D = 100 mm and resistivity of ρv= 0,01 Ohm·cm).
2. Formation of epitaxial films of next types: 17.0SEPh2.0; 25.0SEPh6.0 and 25.0SEPh 20.0.
3. Pyrogenic oxidation with oxide thickness d=700 nm.
4. Etching-out of windows in deposited oxide. The window diameter is 180 μm.
5. The prior oxidation with oxide thickness d=150 nm.
6. The ion-implantation doping by boron.