Materials Physics and Mechanics 15 (2012) 167-172 Received: November 1, 2012

PHYSICAL PROPERTIES OF TITANIUM NITRIDE THIN FILM PREPARED BY DC MAGNETRON SPUTTERING

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Abstract. The physical properties of the titanium nitride thin film have been prepared on p-type silicon (100) substrates by at room temperature by reactive DC magnetron sputtering technique using pure Si target with varying oxygen partial pressure during growth at reported. The oxygen partial pressure in the growth chamber is varied between (97 % argon) and (3 % oxygen). The X ray diffraction (XRD) analysis showed that all the films were polycrystalline.

1. Introduction

Titanium nitride (TiN) has been widely used as a coating material, ranging from diffusion barrier in microelectronic industry, to the hard and protective coatings on mechanical tools and decorative coatings [1, 2]. Because of the well-established application history, TiN thin films are good choices to meet the requirements. To improve the characteristics of TiN thin film, many studies have been presented to understand the relationships between the processing parameters, the film structure and properties [3, 4]. The previous research shows that the mechanical properties of TiN film are strongly affected by its preferred orientation, residual stress, packing factor, and grain size. Also the resistivity of TiN thin films is correlated to the packing factor [5]. DC magnetron sputtering is presently used for the deposition of a wide variety of thin films, especially oxides, nitrides and carbides [6-8]. The presented models do not include the effect of different reactivities of the reactive sputter process [9]. DC magnetron sputtering from elemental targets is a suitable technique for the preparation of compounds. In the past decade, DC magnetron sputtering technique has been used especially for hard coating.Presently, semiconducting nitrides (GaN, InN) are very important. DC magnetron sputtering is a cheap and well developed deposition technique that should be applied also for the preparation of these nitrides. The reactive sputtering of nitrides, especially that of the refractory nitrides (TiN, TaN, etc.), has been investigated greatly over the past years. Hofmann was the first to make a systematic study formation of nitrides by sputtering titanium targets in Ar/N2 mixtures [10]. In his model he discovered a parameter that took into account the different reactivities of metals to nitrogen. But he could not find a relationship between the heat of formation of the nitrides and the discharge characteristics. Mientus and Ellmer have investigated the changes of nitrogen partial pressure for formation of the nitrides and they discovered that both the discharge voltage and the deposition rate show a significant change when the nitrogen partial pressure increased. The discharge voltage increases or decreases depending on a decreased or increased secondary electron emission coefficient of the nitride target surface. For Ti and TiN, the discharge voltage increases by about 20–30 % when nitrogen partial pressure increased from zero to 3.7×10^{-3} Torr. In

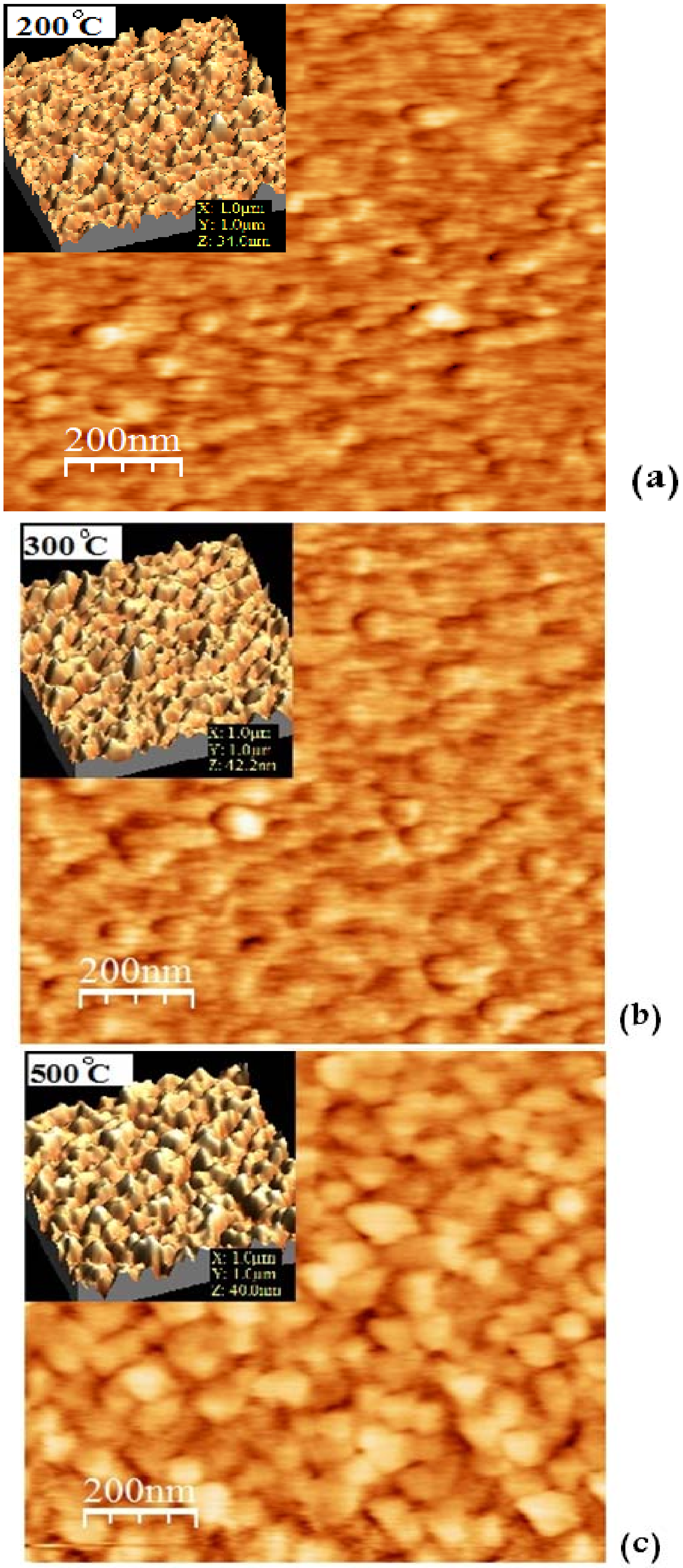

Fig. 1. 2D and 3D AFM images of grown layers: a) 200 ºC, b) 300 ºC, and c) 500 ºC.

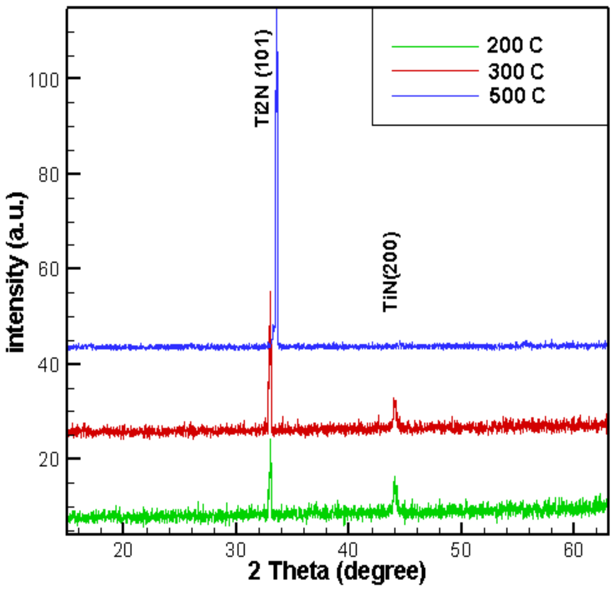

Fig. 4. The X-ray diffraction result on the titanium nitride thin films for different substrate temperatures.

Table 1. Characteristics and size of nanoparticles using Debye - Scherrer.

No	FWHM[°2T](101)	D, nm	FWHM[°2T](200)	D, nm
A200	0.2363	35.1	0.3840	22.3
A300	0.21	39.5	0.3360	25.5
A500	0.14	59.3	----	----

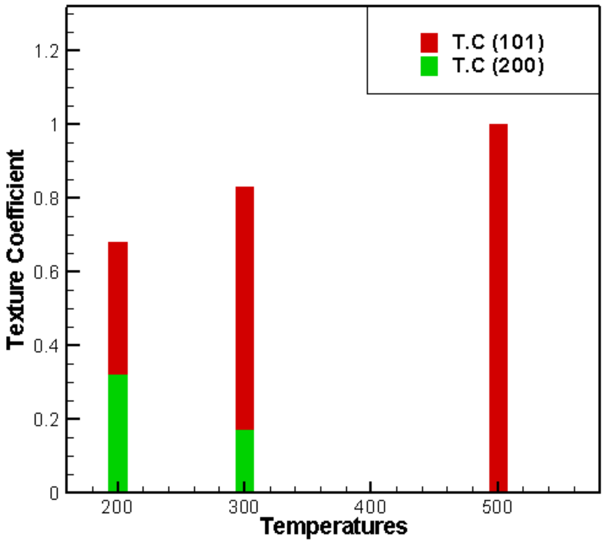

Fig. 5. The tissue coefficient of films.

Figure 5 shows the tissue coefficient of films. Tissue coefficient was respective intensity of XRD pattern peak for orientation of different layers and calculated from:

$$\mathrm{T.C}_{(hkl)} = \frac{I_{(hkl)}}{I_{(101)} + I_{(200)}}.$$

4. Conclusions

Titanium nitride thin films have been prepared at different temperature of substrate by reactive DC magnetron sputtering. Crystal structure and surface morphology of the thin films were evaluated by XRD and AFM analysis. With increased substrate temperature and lattice structure the diffraction peak and crystal structure were translated to single crystal of Ti_2N (phase (101) and tetragonal). AFM images show the creation of nanostructure thin films and with increasing substrate temperature variation of surface topography and increasing of surface roughness. Grain size was evaluated by scherrer's formula and XRD patterns and concord with calculated grain size of AFM images.

References

[1] W.J. Chou, G.P. Yu, J.H. Huang // *Surface and Coatings Technology* **140 (1)** (2001) 206.
[2] W.J. Chou, G.P. Yu, J.H. Huang // *Surface and Coatings Technology* **149 (1)** (2002) 7.
[3] H. Oettel, R. Wiedemann, S. Preibler // *Surface and Coatings Technology* **74–75 (1)** (1995) 273.
[4] Z. Cheng, H. Peng, G. Xie, Y. Shi // *Surface and Coatings Technology* **138 (2-3)** (2001) 237.
[5] W. Tamura, H. Kubo // *Surface and Coatings Technology* **49 (1–3)** (1991) 194.
[6] H. Seifarth // *Thin Solid Films* **172 (1)** (1989) 61.
[7] K. Steenbeck, E. Steinbeib, K. D. Ufert // *Thin Solid Films* **92 (4)** (1982) 371.
[8] T. Larsson, H.O. Blom, C. Nender, S. Berg // *J. Vac. Sci. Technol. A* **6** (1988) 1832.
[9] K. Ellmer, R. Mientu, In*: Proc. 4th International Symposium on Trends and New Applications in Thin Films / 11th Conference on High Vacuum, Interfaces and Thin Films* (Dresden, Germany, 1994) p. 131.
[10] S. Hofmann // *Thin Solid Films* **193–194 (2)** (1990) 648.
[11] R. Mientus, K. Ellmer // *Surface and Coatings Technology* **116–119** (1990) 1093.
[12] Vipin Chawla, R. Jayaganthan, Ramesh Chandra // *Materials Characterization* **59 (8)** (2008) 1015.