Influence of N2:Ar Gas Ratio on Surface Morphology of CrN Coated Silicon Wafer

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Abstract

Silicon wafer is widely used in electronics and other industrial application now a day. Surface morphology and surface area plays major role on performance of silicon wafer. Current work represents effect of Nitrogen and argon gas ratio on surface morphology of CrN coated silicon wafer by magnetron sputtering process. 10 × 10 mm size silicon wafer with (1 0 0) was selected as a substrate material and 99.9% pure Cr target was used for deposition. Range of gas ratio selected for applying coating was 20:80, 40:60, 50:50, 60:40 and 80:20. Working pressure for deposition was 8 × 10-3 mbar with rate of deposition 0.1 A0/S. Deposition temperature was 4000 C and 80 nm coating thickness developed during deposition. Maximum surface roughness noted at 50:50 N2:Ar gas ratio of 124 nm, while least surface roughness was achieved at 80:20 N2:Ar gas ratio of 28.4 nm.

Keywords: Nirtogen-Argon gas ratio, CrN Coating, Magnetron Sputtering, Surface roughness

I. Introduction

Nitride coating is highly demandable in Industrial application such as microelectronics industry due to their excellent corrosion, wear and strength properties. CrN and TiAlN are very popular coating material as it has better chemical stability. Due to its better hardness, corrosion and wear properties chromium Nitride is a proper material to apply on thin film. Magnetron sputtering process gives better microstructural results at varied gas ration of Nitrogen and Argon. Combination of CrN coating by magnetron sputtering process gives excellent wear resistance, hardness and better structural properties [1--3].

Shah et.al.[4] deposited CrSiN on Si(1 0 0) thin film by D C Magnetron sputtering method and found fine columnar morphology growth. Van et.al [5]observed that CrN deposited on high speed steel by magnetron sputtering method at varied nitrogen flow of 60 to 100% gives high hardness up to 30GPa.It was also found that at (2 0 0) orientation unbalanced magnetron sputtering CrN deposited thin film on high speed steel gives 16GPa hardness[6--11].

Present work briefs the variable gas ratio of nitrogen and argon and its effects on properties of CrN magnetron sputtered coated Silicon substrate. XRD and AFM is used to analyze surface morphology of CrN coated Silicon thin film.

II. Experimental Work

Silicon Wafer of 10×10 mm size with (1 0 0) Orientationis used as a substrate material. Magnetron sputtering coating process is applied to generate CrN coating on silicon thin film. 99.9% pure Cr target is used to develop deposition. Nitrogen and argon gas at variable ratio is used for nitride coating. Gas ratio of Nitrogen and Argon is varied from 80:20,60:40,50:50,40:60 and 20:80.Before deposition silicon substrate was cleaned ultrasonically with distilled water for 20 minutes and then cleaned with Hf solution with proportion of H_2O:Hf of 1:1 for 5minutes.

Fig. 1: Set-up for Magnetron sputtering and preperation of sample

Advanced process technology magnetron sputtering machine is used for synthesis CrN thin film on silicon substrate. Deposition temperature was maintained up to 4000C at 100W power. Base pressure for deposition was 8×10-6 mbar, while working pressure has been used 5×10^{-3}mbar. Deposition rate was 0.1 A0/S to develop 80nm thickness. Time taken for onecomplete deposition has been noted 143 minutes. Atomic Force Microscope (AFM) is used to observe surface morphology of CrN coated Silicon wafer at variable gas ratio of Nitrogen and Argon.

III. Result and Discussion

Atomic Force Microscope is used to study roughness generated on film and topography of surface. To observe and analyze surface quality of any coating, surface roughness plays major role. To produce high quality surface some of functional characteristics like lubrication, fatigue, wear and friction should be taken in to consideration and this functional characteristic is affected by surface roughness [12].Surface texture and geometry of surface can be describe in a better way by detail study of surface roughness. Any complicated machining process is depends on surface roughness [13--14].

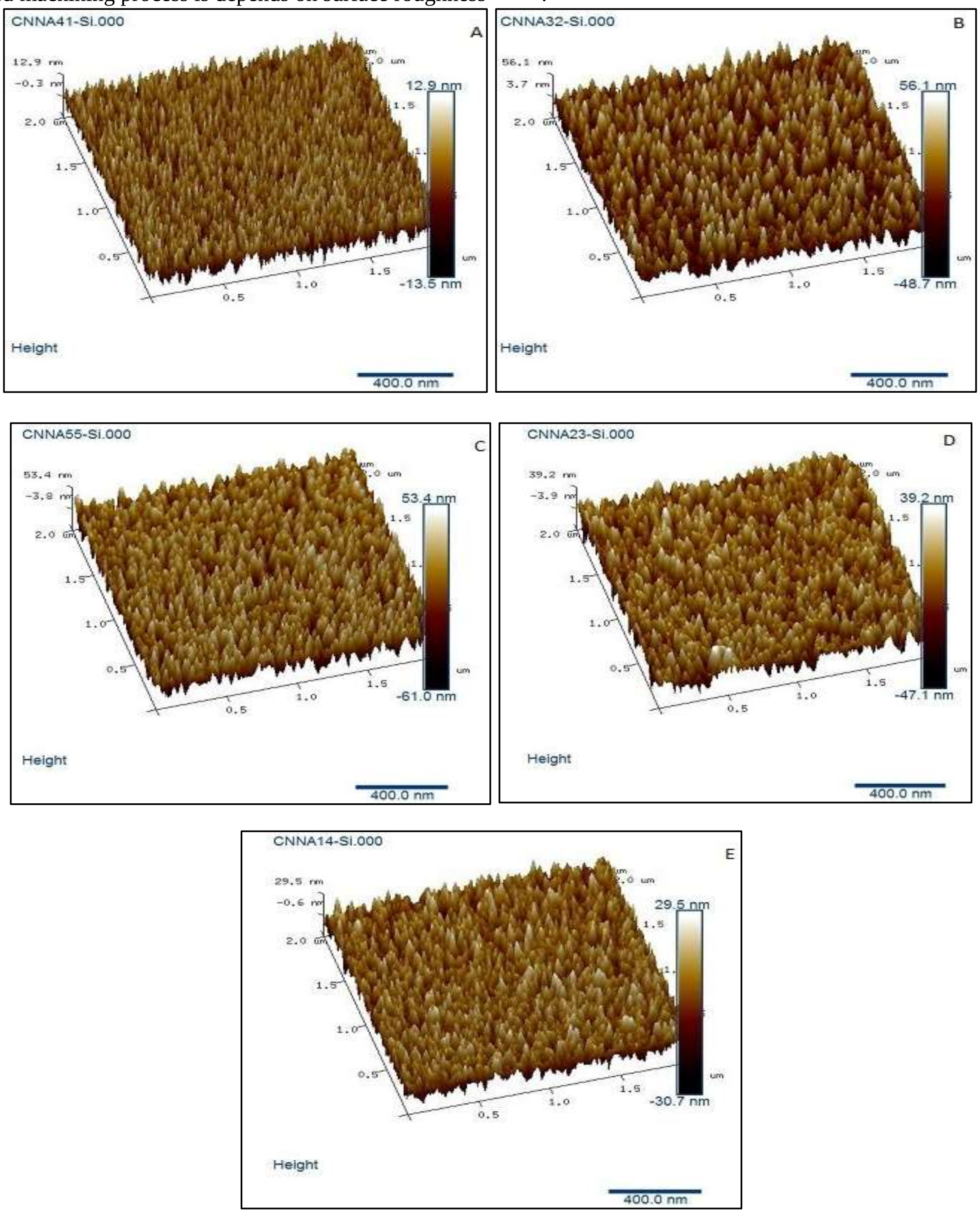

Fig. 2: 3-D Images of CrN coated Silicon wafer at variable N_2:Ar gas ratio(A) 80:20,(B) 60:40,(C) 50:50,(D)40:60 and (E) 20:80

Table - 1
Roughness of CrN coated Silicon substrate at different gas ratio

Sample	*N_2:Ar Gas ratio*	*R_a(nm)*	*R_q(nm)*	*Max. Roughness(nm)*
CNNASi41	*80:20*	*3.23*	*3.98*	*28.4*
CNNASi32	*60:40*	*12.9*	*15.9*	*112*
CNNASi55	*50:50*	*14.0*	*17.3*	*124*
CNNASi23	*40:60*	*9.69*	*12.3*	*114*
CNNASi14	*20:80*	*7.02*	*8.74*	*69.9*

Fig.2 describes the topographical image of Silicon substrate at varied Nitrogen and Argon gas ratio for all coating surfaces. It shows that coating developed at various gas ratio exhibits similar surface morphology structure and gives dense type of growth. It reveals that size and number of individual prolongation varied with different gas ratio of N_2:Ar. With increasing nitrogen and argon gas content number of prolongation increasing, while its size decreasing. The average grain size of coating deposited at 80:20 gas ratio of nitrogen and argon exhibits lowest as compared to grain size at other combination. Surface morphology at 80:20,20:80 and 40:60 observed more compact other than 50:50 and 60:40 gas ratio of N_2:Ar.

The present work shows that CrN deposition on silicon substrate gives smooth and homogeneous structure as shown in table 1.Ra is average roughness, which describe roughness of machine surface. Rq is the Root Mean Square roughness and it provides the finishing of optical surface [15-17]. From table 1 values of Ra, Rq and maximum roughness was achieved. It reveals that surface roughness is affected by gas ratio of Nitrogen and Argon.It has been observed from table 1 that Nitrogen and argon gas ratio is effective in decreasing surface roughness of the CrN coating on substrate. Ra value has been decreasing by increasing nitrogen or argon gas proportion, but surface roughness increasing at equal proportion of N_2:Ar gas ratio.RMS has been found lowest at 80:20 gas ratio and highest at 50:50 gas ratio of N_2: Ar.

IV. Conclusion

Under present deposition condition it has been concluded that N_2:Ar gas ratio is effective parameter to generate better surface morphology. Dense and better columnar growth observed for all conditions. Lowest surface roughness is achieved at 80:20 gas ratios of Nitrogen and Argon, even at 20:80 gas ration surface roughness is lower as compared to other condition. Minimum grain size and least RMS value is achieved at 80:20 gas ratio. It was noted that at equal proportion of N_2: Ar result are not as better as compared to other conditions.

References

[1] I. Safi. Recent aspects concerning DC reactive magnetron sputtering of thin films: a review. Surface and Coatings Technology.2000.127;2(3);203-218.
[2] H.N. Shah, R.Jayaganthan, D.Kaur. Effect of Sputtering pressure and temperature on DC magnetron sputtered CrN films. Surface Engineering.2010;26(8);629-637.
[3] H.N.Shah,R.Jayaganthan, D.Kaur. Synthesis and microstructural characterization ofCrSiN thin films deposited on Si (100) substrate. Surface Engineering.2010;26(8);596-601.
[4] H.N.Shah, R. Jayaganthan, DavinderKaur. Influence of silicon content on the microstructure and hardness of CrN coatings deposited by reactive magnetron sputtering. Material Chemistry and Physics.2010;121;567-571.
[5] P. Essen, Hoy, Kamminga, *et.al*. Scratch resistance and wear of CrNx coatings. Surface Coat9ing Technology.2006; 200;3496-3502.
[6] H.N.Shah, R. Jayaganthan, DavinderKaur,*et.al*. Influence of sputtering parameters and nitrogen on the microstructure of chromium nitride thin films deposited on steel substrate by direct-current reactive magnetron sputtering.2010;518;5762-5768.
[7] H.N. Shah, Kaur, Jayaganthan, *et al*. Influence of Sputtering parameters and Reactive gasses on Microstructure of Chromium Nitride thin films deposited on SS-304 substrates by DC-Reactive Magnetron Sputtering. Thin Solid Films. 2009;518(20):5762-6
[8] H.N.Shah, Jayaganthan, Kaur. Influence of Reactive gas and Temperatureon Structural properties of Magnetron Sputtered CrSiN coatings. Appliedsurface science.2011;257(13):5535-7.
[9] H.N.Shah, Pandey, Jayaganthan. Nanoindentation study of magnetronsputteredCrN and CrSiN coatings. Materials and Design.2011;32:2628-7.
[10] H.N.Shah, Jayaganthan. Influence of Al Contents on the Microstructure,Mechanical, and Wear properties of Magnetron Sputtered CrAlNCoatings.Journal of Materials Engineering and Performance.2011; 112.
[11] H.N.Shah, Kaur, Jayaganthan. Synthesis and Characterization ofCrSiN thin films deposited on Si(1 0 0) substrate. SurfaceEngineering.2010;26(8):596-5.
[12] MohamadRais Bin Ramli. Investigation on Surface Roughness of Mild Steel Using Coated Carbide Cutting Tools. Thesis. Faculty of Mechanical Engineering University, Malaysia Pahang. 2007.
[13] Benardos PG, Vosniakos GC. Predicting Surface Roughness in Machining: A Review. Int. J. Mach. Tools Manuf. 2003; 43(8): 833–844.
[14] Pina Bhatt, H.N.Shah. Morphological analysis of nitride coated steel for Industrial Application. Trends in Mechanical Engineering and Technology.2016;6(1);1-5.
[15] D. Raoufi, A. Kiasatpour, H.R. Fallah, *et.al*.Surface Characterization and Microstructure of ITO Thin Films at Different Annealing Temperatures. Applied. Surface. Science.2007; 253(23), 9085-9090.
[16] Gadelmawlaa, Kourab, Elewaa, *et.al.* Roughnessparameters. Journal of Materials Processing Technology.2002. 123(1).133–145.
[17] Rajesh Kumar, SubbaRao. AFM studies on surface morphology, topography and texture of nanostructured zinc aluminum oxide thin films. Digest Journal of Nano materials and Bio structures.2012.7 (4);1881-1889.