Journal of Manufacturing Engineering, March 2021, Vol.16, Issue.1, pp 029-031

D.C. MAGNETRON SPUTTERING COATING ON TRENCHES

Srikumaran V

Department of Mechanical Engineering, Arifa Institute of Technology, Esanoor, Tamil Nadu-610204, India

ABSTRACT

The development and application of plasma processing such as plasma assisted CVD and PVD become highly important in various industrial fields such as microelectronics, sensors, solar cells, automobiles, cutting tools, etc. In PVD different process are used such as Vacuum Evaporation, Electron Beam evaporation, Sputtering etc. But all processes have common limitation of one as such deposition is inline sight. It is difficult to achieve uniform coating on complex surfaces, holes and trenches. The width dimension and higher aspect ratio (Depth: width >1) of trenches generally in compatible with sputter deposition. When aspect ratio is increased, undesirable discontinuity can be observed at the lower half compared to upper half of trenches. So that 3 axis rotation of substrate holder was designed with a stepper motors to get uniform coating on complex surfaces and holes. The angle of rotation and the speed are controlled by programmed micro controller. By positioning the surface features perpendicular to the plasma the holes, grooves are coated uniformly. The coating was characterized using X-ray diffractometer, SEM and micro hardness tester.

Keywords: *Plasma processing, CVD, PVD, substrate holder, micro controller and X-ray diffractometer*

1. Introduction

PVD in the micro electronics industry generally refers to sputter deposition. Sputtering deposition is preferred in the PVD field. First, sputtering can be used to deposit all of the conducting films used in the interconnect metallization's. Second deposition of alloys can be accomplished from a single alloy target with the film retaining the stoichiometry [1]. This problematic with evaporation due to different individual vapor pressures. Third, the deposition rate can reach 1 μ m /min for thick films, sufficient for economical wafer fabrication. Fourth, sputter films have superior purity, micro structure and surface roughness for physical & process requirements. Finally, the use of an extended target area minimizes special variations of film thickness and shadowing with results in good step coverage over features provided aspect ratio <1 [2].

The isotropic nature of the sputter atoms, valuable for coherently coating over steps, edges and other low aspect ratio surface features, creates a problem for deposition into high aspect ratio [3]. The majority of the depositing atoms are moving at angles far from normal incidences, which results insignificant lateral deposition on the upper side walls. Such lateral build up quickly results in a narrowing and eventual closer of the trench or via. Since sputtered atoms are primarily neutral, trajectory cannot be controlled by electric fields. Mainly two approaches are used to fill the trenches, 1) the deposition of neutral species and 2) based on deposition of ions [4]. The former includes the geometrical filtering of the sputter flux and increase of the surface mobility of the deposited atoms on the wafer surface. The later controls incidence directionality by using in-flight ionization of a sputtered or evaporated flux tighter with acceleration of the metal ions to the sample using a bias voltage. In such case re sputtering and grazing angle ion bombardment can then be induced.

Long throw deposition is another geometrical filtering by moving the sample farther away from the target, an increasing fraction of the sputtered atoms which are moving mostly laterally are lost to the chamber walls. This practice requires low chamber pressure to reduce in flight gas scattering. It also introduce fundamental geometric asymmetric because the incidence angle distribution at the substrate edge is intrinsically different from that the center. Because of the long distance the deposition rate is also low.

Discussed about treating irregular targets for high ion flux and throughput for complex coatings. But still the achievement of uniformity is difficult.

So that we have designed 3 axis substrate holder for getting uniform coating on complex surfaces.

2. Experimental Details

The coating was done in Palaner D.C. Magnetron Sputtering machine. Sputtering is a process

**Corresponding Author - E- mail:srikumaranmech@gmail.com*

in which atoms are physically ejected from a surface by momentum transfer from energetic bombarding species of atomic levels. Magnetron sputtering uses glow discharge to generate a flux of ions incidents on the target surface. These ions cause atoms to be knocked free from target surface by impact transfer. Due to applying large potential difference between cathode (target) and anode (substrate) a plasma is formed. The line diagram of the system is shown in Figure 1.

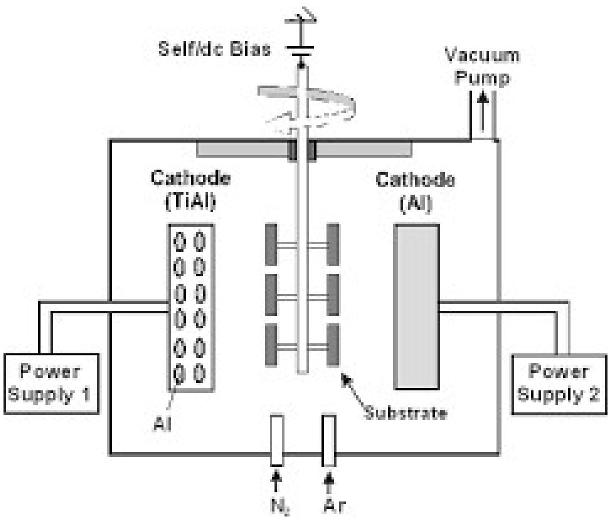

Fig. 1 PVD system

The deposition depends on bias voltage, distance between the target and substrate, argon gas pressure, substrate temperature. Especially in complex surface coating and trench filling the distance between the substrate and the target & the angular position of the substrate with the plasma are significant factors. So that a three directional rotational substrate holder has been designed and shown in Figure 2 to get uniform coating on trenches.

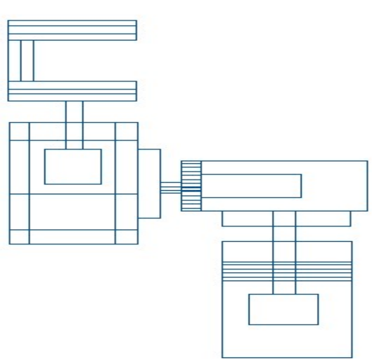

Fig. 2 Substrate holder with 3 stepper motors

3. Results and discussion

The Si plate size of 75x2.5x2 mm was coated with the copper at the condition of bias voltage 430V , current 1.08 ampere , time 3min at the distance of 50mm from the target and the argon pressure was maintained at 1 bar. During coating the chamber pressure was maintained at 0.02 mbar. The target size is 50.8mm diameter. The plate is positioned horizontally in the substrate holder in such a way that the top of plate facing the target perpendicular. The coating obtained was uniform which is shown in Figure 3.

Fig. 3 Copper coating on Si for normal position

The trench was made in Si with the aspect ratio of 3.5 (depth :width) as shown in Figure 4 was placed in the substrate holder with the normal position to the target.

Fig. 4 Before coating

The target was adjusted to maintain the distance at 50mm and coated with the condition of bias voltage 475V and pressure was maintained at 0.02mbar. But it was not coated uniformly which is shown in Figure 5.

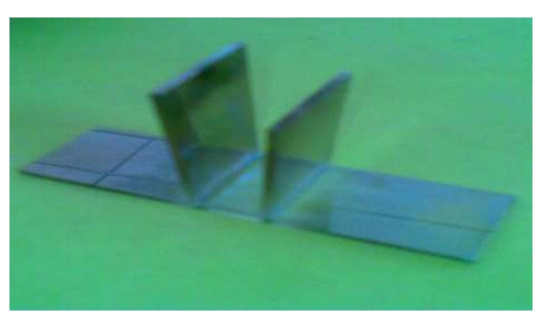

Fig. 5 Trench which is not evenly coated

To maintain the side walls of the trenches to expose more area with plasma, the various positions of box is simulated in AUTOCAD. Two positions of the drawing are shown in Figure 6, Figure 7 and Figure 8 for angle of inclination of 24.7 °& 45°. At 45° angles the side wall coverage was minimum. The maximum area coverage was identified in the inclination of X=24.7°and y=24.7°.

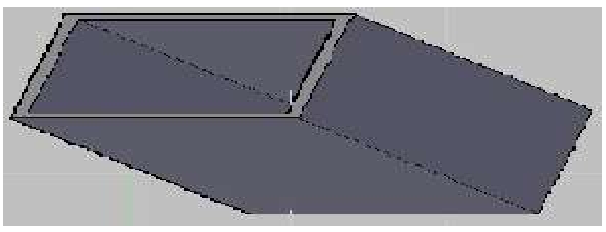

Fig. 6 Box inclination at 24.7°

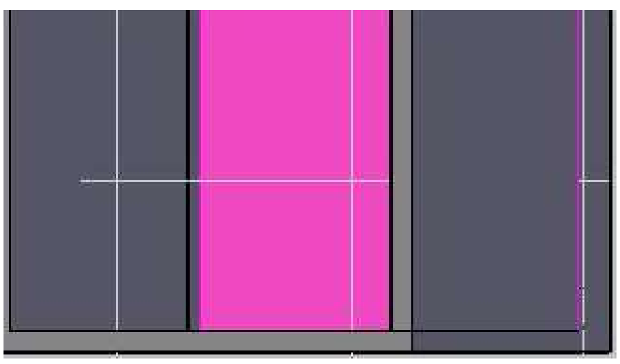

Fig. 7 The coloured part was the perpendicular area of the side wall with the plasma in angle of 24.7°

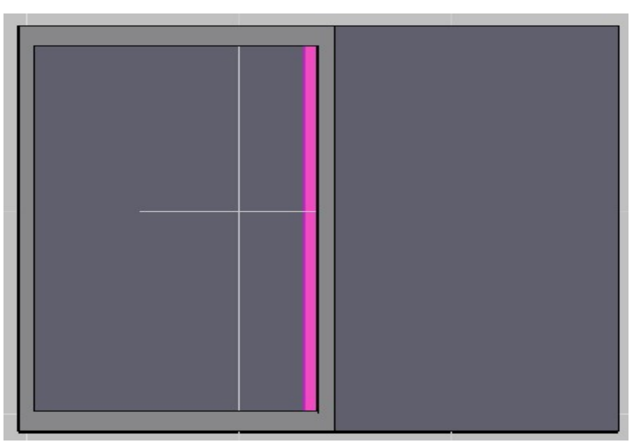

Fig. 8 The coloured area was the perpendicular area of the side wall with the plasma in angle of 40°

The trench was made in Si wafer and it was coated with copper at the angle of 24.7°to verify the uniformity which is shown in Figure 9.

Fig. 9 uniform coated side wall at 24.7°

To validate the results the coated parts are to be tested in X-raydiffaractometer and SEM.

4. Conclusions

A trench with a width of 10 mm and a depth of 30mm is coated with copper at an angle of 24.7. Other higher aspect ratio trenches and concave& convex surfaces are to be verified with substrate rotation for uniformity of coating.

References

1. *J R Conrad, J L Radtke, R A Dodd, F J Worzala, N C Tran (1987), "Plasma source ion-implantation technique for surface modification of materials", Journal of Applied Physics, 62 (11), 4591-4596*

2. *X B Tian, S Q Yang, Y X Huang, C Z Gong, G C Xu, Ricky K Y Fu, Paul K Chu (2004), "Two dimensional numerical simulation of nonuniform plasma immersion ion implantation", Suface and coating Technology, 186, 47-52*

3. *Y Miyagawa, H Nakadate, M Tanaka, M I keyama, S Miyagawa (2004), "Particle–in-cell/Monte carlo simulation for PBII processing of a trench shaped target and a cylindrical", Suface& coating Technology, 186,2-9*

4. *S Mändl, H Reuther, J Brutscher, R Günzel, W Möller (1997) "Measured and calculated dose distribution for 2d plasma immersion ion implantion" Suface and coating Technoloy, 93, 229-233*

