Influence of TaN/Ta Barrier Layer Thickness on Wafer Curvature and Via Chain Resistance

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Tantalum (Ta) and tantalum nitride (TaN) are extensively utilized in the semiconductor industry, particularly as barrier layers in integrated circuits. A common approach involves using a bilayer structure, where a layer of TaN is first deposited, followed by a layer of Ta to provide effective barrier performance against copper diffusion and ensures good adhesion to various substrates. [1] One of the most widely used techniques to obtain these thin bilayers is DC magnetron sputtering. [2] This study aims to analyze the effect that variations in bilayer thickness have on wafer curvature and via chain resistance. Bilayers are deposited on 300 mm wafers in a standard PVD chamber by Applied Materials (AMAT). During TaN deposition nitrogen (N_2) is used together with argon (Ar). During Ta deposition the same Ar flux is maintained and N_2 flow is stopped. The chamber is heated at 200°C. As a substrate, a silicon wafer with a 200 nm silicon oxide layer is used. The composition of the bilayer is varied by changing the deposition time for each layer. In Table 1, the RECIPEs used for this study are presented, distinguished by deposition time and deposition time ratio of TaN deposition time to bilayer deposition time.

The thicknesses of Ta and TaN layers are measured using Transmission Electron Microscopy (TEM) at the center of the wafer, with each measurement repeated three times for accuracy. Deposited bilayers have an average thickness between 65 nm and 85 nm. By analyzing the results, it is observed that the TaN deposition rate is slower compared to the Ta deposition rate by 5%. This behavior must be considered when designing deposition recipes.

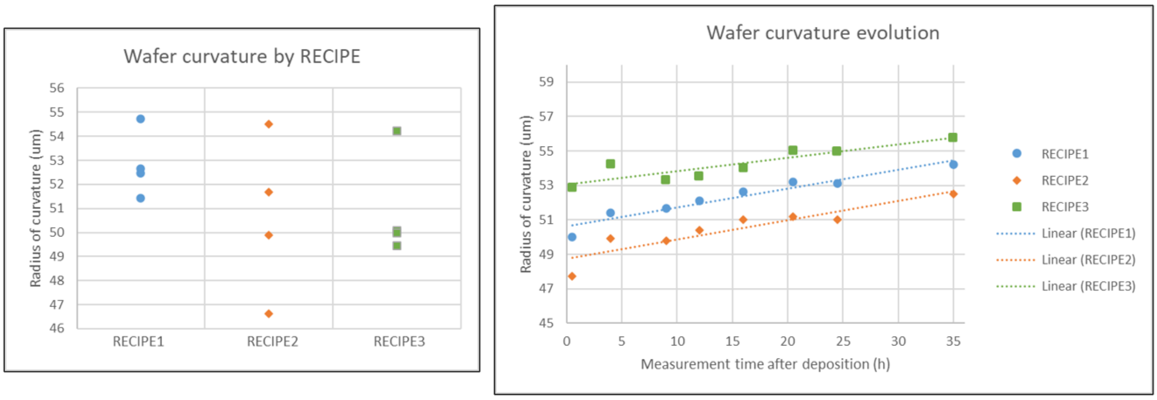
Thin metallic films deposited on wafers can induce stress, which can alter the wafer's curvature. A study was conducted to investigate the impact of bilayer thickness on curvature and its evolution over time. Films using RECIPE1, RECIPE2 and RECIPE3 were deposited to investigate composition influence by maintaining the same bilayer thicknesses. Four samples per each RECIPE were obtained and the change in the radius of curvature after deposition with respect to before deposition was measured (Figure 1a). Measurements for one sample of each kind were repeated at different times to monitor stress evolution (Figure 1b). The analysis demonstrates that the TaN/Ta bilayers induce a positive curvature, indicative of compressive stress, without a recipe dependence. Since tantalum is a high-density material, the induced stress is likely to be of intrinsic nature, given that the deposition temperature of 200°C is significantly lower than the tantalum melting point. [3] A slight change in curvature is observed over time, with a variation of about 4 µm detected 35 hours after deposition. For industrial applications, stress relaxation is negligible for this bilayer.

Via chain resistance is a critical parameter for barrier layers, as it directly impacts the performance of semiconductor devices. The influence of variations in the bilayer thickness on Copper Bondpad (CB)-via chain resistance was studied. Samples were tested on 9 different sites, and the CB-via chain resistance median for each wafer was calculated. The normalized resistance by wafer is reported in Figure 2a and Figure 2b. An increase in resistance is observed as the TaN thickness increases while maintaining the same total bilayer thickness. By changing the ratio of TaN deposition time to bilayer deposition time in the recipes from 0.23 to 0.26, an increase of 0.6% in the CB-via chain resistance of the device is observed. Additionally, an increase in resistance is also noted with an increase in the total bilayer thickness. By applying a change of 2s in the deposition time, the CB-via chain resistance in the device changes by 1%. However, the individual contributions of the TaN and Ta layers to this increase in resistance are more challenging to discern.

In this study, the TaN/Ta bilayer was first characterized by measuring single layer thicknesses using TEM; it was then observed that bilayer composition does not influence wafer curvature while an influence was shown for chain resistance. Correlations to thickness variations were evaluated. Given the significant role these films play in semiconductor devices, further studies are necessary to deepen our understanding and optimize their application.

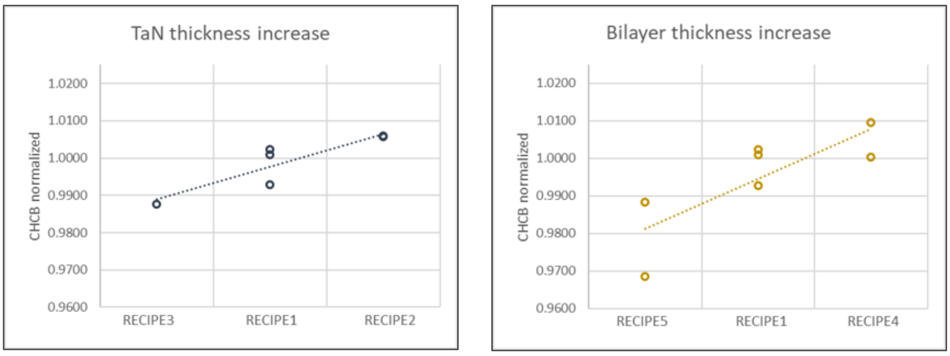
Table 1 The recipes used for this study are distinguished by deposition time and the ratio of TaN deposition time to bilayer deposition time.

RECIPE	BILAYER DEP TIME	TAN/BILAYER DEP TIME
RECIPE1	T1	0.25
RECIPE2	T1	0.28
RECIPE3	T1	0.23
RECIPE4	T1+1S	0.25
RECIPE5	T1-1S	0.25



a) b)

Figure 1 The change in the radius of curvature before and after deposition is plotted. a) Measurements for four different samples for each of RECIPE1, RECIPE2, and RECIPE3, which differ by TaN thickness, are reported. b) The evolution of the wafer curvature with respect to the time at which the measurement was performed after deposition is reported.



a) b)

Figure 2 The CHCB values are plotted by calculating the median value for each wafer and normalizing it by the average value of all measured values. a) Samples with the same bilayer thickness and different TaN thicknesses are compared. b) Samples with the same ratio of TaN deposition time to bilayer deposition time and different total bilayer thicknesses are compared.

References

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