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# Effects of Pre- and Post-treatment of TaN Barrier Metal deposited by Plasma Enhanced Atomic Layer Deposition (PEALD) Method on Electromigration Resistance in Cu Interconnect

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## 1. Introduction

Recently, atomic layer deposition (ALD) was proposed as the Cu barrier deposition method due to its excellent coverage ability and low via resistance, but some issues, such as low throughput and poor reliability, need to be resolved for manufacturing [1,2]. In this paper, we improved EM resistance for Cu interconnect with PEALD TaN Cu barrier metal by optimizing pre- and post-treatment using H2 or NH3 gas and direct contact via (DCV) process [3], respectively, for PEALD TaN film. And we tuned the plasma treatment time in PEALD TaN deposition process for application to mass production of sub-65nm Cu interconnect.

## 2. Experimental

PEALD TaN film was prepared from tert-amylimidotrisdim-ethylamidotantalum (TAIMATA) and H2 as precursor and reactant, respectively. The PEALD TaN layer was deposited at 300℃ on the dual damascene structure made of a SiOC low-k dielectric (k=2.9). Pre- and post-treatment were performed using H2 or NH3 gas at 200$^{o}$C prior to and DC-biased Ar+ plasma posterior to PEALD TaN deposition, respectively

## 3. Results and Discussion

We optimized PEALD TaN deposition process by tun-ing the plasma treatment condition, and then we achieved the low resistivity of 280uohm cm with under 3% (1 sigma) uniformity for PEALD TaN film. From the AES analysis, it was shown that this PEALD TaN contains carbon contents about 20% as can be seen in Fig. 1. We also confirmed Ta-C bonding by using XPS (Fig. 2).

In the previous work [4], it was reported that the diffusion barrier property can be degraded by high carbon contents in TaN film and consequently copper silicide can be formed at the interface of Cu and TaN in multi-stacked Cu / TaN / Si films by diffusion of silicon through TaN film. So, we investigated the Cu diffusion barrier property at the temperature up to 450$^{o}$C during 1 hr for PEALD TaN film. For this test, multi-stacked films with SiO2 / PEALD TaN 30Å / Cu 1000Å on Si wafers are used and we concluded that the Cu does not diffuse even through PEALD TaN 30A film at the temperature up to 450$^{o}$C by the AES analysis in Fig. 3.

To apply PEALD TaN film for Cu barrier metal in Cu interconnect, we adopted the pre- and porst-treatment using H2 or NH3 gas prior to PEALD TaN deposition and direct contact via (DCV) process, respectively, for removing the copper oxide and polymer residue at the bottom of via after via etching process. Additionally, PVD Ta is subsequently deposited onto PEALD TaN film to improve the adhesion between Cu and TaN. Fig.4 shows that metal resistance is slightly reduced according to application of H2 or NH3 treatment before PEALD TaN deposition. There is insignificant different in Leakage current between metal and metal regardless of pre- and post-treatment condition (Fig. 5). Fig. 6 represents the via chain resistance according to pre- and post-treatment conditions for PEALD TaN film. Both the value of via chain resistance and its distribution in Cu interconnect with only PEALD TaN for Cu barrier metal are dramatically reduced by applying PEALD TaN/PVD Ta bilayer for Cu barrier metal. And via chain resistance is additionally decrease by adopting the pre- and post-treatment, which can be explained by removal of copper oxide and via residue or decrease of barrier metal thickness at the bottom of via. We also confirmed the effect of queue time between pre-treatment and PEALD TaN deposition on via chain resistance (Fig. 7), which is concluded that the via chain resistance is abruptly increased with queue time, 10hrs. So, the result of via chain resistance in Fig. 6 is achieved by the queue time control between pre-treatment and PEALD TaN deposition under 5 hrs.

Finally, we considered the EM resistance according to pre- and post-treatment for PEALD TaN film. In via upstream EM test, there is insignificant difference in EM failure distribution regardless of pre- and post-treatment condition (Fig. 8(a)) . However, in via downstream EM test, EM failure distribution shows two failure mode according to pre- and post-treatment condition (Fig. 8(b)). EM failure distribution for Cu interconnect using only PEALD TaN film shows early failure mode with gentle slope. However, as the pre-clean and DCV process is applied, EM failure distribution is changed to late failure mode with steeper slope : In case of EM failure distribution with pre-clean

represents bimodal failure distribution. It means that the pre-clean uniformity is deteriorated within the wafer compared with Ar+ re-sputtering uniformity in DCV process.

## 4. Conclusions

In this paper, we developed mass productive PEALD TaN film using TAIMATA precursor and investigated its Cu barrier chacteristics and EM reliability according to pre- and post-treatment condtion for PEALD TaN film in Cu interconnect. From the good Cu barrier metal property and high EM resistance by optimizing pre- and post-treatment PEALD TaN film, we concluded that PEALD TaN film is applicable for mass production of Cu nano-interconnect sub 45nm technology.


## Acknowledgements

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## References


[1] H. Chung et al., *Proc. ISSM*, (2003) 454.

[2] T. Oshima et al., *IEEE IEDM Proc.*, (2002) 757.

[3] H.C. Lee et al., *SSDM* (2006) pp 146~147.

[4] AMAT presentation material (2006).


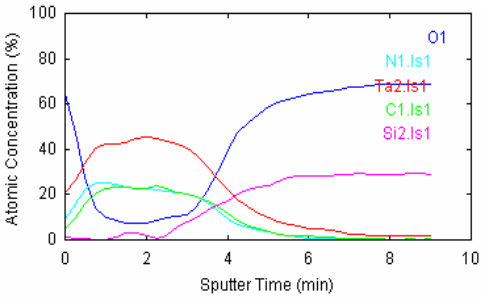


Fig. 1. AES analysis result for component concentration within TaN film

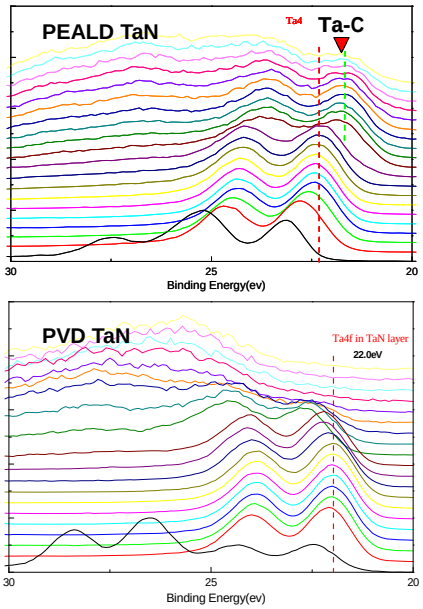


Fig. 2 XPS analysis results of PEALD TaN and PVD TaN

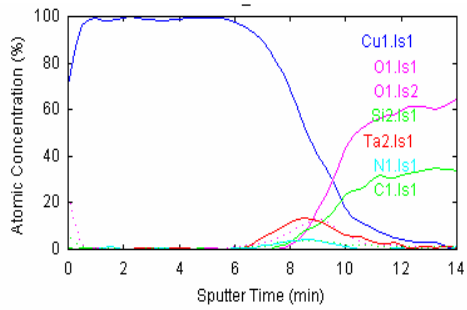


Fig. 3 AES Analysis result of Cu/PEALD TaN/SiO2 after 450℃, 1hr for investigation diffusion barrier properties

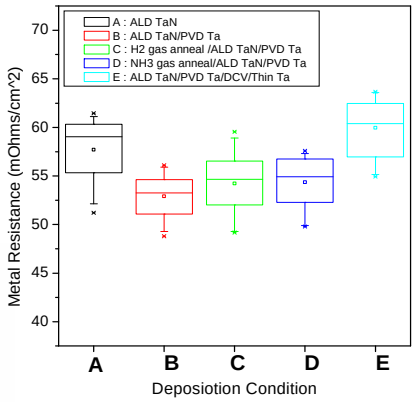


Fig. 4 The change of metal resistance as a function of pre- and post treatment

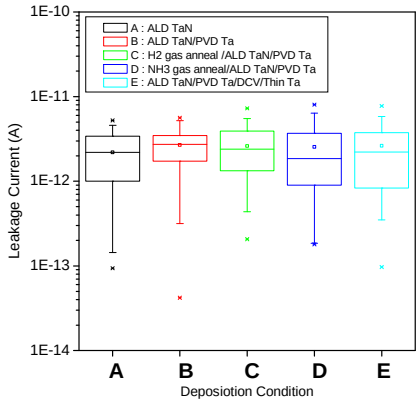


Fig.5 Leakage current result between metal and metal line according to pre-and post treatment

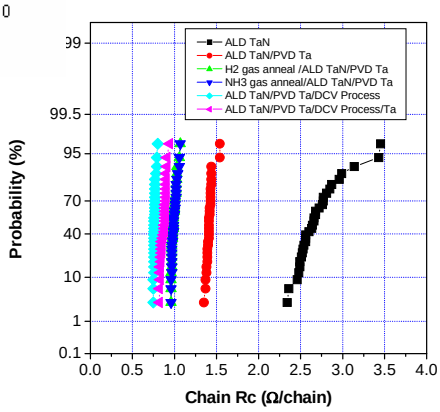


Fig. 6 via chain resistance according to pre- and post-treatment conditions for PEALD TaN film deposited within 5hrs

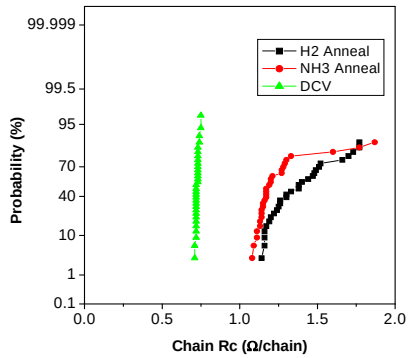


Fig. 7 The change of via resistance according to queue time of 10 hrs in between pre-treatment and PEALD TaN deposition

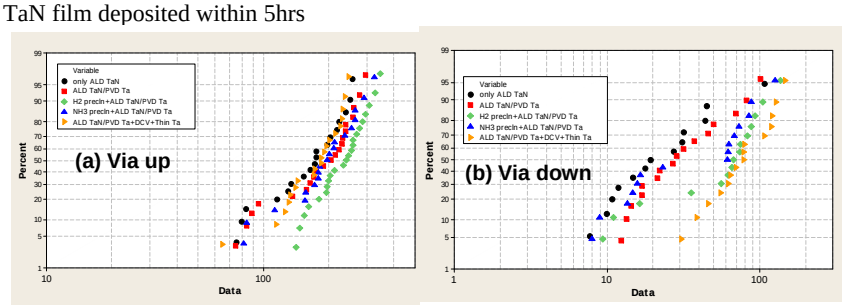


Fig. 8 EM resistance according to pre- and post-treatment for PEALD TaN film under 2MV/cm at 325℃