Plasma Enhanced Atomic Layer Deposition of Cu for Interconnect Applications

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Cu is employed as a primary interconnect material owing to its low resistivity and high electromigration resistance. Current processes for interconnect formation typically require a copper seeding layer to enable a high quality electrochemical deposition (ECD) filling step. This seed layer is typically deposited using a non-conformal ionized physical vapor deposition (iPVD) process. However, the continuous interconnect scaling will require a more conformal Cu seed layer to allow complete filling narrow interconnect structures. Among candidate processes for emerging seed layer processes, atomic layer deposition (ALD) is under strong consideration because of its excellent conformality and thickness control capability.[1] In particular, plasma enhanced ALD (PEALD) has additional advantages compared to thermal ALD, including high film density and low processing temperatures, the latter being critical to prevent thin Cu films from agglomerating. However, while a number of groups have reported the growth of Cu films by ALD, to date no practical ALD Cu processes have been established.[2, 3,4]

In this research, $Cu^{II}(acac)_2$ was selected as the Cu precursor because of its non-flurorinated character, excellent thermal stability, and demonstrated self-limiting growth mechanism.[2] The processes were carried out using a modified 200mm wafer capable commercial processing tool. $Cu^{II}(acac)_2$ was delivered into the chamber with use of He carrier gas. H_2 was used as both purge gas and reactant (with the application of a plasma). For this work, a wafer temperature of 80°C was used, the rf plasma power ranged from 10W to 1000W. PEALD Ru and PVD TaN were used as substrates.

Self-limiting PEALD Cu growth behavior was observed, as shown in Figure 1, which plots Cu growth rate on Ru substrate as a function of precursor pulse time saturating at ~0.2Å/cycle. Figure 2 is an SEM image showing a 10nm thick continuous thin Cu film deposited directly on TaN. Figure 3 is an AES profile shows the composition of a typical PEALD Cu film grown on TaN. A purity of greater than 95% Cu is observed, with O, C and N concentrations all at noise level, except the oxidized layer on the surface. For a 30nm thick Cu film, the resistivity was approximately 5μΩ-cm on TaN and 8μΩ-cm on Ru. Additionally, conformal deposition was observed over high aspect ratio (5:1) structures. All Cu films passed a scotch tape adhesion test. These results suggest that PEALD Cu is a promising approach for advanced seed layer applications in CMOS metallization.

References

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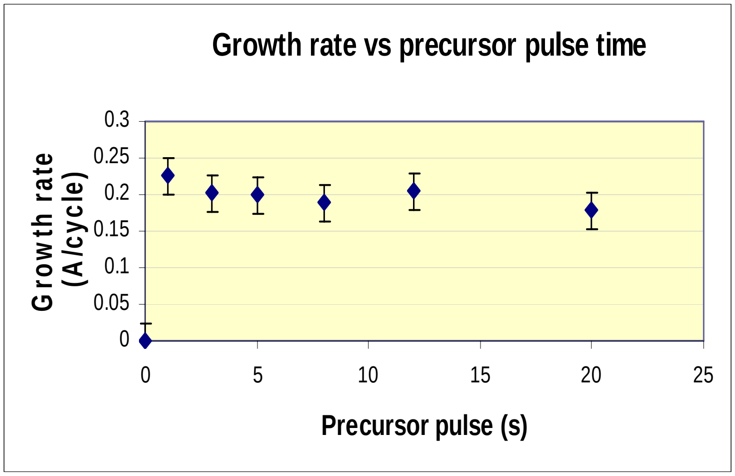

Figure 1. Precursor pulse saturation curve: growth rate vs precursor pulse time on PEALD Ru substrates. Saturated growth is observed.

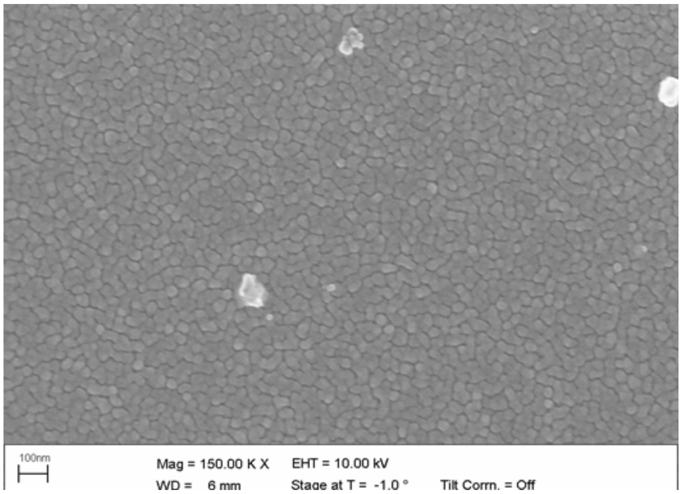

Figure 2. SEM image of 10nm continuous Cu film on TaN

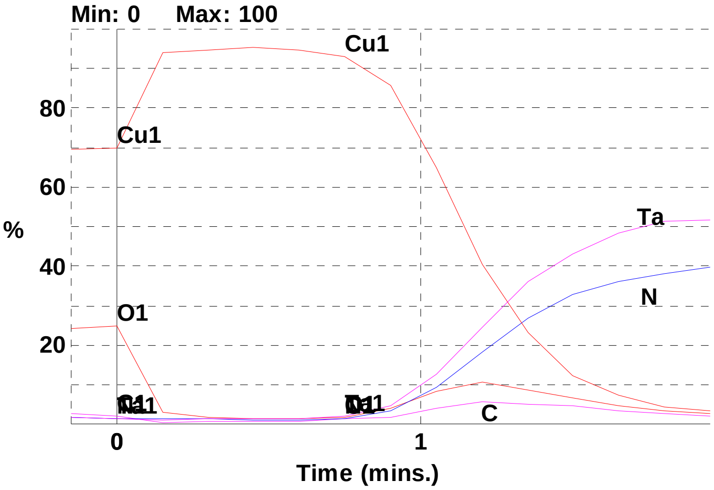

Figure 3. AES depth profile of 30nm Cu film on TaN. Cu purity is >at. 95%.