Abstract #2217, 224th ECS Meeting, © 2013 The Electrochemical Society

"Development of Multifunctional Liner/Barrier Systems for Sub-14nm Metallization"

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The use of Cu damascene for interconnects in traditional semiconductor technology requires the use of a sputtered seed layer to enhance the electrochemically deposited (ECD) Cu. The Cu seed layer is deposited on top of a sputtered Ta/TaN bi-layer stack. The Ta layer acts as an adhesion layer between the Cu seed and the TaN layer. The TaN layer prevents the Cu from diffusing out of the interconnect. As devices continue to shrink scaling this stack becomes more difficult making a barrier layer that can be direct plated become increasingly attractive.[1]

Our preliminary work in this area has shown that mixed phase materials composed of refractory metal-based pairs such as Ru/TaN and Ru/WCN, grown by plasma enhanced atomic layer deposition (PEALD), can perform as directly platable Cu diffusion barriers.[2,3] While such direct plate liners were developed using conventional barrier materials such as TaN and WCN, and have been shown to work effectively, subsequent studies have been performed by consideration that direct plate liner extendibility may be enhanced by employing a barrier metal with a lower intrinsic resistivity without the presence of carbide or nitride phases that prevent the diffusion of Cu.

In considering suitable materials for this application, both the ability to support copper electrodeposition as well as good intrinsic copper and oxygen diffusion barrier performance are all critical characteristics. Based on reports in literature[4], and the fact that Co should reduce in a standard ECD Cu bath at about -0.4 volts, Co was selected as material to investigate for replacement of conventional barrier materials in direct plate barriers by combining with Ru to form RuCo mixtures.

Figure 1 shows a 3nm RuCo film with a Ru/Co metal ratio of 5 deposited by PEALD. The film does not exhibit the phase separation seen previously in PEALD grown RuTaN or RuWCN systems, which is consistent with reports in literature that Ru and Co are miscible[5,6] it is believed the RuCo film is forming a solid solution, rather than a mixed-phase nanocomposite as with the other directly platable barriers. As with the other materials evaluated, Cu has successfully been plated onto 2-3nm thick PEALD RuCo liners.

With respect to diffusion barrier testing, Figure 2 shows the results of triangle voltage sweep testing, which yields a semi-quantitative measurement of copper barrier performance. The results show that the PEALD Co and RuCo films (varying in metal ratios from 5:1 to 15:1 Ru/Co) are all comparable to PVD TaN, which is used as a benchmark. Cu ion migration through Ru films is several orders of magnitude higher, consistent with data indicating that Ru is known to be a poor Cu diffusion barrier.[7]

The effects of changing the component metals, metal ratio, and film thickness on the subsequent diffusion barrier and direct plate characteristics of these novel liner materials can be complex, and can relate to the material performance via the corresponding structural, compositional, and electrical characteristics of the liners. These interactions will be discussed, and the implications for the ultimate scalability of metallic copper diffusion barriers will be presented.

This work was supported by the Semiconductor Research Corporation (SRC) and the New York State Office of Science, Technology and Academic Research (NYSTAR) as part of the New York Center for Advanced Interconnect Science and Technology (NYCAIST).

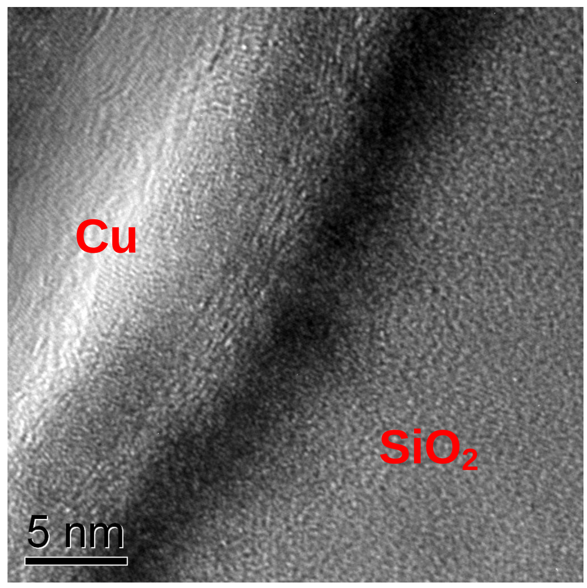

Figure 1 - TEM image showing ECD Cu on a 3nm 5:1 metal ration RuCo film.

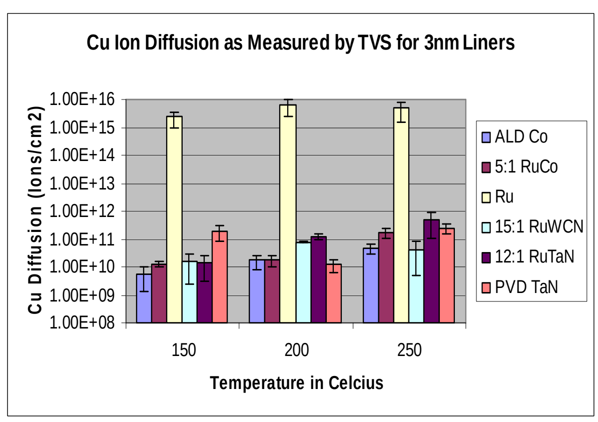

Figure 2 - Cu ion migration through 3nm thick liners. All liners are comparable to the PVD TaN standard, except for Ru which is known to be a poor Cu diffusion barrier.

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