ALD Applications
Room On Demand - Session AA7
Applications in ULSI BEOL: Interconnects, Diffusion Barriers, Low-k

AA7-1 Grain-Resistivity Relationship of Ru ALD Precursors*, Michael Breeden, V. Wang,* University of California at San Diego*; R. Kanjolia, M. Moinpour, J. Woodruff,* EMD Performance Materials*; H. Simka,* Samsung*; A. Kummel,* University of California at San Diego

Ru is viewed as an alternative to Cu and Co interconnect layers at M0/M1 due to its lower effective resistivity in confined vias. In addition, Ru's low diffusion into porous low-K dielectrics (SiCOH) removes the need for a barrier layer, further decreasing effective resistivity [1,2]. However, the search for a Ru ALD process that can deposit Ru with near-bulk resistivity (6 μΩ·cm) is ongoing, with an emerging interest in selective ALD without passivants. In this work, the grain structure-resistivity relationship for 300C Ru ALD with precursors Ru-Carish ($Ru(IHD)_2(CO)_2$) and $Ru(CpEt)_2$ using O_2 as co-reactant were investigated by four-point-probe measurements, in-situ X-ray photoelectron spectroscopy (XPS) for chemical composition, and X-ray diffraction/reflectometry (XRD/XRR) for grain size and thickness.

Ru ALD precursor dose studies have shown a relationship between the precursor dose and resistivity. To limit pressure through the turbomolecular pump, multiple precursor pulses were dosed to control dosing. For Ru ALD using Ru-Carish on SiO_2, doubling the Ru-carish dose decreased resistivity from 18.5 to 10.2 μΩ·cm at 40 nm thickness. This effect can be attributed to the additional precursor dose consuming oxygen to form volatile RuO_4 resulting in a film with less oxygen content. Furthermore, film thickness can be scaled to 16 nm without increasing resistivity, consistent with studies showing the deposition mechanism involving the presence of adsorbed oxygen, promoting nucleation and reducing resistivity [3].

While the Ru-Carish process requires passivation for selective ALD, inherent selectivity using $Ru(CpEt)_2$ is demonstrated with low resistivity. Substrate selectivity for the $Ru(CpEt)_2$ precursor on SiO2 was demonstrated, with increased oxygen dose increasing the growth rate, but retaining high selectivity after 350 cycles. A resistivity-oxygen relationship can be observed, with a doubling of oxygen dose reducing resistivity from 14 to 9 μΩ·cm for a 30 nm film and XRD showing an increase in grain size from 18 nm to 28 nm for the Ru(002) orientation. Additionally, post deposition forming gas anneal at 450C for 30 min further reduced the resistivity to 8.1 μΩ·cm. These low resistivity Ru ALD processes have potential to allow for low-resistivity Ru films in barrierless via filling for M0/M1 interconnect fill, and the $Ru(CpEt)_2$ precursor shows promise for selective Ru ALD without passivation.

1. D. Gall. J. Appl. Phys, 2020 **119**, pp. 050901.

2. X.P. Qu, et al. Appl. Phys. Lett., 2006, **88**, pp. 151912

3. T. Aaltonen, et. al. Electrochem. & Solid State Lett. 2003, 5 pp. C130-C13

AA7-2 Atomic Layer Deposition of RuO_2 Using a New Metalorganic Precursor as a Diffusion Barrier for Ru Interconnect*, **Youn-Hye Kim,*** Yeungnam University, Korea (Republic of)*; Y. Kotsugi,* Tanaka Precious Metals, Japan*; T. Cheon, R. Ramesh, S. Kim,* Yeungnam University, Korea (Republic of)

The extremely narrow dimensions required for the metal interconnect in the sub-10 nm technology node would lead to very high electrical resistance of Cu due to the significant influence mainly from the surface scattering of electrons. For these reasons, the trend in interconnect technology is changing from Cu to Ru due to its low resistivity at narrow line width. However, there are some reports that Ru starts to diffuse into Si at temperature above 700°C. Therefore, a diffusion barrier layer is required to prevent diffusion of Ru that degrades electrical properties. In this regard, RuO_2 has good properties as a diffusion barrier, such as low resistivity(~46 μΩ・cm), high chemical and thermal stability. In this study, the RuO_2 thin films were grown at the relatively low temperature of 180 °C by ALD using the new liquid Ru precursor, tricarbonyl (trimethylenemethane) ruthenium and O_2 molecules for diffusion barrier application of Ru interconnect. For optimization of deposition parameters, the effects of pulsing time ratio (t_{O2}/t_{Ru}) and deposition pressure on the formation of RuO_2 phase were investigated. The formation of a RuO_2 phase is favorable with increasing the pulsing time ratio (t_{O2}/t_{Ru}) and deposition pressure. It was also demonstrated that Ru single phase, the mixture phase of Ru and RuO_2, and RuO_2 single phase could be controllably grown with deposition condition. The ALD-RuO_2 films deposited with optimized conditions have a resistivity of ~103 μΩ・cm and a growth rate of ~0.056 nm/cycle with short incubation cycles of 15. The non-barrier layer structure [ALD-Ru(50 nm)/Si] began to lose its stability by forming ruthenium silicides at 750 °C, while the structure with a barrier layer [ALD-Ru/ALD-RuO_2 (5 nm)/Si] were stable up to 850 °C. This indicates that the ALD-RuO_2 thin films have superior performance in preventing the diffusion of Ru. Furthermore, it is expected to improve the process throughput by depositing in the same chamber using same precursor and reactant as Ru.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (2021R1A2C1007601).The precursor used in this study was provided by Tanaka precious metals in Japan.

Author Index

Bold page numbers indicate presenter

— B —
Breeden, M.: AA7-1, **1**
— C —
Cheon, T.: AA7-2, 1
— K —
Kanjolia, R.: AA7-1, 1
Kim, S.: AA7-2, 1
Kim, Y.: AA7-2, **1**
Kotsugi, Y.: AA7-2, 1
Kummel, A.: AA7-1, 1
— M —
Moinpour, M.: AA7-1, 1
— R —
Ramesh, R.: AA7-2, 1
— S —
Simka, H.: AA7-1, 1
— W —
Wang, V.: AA7-1, 1
Woodruff, J.: AA7-1, 1