ATOMIC LAYER DEPOSITION OF RUTHENIUM GLUE LAYER FOR COPPER DAMASCENE INTERCONNECT

Oh-Kyum Kwon, Jae-Hoon Kim, and Sang-Won Kang

Department of Materials Science and Engineering, Korea Advanced Institute of Science and Technology, 373-1 Guseong-Dong, Yuseong-Gu, Daejeon, Korea 305-701

As the packing density of microelectronic devices increases, copper is regarded as a potential interconnection metal to enhance operating speed and reliability.[1] Electrochemical deposition (ECD) is widely acknowledged as the process of choice for the main damascene fill process. ECD process requires thin copper seed layer in general. Currently, copper seed-layer is usually deposited using a PVD technique. However, PVD technique is inadequate owing to its inherent inability to deposit conformal thin films as the aspect ratio of submicron features increases. Therefore, copper interconnect may require introduction of CVD method for the seed layer. Since, however, copper films deposited by CVD have poor adhesion to common barrier metals such as TiN and TaN, they peel easily during subsequent CMP process. Copper interconnect structures, therefore, need glue layer for reliable adhesion.

Generally, the deterioration of surface condition during copper CVD by residual F and C has been regarded as the major cause of poor adhesion of copper films.[2] To address this issue, we have performed atomic layer deposition (ALD) of ruthenium thin films. Ruthenium was selected as a glue layer due to low reactivity with F, C and being immiscible with copper. Also, as known, ALD, in which reactants are supplied as non-overlapping pulses in order to prevent gas phase reaction, can achieve near perfect step coverage and precisely control the film thickness in an atomic scale.[3, 4]

ALD of ruthenium thin film was carried out on 5-inch TiN(20 nm)/SiO_2(100 nm)/Si wafer at a deposition temperature of 270 □ and a pressure of 1 Torr in a cold-walled reactor using bis(ethylcyclopentadienyl)ruthenium [$Ru(EtCp)_2$] as a precursor of ruthenium. One deposition cycle of ruthenium ALD consisted of an expose to $Ru(EtCp)_2$ vapor, a purge period with argon, an expose to oxygen gas, and another purge period with argon. Deposited ruthenium films were characterized by scanning electron microscope (SEM), transmission electron microscopy (TEM), and elastic recoil detection (ERD-TOF). The concentration of F, C at the interface of Cu/Ru and Cu/TiN was analyzed by secondary ion mass spectroscopy (SIMS).

A cross sectional SEM image of an ALD ruthenium thin film deposited on trench pattern is shown in Fig. 1, which shows excellent step coverage. The deposition rate per cycle was 0.15 nm/cycle, and the resistivity of ALD ruthenium film was about 16 μΩ·cm. The impurities in ruthenium were carbon (2 at. %) and oxygen (2 at. %).

A peel-off test using 3M scotch tape confirmed that ALD ruthenium glue layer greatly improved the adhesion of CVD Cu to TiN. 1μm-thick CVD copper films were deposited on ALD ruthenium with various thicknesses. As shown in Table 1, the adhesion of 1 μm-thick copper films deposited on the stacked films of 4 nm-thick ruthenium glue layer and TiN films were excellent without any fail in the Scotch tape peel test. SIMS analysis confirmed that the enhancement of adhesion strength was attributed to the decrease of interface contamination such as F, C by introducing ruthenium glue layer. Thus, it is concluded that the ALD ruthenium films were effective as a glue layer between CVD copper and diffusion barrier metal of TiN.

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References

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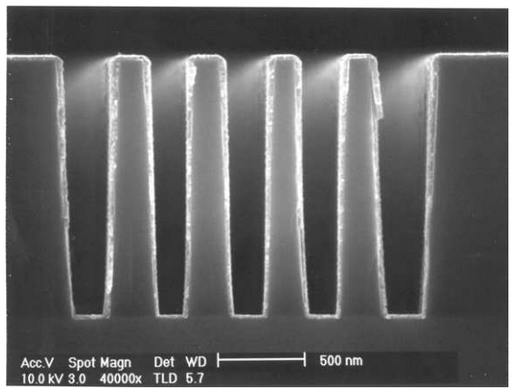

Fig. 1. Cross sectional SEM image showing the excellent step coverage of an ALD ruthenium.

Thickness of ruthenium layer on TiN	4 nm	10 nm	15 nm	20 nm
Tape peel-off test	Pass	Pass	Pass	Pass

Table 1. The results of adhesion test.

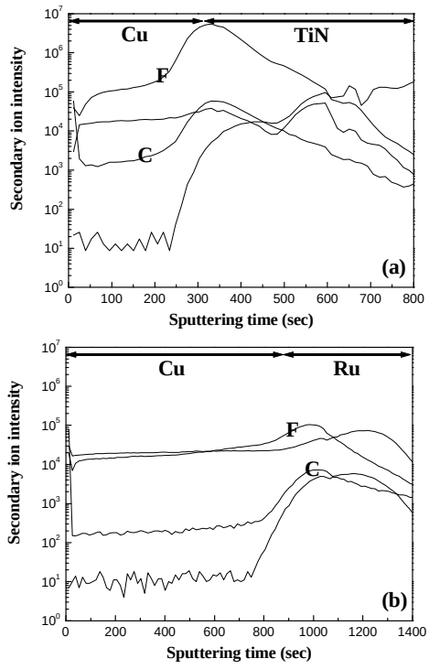

Fig. 2. The depth profiles of copper films (a) on TiN, (b) on ruthenium substrates.