LOW TEMPERATURE Cu THIN FILM GROWTH USING CYCLES OF ALTERNATE SUPPLY OF (HFAC)$Cu^{(I)}$(DMB) AND Ar PURGE GAS

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Introduction

Deposition of copper thin films has been studied for the next generation of ultra-large-scale integration (ULSI) devices. Copper has lower resistivity than aluminum and also it has higher resistance to electro-migration (EM) and stress-migration (SM). Several growth methods have been used to deposit copper thin films, which include physical vapor deposition (PVD), metal-organic chemical vapor deposition (MOCVD), atomic layer chemical vapor deposition (ALCVD), and electroplating [1]. Among these methods, MOCVD and ALCVD are most appropriate for filling via/trench structures because they are based on surface reactions and ensure high conformal, uniform thin film growth. In this investigation, we deposited thin and continuous Cu films using cycles of alternate supply of (hfac)$Cu^{(I)}$(DMB) pulse and argon purge gas. This pulsed-MOCVD grown films were compared with those deposited by MOCVD to investigate the effects of purge steps in pulsed growth.

Experiment

(Hfac)Cu(DMB) was used as a Cu precursor. The Cu films were deposited on the Ta/Si substrate A bubbler containing (hfac)Cu(DMB) was maintained at room temperature. The carrier gas (Ar) was bubbled through the liquid (hfac)Cu(DMB) precursor to carry the Cu source into the reactor via a delivery line kept at a temperature of 50 °C. The Cu deposition was performed at 70 °C. The Cu growth was proceeded by cycles of two steps. A cycle consisted of a 20 s Ar purge step, then a 5 s (hfac)Cu(DMB) pulse step. Ar gases as carrier gas for Cu precursor and purge gas were dosed by 40 sccm and 200 sccm, respectively.

Results and Discussions

Fig. 1 shows a plot of the Cu film thickness versus the number of cycles. The growth temperature was 70 °C. The thickness of Cu films was ranged from 38 nm to 100 nm on the Ta/Si substrates. The thickness increases linearly with an increase in cycle number. The growth rate for Cu film deposited was estimated to about 0.75 Å/cycle. A lattice constant of Cu (fcc) is 3.62 Å. Thus, the growth rate for Cu film was less than a monolayer, which makes controlling film thickness convenient in nano-meter scale Cu film growth.

Fig. 2 shows the plane SEM images of Cu films on the Ta/Si substrates. For comparison between films grown by pulsed MOCVD and those by MOCVD, the morphology of both films was shown. SEM results showed that Cu films deposited by pulsed-MOCVD were dense, uniform, and continuous, while films grown by MOCVD showed voids in the films. The void formation of MOCVD films was decreased as the film thickness increased.

Fig. 3 showed the resistivity of Cu films grown by pulsed MOCVD and MOCVD. The measured resistivity for both Cu films was somewhat high in comparison with bulk Cu (1.67 μΩ·cm). Pulsed MOCVD Cu films showed much lower resistivity than MOCVD Cu films. In the case of 1000 cycles, the Cu film thickness was about 100 nm and the resistivity of the Cu film was about 6 μΩ·cm. The relative high resistivity compared to bulk Cu is due to some impurity concentrations and thin film effects. On the other hand, MOCVD Cu films showed much higher resisitivity over 90 μΩ·cm is thought to be due to the void formation as shown in SEM results and high impurity concentrations as shown in XPS results.

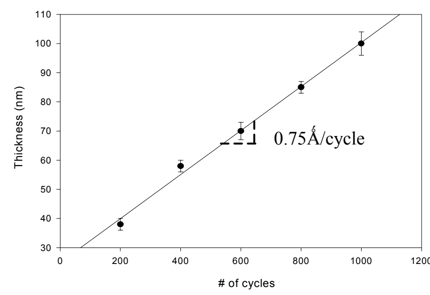

Fig. 1 Dependence of film thickness on the number of cycles

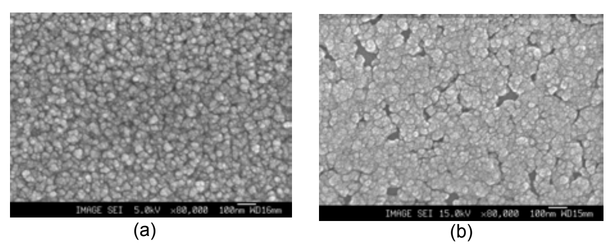

Fig. 2 Cu films deposited by pulsed MOCVD (a) and MOCVD (b), respectively.

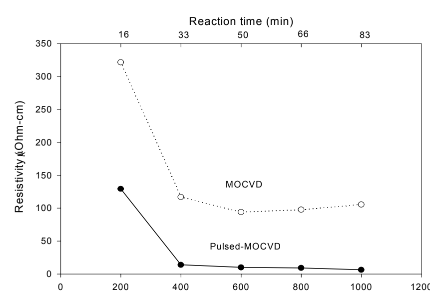

Fig. 3 Comparison of resistivities of Cu films deposited by MOCVD and pulsed-MOCVD.

CONCLUSIONS

Cu films on the sputter-deposited Ta/Si substrate were deposited at the growth temperature of 70 °C by alternate supply of (hfac)Cu(DMB) and argon purge gas. Growth rate of Cu film was about 0.75 Å/cycle, which represent submonolayer growth per cycle. The Cu films deposited by pulsed MOCVD showed lower impurity concentrations, better resistivity, and better uniformity than those by MOCVD.

[1] Raj Solanki, Balu Pathangey, Electrochem. Sol. Sta. Lett. 3 (2000), 479.