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Ag diffusion in Low-K material (SiOC and BCN) and its challenges using as an interconnection

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Abstract

As diffusion barrier liner in Cu/Low-K interconnection is one of serious issues for post 45nm generation, we have investigated the diffusion behavior of Ag and Cu in low-k material such as SiOC and BCN (Boron-Carbon-Nitride) films. From the depth profiles of Low-k film after annealing, it was found that Ag+ diffusion was less in SiOC film compared to Cu+ diffusion.

From the I-V characteristics, it is observed that current increases in SiOC dielectric film but the variation for Ag electrode was less than the Cu electrode. It can be demonstrated that to improve the RC delay time, Ag can be used as it has lower resistivity and lower diffusion than the Cu. In addition, as a low-k dielectric BCN film, which contains N atom, can suppress metal (Ag, Cu) diffusion compared to the SiOC film.

Introduction

As devices are scaled down below 45 nm in system LSI applications, it is found that higher packing density reduces the signal transmission time (i.e. RC delay), which in turn curtail the benefits of interconnection scaling. In order to reduce the time delay of ULSI circuits, interconnection materials with a low resistance and interlayer films with a low dielectric constant are required. Diffusion barrier liner in Cu/Low-K interconnection is one of serious issues for post 45nm generation. Ru liner as barrier material has been investigated. [1].

As silver has high electromigration resistance [2], it will be a next selection with thin barrier metal or without barrier metal, which has not been reported yet.

In this paper, we evaluate the Ag and Cu drift behavior in low-k such as SiOC and BCN and try to find out the possibility of using BCN as an inter-level dielectric material. Moreover, the BCN film composed of N atoms with high electronegativity and it has a low dielectric constant of 1.9 without porous structure. [3]

Experimental

Si substrate was used for the deposition of BCN dielectric film. Samples were placed on the holder and were placed inside the reactor tube for deposition of BCN film. BCN films of nearly 300 nm in thickness were obtained. To investigate the diffusion behavior, Cu and Ag deposition were done on the BCN and SiOC(400 nm) film surface. For I-V measurements, Cu and Ag electrodes were also made. A thermal annealing was carried out in N_2 gas ambient at 390C for 1 hr. Glow Discharge Optical Emission Spectroscopy (GDOES) was used to study the depth profile. In GDOES method, sputtered molecule is excited by plasma and the optical emission spectra are detected. As in this method, the measurement of optical spectrum and sputtering of the sample surface are done at the same time, just like the method of SIMS a depth profile can be measured. In addition, in GDOES method very low sputtering energy is used which is of two orders of magnitude less than the SIMS. The ion-mixing and knoking-on effect are not also observed.

Results and discussion

Fig. 1 (a) and (b) represent the model of interconnection how to change from 90 nm to below 50 nm for the future high-density circuit. Fig. 2 shows the simulation result using Ag and Cu with various wiring widths. It is observed that with decreasing the width of wiring, resistance increases more for Cu metal. For silver metal, resistance increases also but it is very slowly. Fig. 3 represents GDS result for Ag and Cu depth profiles in SiOC film after annealing. It is observed that Ag diffuses less in SiOC film compared to the Cu. Fig. 4 (a) and (b) show the I-V characteristics before and after annealing when Ag and Cu were used as an electrode, respectively. It is observed that both for Cu and Ag electrodes, current increases more comparing to the without annealing but for Cu electrode, current increases more than the Ag electrode after annealing. Fig. 5 represents depth profiles of silver diffusion in BCN and SiOC dielectric film after annealing. Fig. 6 shows the silver diffusion behavior in BCN film before and after annealing. In BCN film with and without annealing silver depth profile does not show much difference. From these two depth profiles of silver, it is assured that BCN has more resistance of diffusion than the SiOC film.

Conclusion

Using Ag and Cu, the diffusion behavior with and without annealing is studied. It is observed that Ag diffusion in low-k film suppresses more than the Cu. Moreover, it is also found that the BCN film can suppress metal (Ag, Cu) diffusion compared to the SiOC film. From the electrical characteristics, it is observed that when annealing is done, a less variation of current is observed in case of silver electrode. From the physical and electrical characteristics results, it is demonstrated that for the next generation there is a possibility of using Ag instead of Cu with thin barrier layer and hence the RC delay can be suppressed and improves the performances of the devices for the next high-density generation.

Acknowledgements

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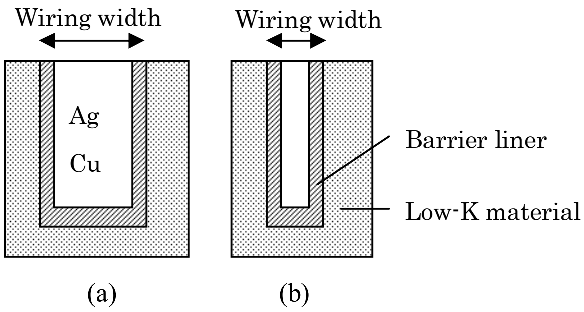

Fig. 1. The model of interconnection how to change from (a) 90 nm to (b) below 50 nm for the future high-density circuit.

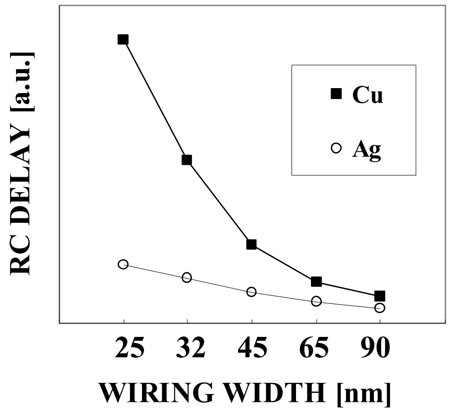

Fig.2 The simulation result using Ag and Cu with various wiring widths. Simulation Condition: Diffusion barrier width 20nm for (Cu) and 5nm for (Ag). Barrier metal from 90nm generation, every generation reduces 15 %.

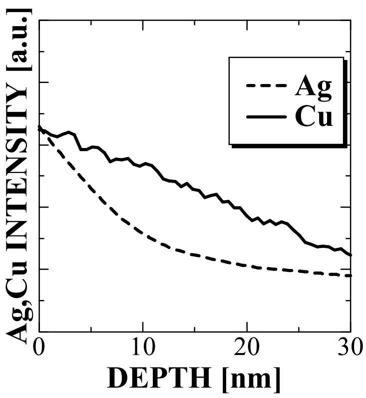

Fig.3. Ag and Cu depth profile in SiOC film after annealing..

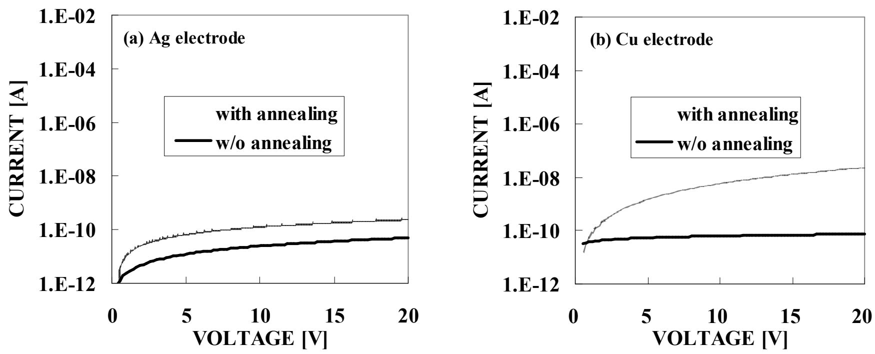

Fig.4. The I-V characteristics before and after annealing when electrodes were (a) Ag and (b) Cu electrode, respectively.

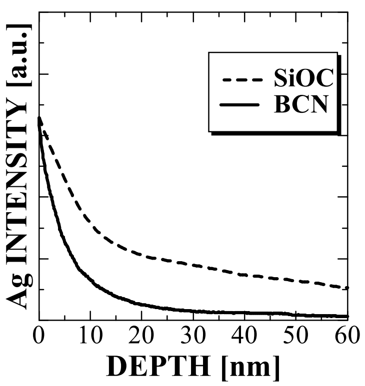

Fig.5. The depth profiles of Ag in BCN and SiOC dielectric films after annealing .

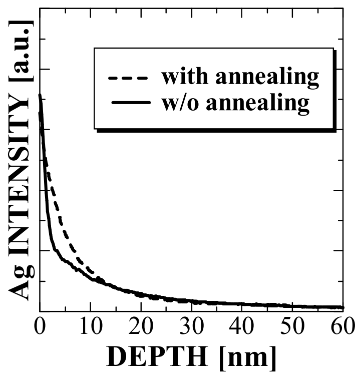

Fig. 6. The depth profiles of Ag in BCN film before and after annealing.