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New Low k Material "LKD™" for Al Damascene Process Application

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Introduction

Reducing the parasitic capacitance of wiring is highly effective in realizing high performance devices such as RISC. Therefore, organic polymers, organic SOG and etc. have been widely investigated as low dielectric constant (low k) interlayer dielectrics (ILD) materials. Organic SOG have already been widely used as gap filling layers because it has good gap-filling capability, high thermal stability and low k. However, in order to apply this film to damascene process, high mechanical strength is required to stand a metal CMP step. Lack of mechanical strength cause wiring resistance increase and degradation of open/short yield due to wiring thinning or scratching. *LKD™* film, methyl-polysiloxane based organic SOG from JSR Corporation, has sufficient mechanical strength to stand a metal CMP step without capping PE-SiO_2 layer. We applied *LKD™* film to Al damascene process using Al reflow sputtering technique, and it was confirmed that *LKD™* film is compatible with that process.

Experiment and Results

Two types of *LKD™* films and PE-SiO_2 film as shown in Table 1 were prepared for comparison. *LKD™ A* film has similar properties as conventional organic SOG has. *LKD™ B* film is an improved material of *LKD™ A* film which has stronger mechanical strength.

Fig.1 shows the fabrication process for the double level Al damascene structure using *LKD™* films. This structure was composed of the first level Al wiring (D1) by a single damascene, the second level Al wiring (D2) by a dual damascene and the ILD by ILD/PE-SiO2 stack films, where *LKD™* films were embedded between Al wiring. As comparison, the same structure using only PE-SiO_2 film was fabricated. *LKD™* films were spin-coated on PE-SiO_2 film and cured in N_2. The wiring trench and via hole were formed by photo-resist and RIE process. ARL and photo-resist stripping were done by oxygen reactive ion etching (O_2 RIE) due to prevent decrement of CH_3 radicals by O_2 plasma[1)]. The wiring trench and via hole were filled by Al reflow sputtering process using a Nb liner[2)], whose maximum temperature was 450℃. Al and Nb liner outside the trench were removed by CMP.

Fig.2 shows photographs of the fabricated double level Al damascene structure. There is no degradation of Al reflow characteristics due to degas from *LKD™* films or scratching on surface of Al wiring and *LKD™* films after CMP. Good wiring open/short yield was obtained.

Fig.3 shows the k fitting procedure. First, wiring to wiring capacitance of D1 with comb structure for two types of *LKD™* films was measured. Second, with k of ILD films between Al wiring as an unknown quantity, this capacitance was simulated from actual dimension data obtained from the cross sectional view and k of PE-SiO_2 film (4.0). Lastly, k of *LKD™* film was found from fitting measured capacitance with simulated one. Table 2 shows the obtained results. The k values of both *LKD™* films show 2.5, and it is found that these values are not changed before or after the damascene process step.

Fig.4 shows mean thinning thickness across the wafer after a metal CMP step. Thinning thickness was obtained from wiring resistance of D1 pattern as shown in Fig.5. It is found that even without capping PE-SiO_2 layer, thinning thickness of *LKD™ B* can be decreased to about half of that of *LKD™ A* film, which is practical level. This remarkable decrease is thought to be the effect of the high mechanical strength of *LKD™ B* film. Table2 summarizes obtained results.

At the present time, a single layer *LKD™* film cannot be applied to Al dual damascene process because fine and high aspect via hole opening formation is very difficult due to etch stop phenomena. But, by combining these films to pillar process[3)], where via hole opening process is not required, double level Al damascene structure using single layer *LKD™* film which reduce layer to layer capacitance can be fabricated. Furthermore, k value of *LKD™* film can be reduced to 2.0 by altering its porosity. Not to mention, *LKD™* film can be applied to Cu damascene process.

Conclusions

We have developed *LKD™* film which can be applied to Al damascene process. By using this *LKD™* film and Al reflow sputtering process using a Nb liner, wiring to wiring capacitance can be reduced by 35% and wiring resistance can be reduced by 40-50%[2)] compared with current PE-SiO_2 film and RIE Al wiring process. We plan to apply this technology to 0.18um device and beyond.

Reference

1) Y. Homma et al., Solid-State Electronics Vol. 41, No. 7, P.1005, 1997
2) J. Wada et al., Proc. of VLSI symposium, P.48, 1998
3) K. Kajita et al., Proc. of IITC, 1999 in press

	$LKD^{TM}B$	$LKD^{TM}A$	$PE\text{-}SiO_2$
Thermal stability[a)] (℃)	>450	>450	>1000
H_2O degas level[a)] (A.U.)	<1/4	<1/4	1
Youngs modulus[b)] (Gpa)	3.9	2.7	69
Hardness[b)] (Gpa)	0.63	0.3	8.8
Crack resistance (μm)	1.3	0.8	N/A
Dielectric constant (k)	2.5	2.5	3.9-4.1

a)measured by TDS (RT~450℃)
b)measured by Nano Indenter XP

Table1 Properties of ILD materials

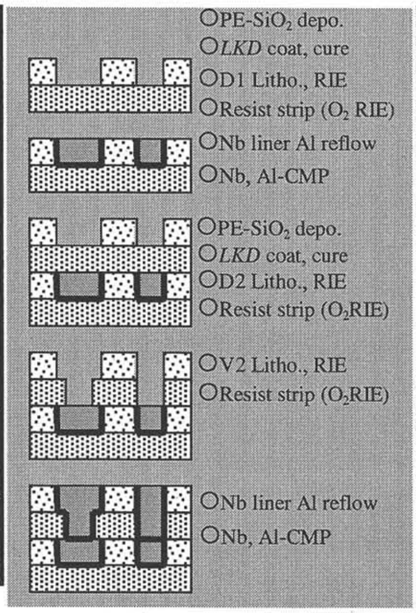

Fig. 1 The fabrication process step for double level Al damascene structure

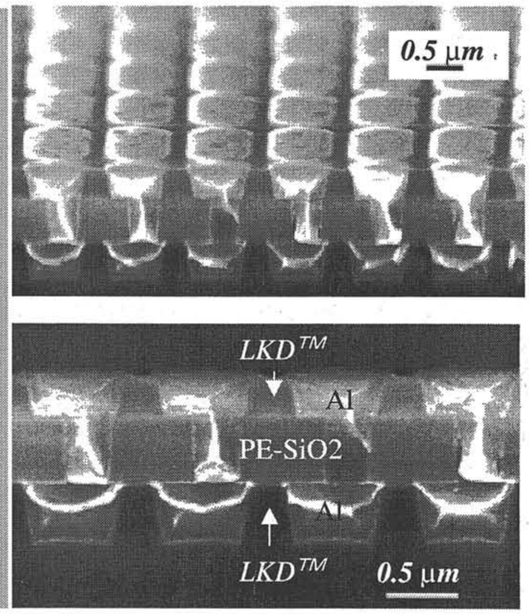

Fig.2 Cross sectional SEM image of double level Al damascene structure

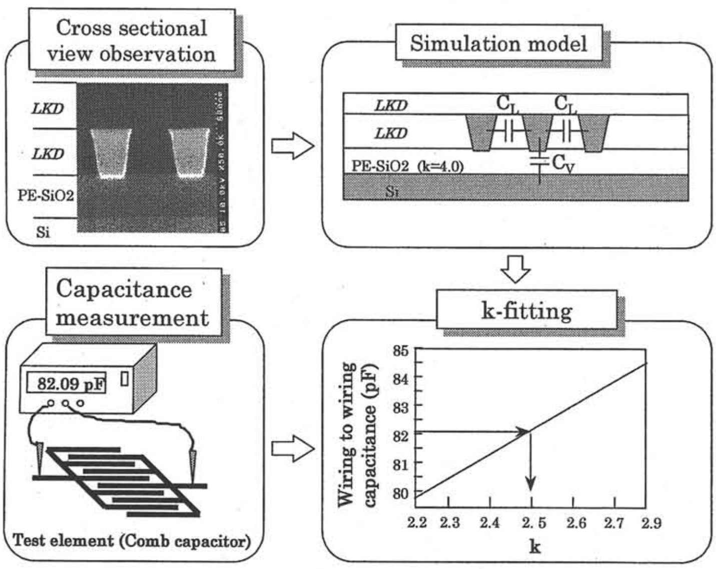

Fig.3 K fitting procedure

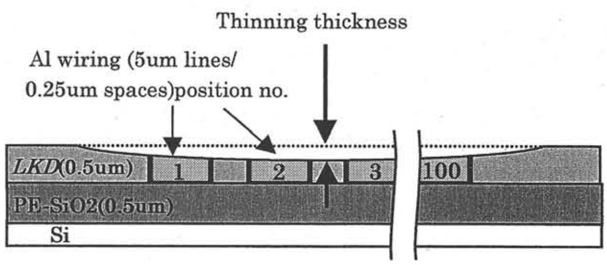

Fig.4 Thinning thickness measurement pattern

	$LKD^{TM}B$	$LKD^{TM}A$	$PE\text{-}SiO_2$
Dielectric constant @400kHz	2.5	2.5	3.9
Electrical leakage (A/cm^2) @0.2MV/cm	<1E-10	<1E-10	<1E-10
Open/short yield [1)] (%)	>96	>96	100
Thinning thickness[2)] (A)	400	900	125

1) 0.25um line/space
2) 5um lines/0.25um spaces

Table2 Comparison of electrical properties

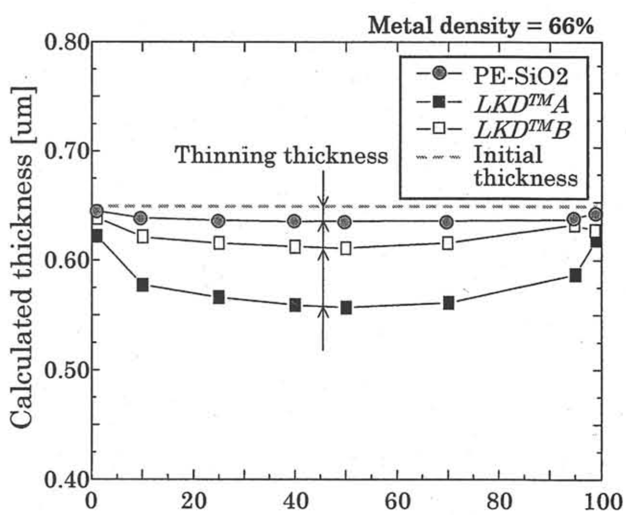

Fig. 5 Comparison of thinning thickness