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Comparison of the Planarization Technologies for the Next Generation

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1. Introduction

The introduction of the Low-k material, which has low mechanical strength, gives the problem of delamination or the damage in the planarization process where CMP is used. Therefore, next generation's planarization technology is newly requested not to damage the Low-k material in addition to high removal rate and excellent planarity (low dishing/erosion). As one of the solution, the decrease of the polishing pressure is enumerated, and a variety of planarization technologies named Low Down Force CMP, ECMP (Electro-Chemical Mechanical Polishing)[1][2][3], and ECP (Electro-Chemical Polishing), CE (Chemical Etching) are being tried now. We also have been developing CMP (mC^2)[4], ECP-DI (Electro-Chemical Polishing in DI water)[4][5] and ECP-C (Electro-Chemical Polishing in Chemical), which is a kind of ECMP, among these planarization technologies.

In this article, the possibility to next generation's planarization technology is considered by comparing these polishing performances.

2. Mechanism of each planarization technology

Fig.1 shows the principle of CMP, CE, ECMP, ECP and ECP-DI in the Cu polishing. The mechanism of CMP is considered as follows : (1) Oxidation of Cu with oxidizer, (2) Complexation of oxidized Cu, (3) Removal of Cu complex of convex portion selectively. As for ECMP, Cu is oxidized electrochemically on step (1). In ECP-DI, the electrolytic etching is caused in the contact part of wafer and ion exchanger. Therefore, the electrolytic etching of convex portion can be done selectively. On the other hand, in ECP and CE, it is difficult to form the etching protective layer selectively to the concave portion, and the etching is caused isotropically.

3. Polishing performance

(A) mC^2

mC^2 is low down force (LDF) CMP developed for Cu bulk and Cu clear polishing step of Cu/ultra low-k devices. LDF CMP shows low friction[4], so it is expected mC^2 reduce not only scratches but also the delamination of low-k film. mC^2 uses chemical enhanced slurry, which isn't governed by Preston's Law but mainly by the Dissolution Law.

Fig.2 shows the removal rate of mC^2. The maximum removal rate depends on not mechanical action (down force) but chemical condition (slurry flow rate).

Fig.3 shows the planarization performance of mC^2. Step height is reduced more ideally in the LDF condition. Fig.4 also shows the post mC^2 performance for Cu bulk and Cu clear step, and the post LDF BM-CMP performance for BM clear step. In the majority of patterns, dishing/erosion are 20nm or less.

Fig.5 shows the scratch performance of mC^2. In the LDF condition, scratch count decreases to 1/10 of conventional polishing condition.

(B) ECP-DI

Fig.6-7 shows the removal rate of ECP-DI. The removal rate only depends on current density, and doesn't depend on down force. In ECP-DI, electrolytic etching is theoretically caused only in the contact area of wafer and ion exchanger in ultra pure water. Therefore ECP-DI doesn't need any mechanical action such as CMP and ECMP.

Fig.8 shows the planarization performance of ECP-DI. ECP-DI can decrease the step height as well as CMP. On the other hand, dishing increases rapidly after Cu Clear because the electrolytic etching concentrates on the Cu wiring portion.

(C) ECP-C

Fig.9 shows the removal rate of ECP-C. Removal rate is proportional to current density under a constant down force condition.

Fig.10 shows the planarization performance of ECP-C. ECP-C can also decrease the step height as well as CMP. However, planarity is deteriorated as the applied voltage increases. Moreover, dishing increases rapidly after Cu Clear as well as ECP-DI (Not shown). In ECP-C, removal rate and planarity are in the relation of the trade-off. Therefore, formulation of Cu complex with high resistance and good mechanical removal property is needed.

4. Comparison of Polishing Performance and CoC

Table.1 shows polishing performance and CoC of mC^2, ECP-DI, and ECP-C. High removal rate under the LDF condition and excellent planarity can be obtained in each process. However, mC^2 is superior to ECP-DI and ECP-C as for dishing after Cu Clear. Therefore, mC^2 is superior to ECP-DI and ECP-C for polishing performance, and ECP-DI and ECP-C are applied only to the Cu bulk polishing. In addition, ECP-DI doesn't basically use chemical such as slurry or electrolyte. Therefore, it can be said that ECP-DI is extremely effective planarization technology to the decrease of CoC.

5. Conclusion

Polishing performances of mC^2, ECP-DI and ECP-C are compared as a candidate of planarization technology for the next generation. The conclusion is as follows.

- High removal rate under the LDF condition and excellent planarity can be obtained in each process.
- Dishing increases rapidly in ECP-DI and ECP-C after Cu Clear.

In our experimental data, mC^2 is superior to ECP-DI and ECP-C for polishing performance. In addition, ECP-DI has advantage for CoC, because ECP-DI doesn't basically use chemical.

Although several planarization technologies have been developed such as CMP, CE, ECMP, ECP and those fusion techniques[6], the optimum technologies for each device would be improved.

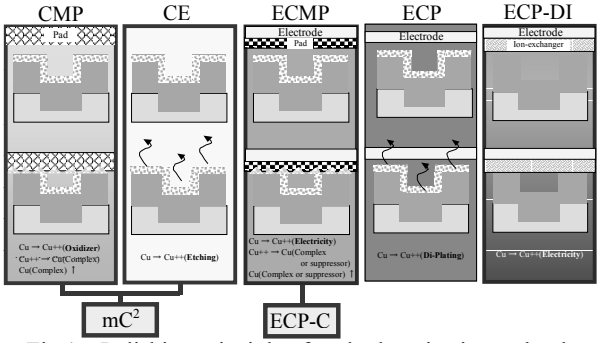
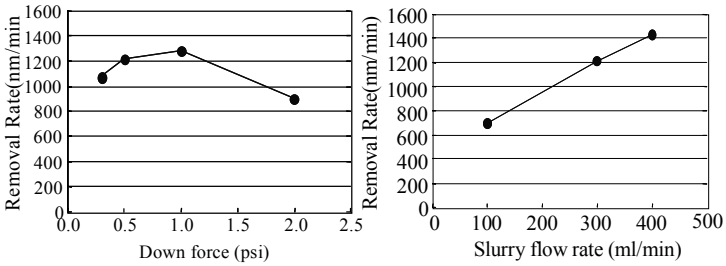


Fig.1 Polishing principle of each planarization technology



(a) down force (b) slurry flow rate

Fig.2 mC^2 : Removal Rate performance

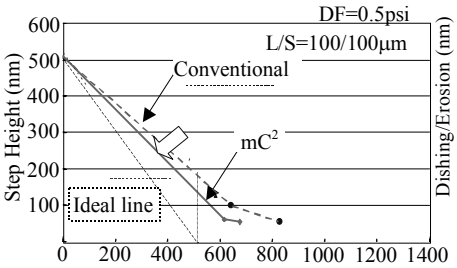
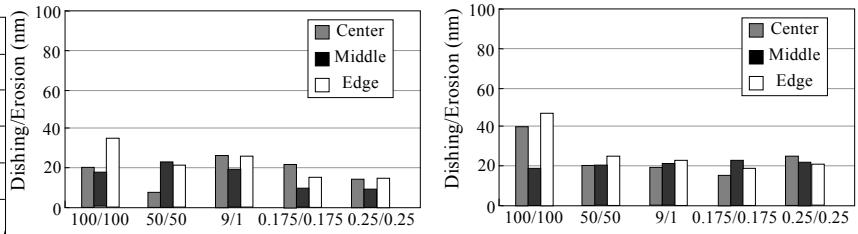


Fig.3 mC^2 : Planarization performance



(a) Post mC^2-CMP (Cu Cleared) (b) Post LDF CMP (BM Cleared)

Fig.4 mC^2 : mC^2+ LDF BM-CMP performance

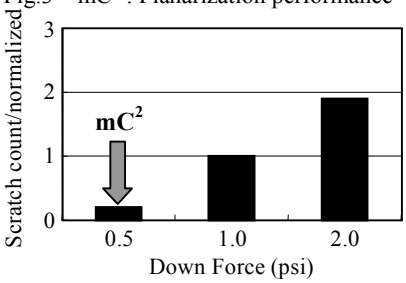


Fig.5 mC^2 : Scratch performance

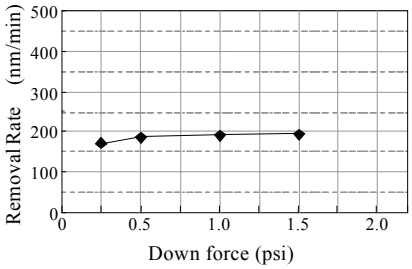


Fig.6 ECP-DI : Down Force dependency of Removal Rate

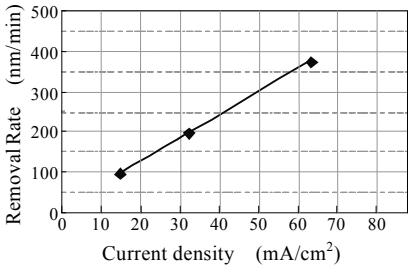


Fig.7 ECP-DI : Current density dependency of Removal Rate

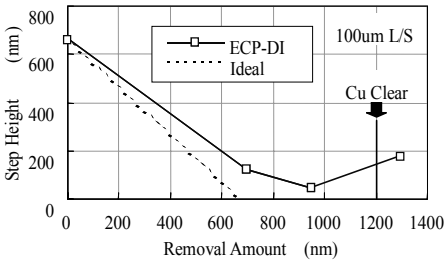


Fig.8 ECP-DI : Planarization performance

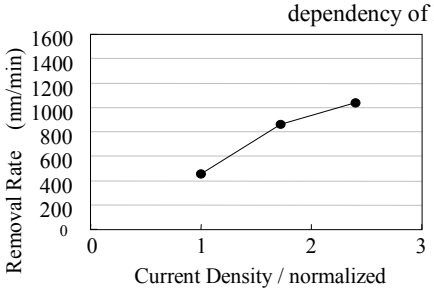


Fig.9 ECP-C : Current density dependency of Removal Rate

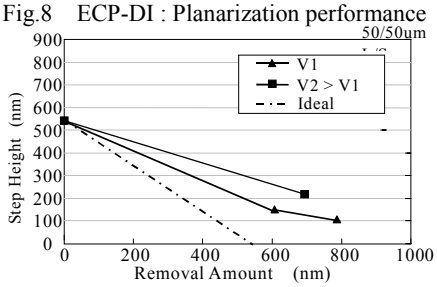


Fig.10 ECP-C : Planarization performance

Table.1 Comparison of polishing performance

	mC^2	ECP-DI	ECP-C
Removal Rate	+	+	+
Planarity	+	+	+
Dishing/Erosion	+	−	−
CoC	0	+	0

+ : Good, 0 : Even, - : Poor

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