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CMP Using Fixed Abrasive Tool (FX-CMP) for Dielectric Planarization

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1. Introduction

Wafer planarization has become a critical process in fabricating current and future devices. Chemical mechanical planarization (CMP) provides higher planarity than that of spin-on-glass (SOG) process; however, it is expensive, because of additional processes involving dummy patterns, etch-back, etc [1]. Moreover, most slurry is wasted without having provided any polishing effort. To solve these problems, a fixed abrasive pad (called a slurry-free pad) has been developed by Funkenbush et al.[2]. However, removal rate with a slurry-free pad is not enough in the use of blanket wafers for process development [3]. We have therefore developed a novel dielectric planarization technique using fixed abrasive tool (FA tool), called FX-CMP, to provide high planarity under practical removal rate, without need for any additional processes when using a FA tool like a grindstone.

2. Basic concepts of FX-CMP

The FA tool, which is made with ceria abrasives, resin binder and microscopic pores, has a Young's modulus of around 0.8Gpa, which is ten times that of a CMP pad. FX-CMP can therefore accomplish both dummy-less and slurry-free planarization as shown in Fig. 1. And simply making the tool a few centimeters-thick will produce a long tool life and low cost. Furthermore, practical removal rate of SiO2 and high selectivity between SiO2 and Si3N4 result in efficient shallow trench isolation (STI) with using chemical additive.

3. Results and discussions

The FX-CMP system consists of an orbital platen, a FA tool, a dresser, a nozzle for providing liquid and a wafer carrier as shown in Fig. 2.

The degree of planarization, residual step, dishing, rounding on different size patterns, were measured as shown in Fig. 3. The initial thickness of SiO2 is 12,000Å and step height of the patterns is 8,000Å. FX-CMP planarity is highly superior to that of CMP on 1-to-5-mm patterns when polishing thickness is 970 nm as shown in Fig. 3. In the case of using CMP, remained step-height skyrocketed to 400 nm on 3 mm pattern. By the contrast, when using FX-CMP, remained step-height was no more than 30 nm. And this high planarity is due to high selectivity of convex patterns by using high Young's modulus of the FA tool.

On the STI, obtaining high selectivity is as important as planarization performance. Figure 4 shows the selectivity between SiO2 and Si3N4 during FX-CMP using a kind of carboxylate macromolecule dispersant. Removal rate of a SiO2-deposited-blanket-wafer increases from 200 to over 240 nm/min as additive concentration increases. At the same time, removal rate of Si3N4 suddenly decreases when additive concentration increases above 1 vol.%. Therefore, selectivity increases when additive concentration increases above 1 vol.% and a maximum selectivity is 41 when the concentration is 3-6 vol.%. This high selectivity is great use in STI planarization. Furthermore, obtained removal rate of SiO2 is high enough to produce practical throughput.

Figure 5 shows a result of applying FX-CMP to STI planarization of a 0.3-μm-node-test pattern without using any additive processes such as etch-back nor dummy patterns. The initial thickness of Si3N4 was 80-90 nm. The variation of remaining Si3N4 thicknesses on several length patterns from left-top to right-top chip after FX-CMP was within 13.5 nm, and its average thickness was around 80 nm because of the stopping effect. Figure 6 shows a bird's eye view cross-sectional SEM photograph and, clearly good planarity without dishing, rounding and defects are observed.

4. Summary

Chemical Mechanical Polishing using a fixed abrasive tool for dielectric planarization has been developed and shown to provide excellent planarity performance. This technique features (1) a high Young's-modulus tool (0.8 GPa) for high planarity, (2) a chemical additive for high SiO2/Si3N4 selectivity, and (3) a thick FA tool for long life tool. Applying FX-CMP to STI process of a 0.3-μm-node-test-pattern resulted in excellent cross sectional shape with low dishing and rounding. Moreover, FX-CMP is a slurry free process that provides a practical removal rate and does not require additional processes using dummy patterns or etch back. Therefore, FX-CMP has a potential to provide low-cost dielectric planarization especially in STI planarization process.

Acknowledgments

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References

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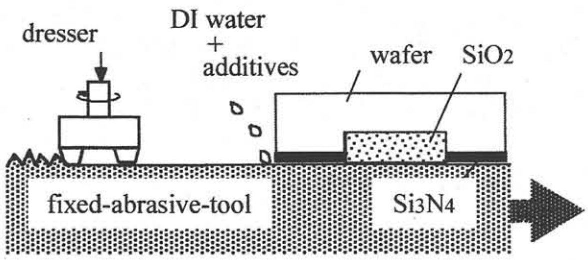

Fig. 1 Basic FX-CMP concepts.

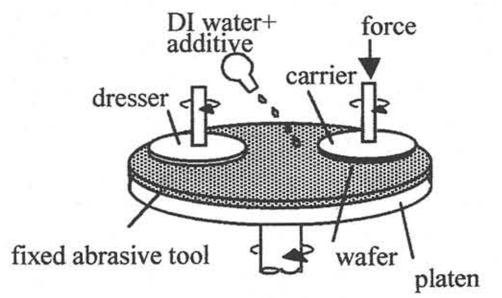

Fig. 2 Schematics of FX-CMP system.

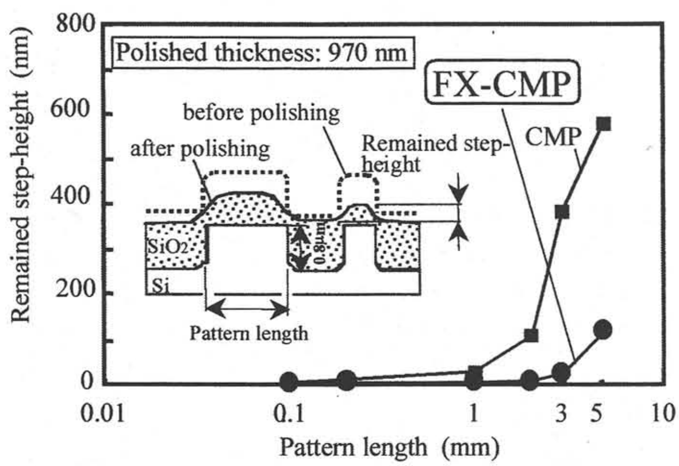

Fig. 3 Degree of planarization characteristics between FX-CMP and CMP.

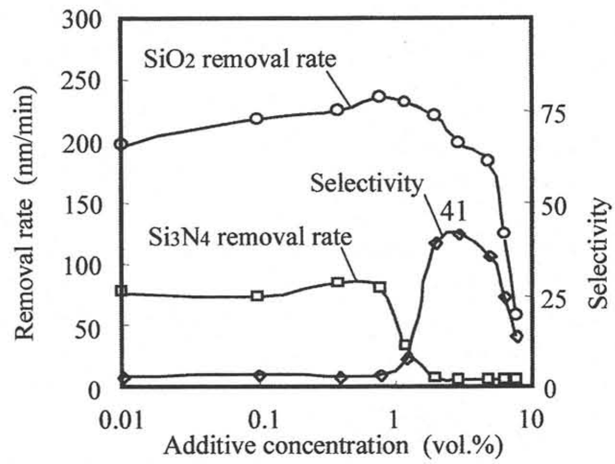

Fig. 4 Selectivity between SiO_2 and Si_3N_4.

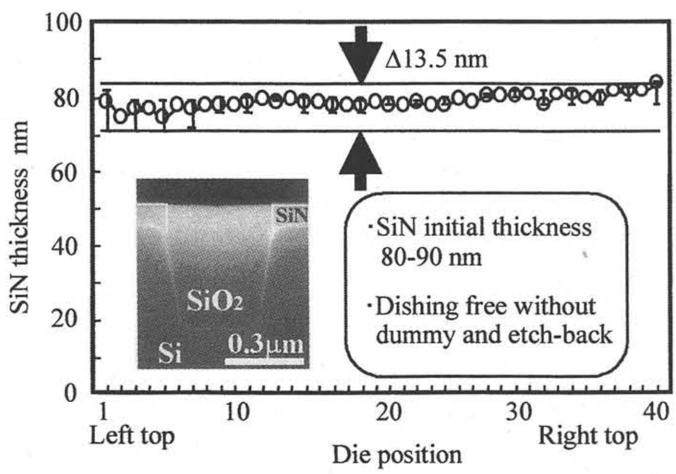

Fig. 5 Within wafer non-uniformity by applying FX-CMP to STI planarization.

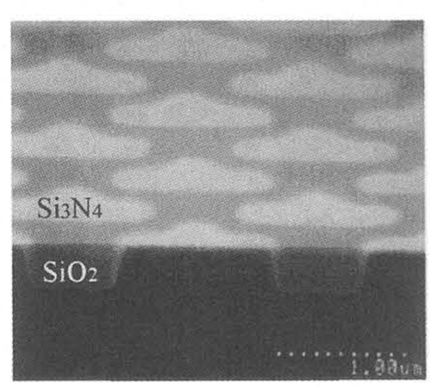

Fig.6 Cross-sectional SEM photograph of 0.3-μm-node-test patterns after STI planarization.