슬러리 Modification 에 대한 연구

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Methodological Study for Recycle of Chemical Mechanical Polishing Slurry

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Abstract : To investigate the recycle possibility of slurry for the oxide-chemical mechanical polishing (oxide-CMP) application, three kinds of retreated methods were introduced as follows: First, the effects on the addition of silica abrasives and the diluted silica slurry (DSS) on CMP performances were investigated. Second, the characteristics of mixed abrasive slurry (MAS) using non-annealed and annealed alumina (Al_2O_3) powder as an abrasive added within DSS were evaluated to achieve the improvement of removal rates (RRs) and within-wafer non-uniformity (WIWNU%). Third, the oxide-CMP wastewater was examined in order to evaluate the possible ways of reusing it. And then, we have discussed the CMP characteristics of silica slurry retreated by mixing of original slurry and used slurry (MOS).

Key Words : Chemical mechanical polishing (CMP), Recycle slurry; Diluted silica slurry (DSS); Mixed abrasive slurry (MAS); Mixing of slurry (MOS); Removal rate (RR); Within-wafer non-uniformity (WIWNU%).

1. Introduction

CMP process has been known to have a significant effect on the global planarization of multi-levelinterconnection structure [1]. However, there are many practical problems in application due to the synchronicity of mechanical and chemical polishing. One of the most critical problems is the higher cost of consumables (COC). So, the slurry recycle and dilution are the most notable ways to reduce the slurry consumption. In case of slurry recycling, the separation of silica (SiO_2) abrasives and oxide residues after CMP process is one of the critical problems. It makes a more difficult revivification. Therefore, the slurry dilution with de-ionized water (DIW) has been adopted over slurry recycle.

First, the changes of pH level due to the dilution of slurry were examined in this paper. Then, the methods to suppress a pH change and maintain a proper pH level were discussed. Also, the addition effects of silica abrasives and the diluted silica slurry (DSS) on CMP performances were evaluated. After the establishments of DSS, secondly, the characteristics of mixed abrasive slurry (MAS) were investigated to evaluate the improvement of the RR and WIWNU%as well as reduction of slurry cost by a dilution of high-cost slurry [2]. In addition, the addition effects of the annealed alumina abrasive in DSS on oxide-CMP were discussed to improve the mechanical strength of MAS and the selectivity between metal and upper oxide. Finally, the RR [3] and WIWNU% as a function of slurry mixing ratio (original slurry: used slurry) with different annealed silica abrasive contentswas also studied. From this work, the two-step CMP process is suggested. In the first-step CMP, the thick and rough film surface can be polished using retreated slurry, and then, in the second-step CMP, the thin film and fine pattern polished using the original slurry.

2. Experiment

A thermal oxide layer of 600-nm-thick was grown on 4-inch blanket silicon wafer during six hours in an electric furnace at 1200°C. CMP process was completed with a G & P Technology POLI-380 [2] and RODEL IC-1000/Suba-IV. The parameter ranges of design of experiments (DOE) technique [4]for the optimized CMP process is summarized as follows: Table speed, head speed, and down force were 60 rpm, 60 rpm, and 300 g/cm^2 respectively. CMP processing time was set to 90 seconds. On Post-CMP cleaning, the wafer was dipped in SC-1 chemical for 1 minute and then dipped DHF for 2 minutes. Finally it was cleaned using mega-sonic cleaner for 4 minutes. SC-1 was compounded with NH_4OH, H_2O_2, and H_2O (1:2:7). Thickness of the oxide after CMP was measured using an ellipsometer (Nanospec/AFT 2100 system). The thickness of 9 points from center to the edge was measured with a clockwise-direction on same wafers. The particle size analysis of the slurries was conducted by AccuSizer 780system during one month. The surface morphology after CMP process was measured with atomic force microscopy (AFM PSIA, XE-100).

3. Results and discussion

Figure 1 illustrates the removal rates of edge and center region after CMP using DSS for 90 seconds. With the increase of dilution ratio, the RR of DSS decreased. The RR of DSS decreased more as compared with that of original slurry. When the dilution ratio was lower, a difference of RRs between edge and center area was larger. In contrast, the RRs of both edge and center were almost same in the higher dilution ratio. This means that the CMP action did not occurred. Hence, the increase of RR by adding the appropriate amount of abrasive is required to prevent those problems.

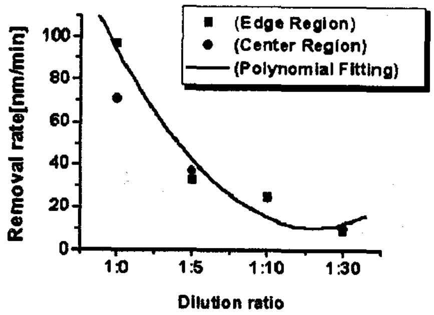


Fig. 1. Comparison of removal rates between the edge and center region as a function of dilution ratio.

Figure 2 shows the removal rates and non-uniformity as a function of annealed Al_2O_3 abrasive contents in the 1:10 diluted silica slurry. The mixed abrasive slurry with non-annealed raw alumina powder showed a removal rate of 90 ~ 100 nm/min and WIWNU of 7 ~ 9 %. However, the 0.5 wt% of 1500℃-annealed alumina mixed slurry had a removal rate of 135nm/min and WIWNU of below 4 %. At higherannealing temperature, the removal rate increased and WIWNU% was slightly decreased. Such a remarkable CMP characteristics is caused by interplay between the mechanical abrasive actionof large alumina particles and chemical nature of the small silica particles surrounding the alumina partcles.

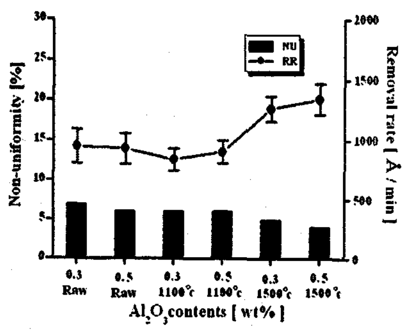
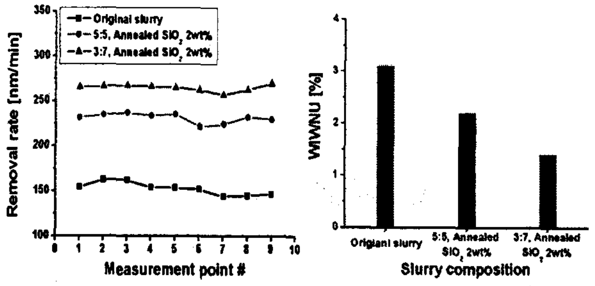


Fig. 2. Relation of removal rate and non-uniformity as a function of annealed Al_2O_3 abrasive contents.

Figure 3 shows the comparison of RR and WIWNU% of MOS after two-step CMP process. For the case of the 5:5 mixed slurry, the first-step CMP process used the retreated slurry with an annealed silica abrasive of 2 wt% content, and the second-step CMP was performed with the original slurry. As a result, the removal rate was about 230 nm/min. Similarly, the same sequence was applied for the 3:7 mixed slurry. After the two-step CMP process, the removal rate increased to about 260 nm/min. For the two-step CMP using 5:5 mixed slurry and 3:7 mixed slurry with the annealed silica abrasive of 2wt% content, the WIWNU% values are 2.2 % and 1.4 %, respectively



(a) (b)

Fig. 3. Comparison of removal rate and WIWNU% after finishing of two-step CMP using MOS. (a) Removal rates, (b) WIWNU%.

4. Conclusion

In order to investigate the recycle possibility of slurry for the oxide-CMP application, the three kinds of retreated slurry such as DSS, MAS, and MOS were developed. The possibility of recycled slurry for oxide-CMP was sufficiently confirmed. This suggests a saving of slurry cost as well as the improvement of RR and WIWNU%. However, lots of micro scratches were still observed. They may be caused by the influx of outer impurities during milling of annealed alumina abrasive or the relatively bigger abrasives over 1 ㎛. This problem will be resolved by a future work involved in the settlement of annealing and milling conditions.However, further investigation about the polishing characteristic of a patterned wafer and process defects such as micro-scratches on the wafer surface must be made for the reliability of the slurry used in this paper.

Acknowledgements

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