Dishing and Erosion Evaluations of Tungsten CMP Slurry in the Orbital Polishing System

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The dishing and the erosion were evaluated on the tungsten CMP process with conventional and new developed slurry. The tungsten thin film was polished by orbital polishing equipment. Commercial pattern wafer was used for the evaluation. Both slurries were pre tested on the oxide region on the wafer surface and the removal rate was not different very much. At the pattern density examination, the erosion performance was increased at all processing condition due to the reduction of thickness loss in new slurry. However, the dishing thickness was not remarkably changed at high pattern density despite of the improvement at low pattern density. At the large pad area, the reduction of dishing thickness was clearly found at new tungsten slurry.

Keywords : Tungsten CMP, Dishing, Erosion, Tungsten slurry, Orbital polishing

1. INTRODUCTION

The dishing and erosion in metal chemical mechanical polishing (CMP) depend on the number of factors including down force, relative velocity, pattern density and pitch, pad conditioning and consumables. Pattern dependent dishing issues in tungsten plug or lines and erosion of oxide layers have been realized as a critical problem in the manufacturing technology of flash device [1-3]. As the feature size of devices is continuously being shrunken, the demand decreasing the dishing and erosion of line width and space is highly increasing. To meet the requirement of reducing the dishing and erosion, polishing behavior and slurry chemistry have been investigated respectively.

Generally, tungsten slurry is composed of alumina abrasive particles, etchant, oxidizing agent and additives. Tungsten CMP mechanism is well known that tungsten oxide is firstly formed on the surface by oxidizing agent and then mechanical abrasion of particles contributed to remove the oxidized layer[4]. The basic reaction for the oxide formation is shown in Eq. (1)[4].

$$\mathrm{W} + 6\mathrm{Fe(CN)}_6^{-3} + 3\mathrm{H_2O} \rightarrow \mathrm{WO_3} + 6\mathrm{Fe(CN)}_6^{-4} + 8\mathrm{H}^+ \quad (1)$$

In the Eq. (1), potassium ferric cyanide ($K_3Fe(CN)_6$) was used as an oxidizing agent.

Recently, new tungsten slurries are being developed to meet the severe requirement of dishing and erosion as the device feature size is shrinking. Another abrasive particle such as colloidal silica[5] or new oxidants[6-8] has been researched as well as polishing process and equipment has been developed.

In this work, conventional and new developed tungsten slurries were evaluated in the point of view of dishing and erosion with commercial patterned tungsten wafer and orbital polishing equipment.

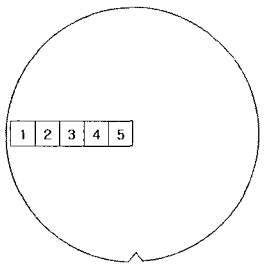


Fig. 1. The points on the wafer surface for evaluation of oxide removal rate.

Table 1. Process conditions for the slurry evaluation.

Process	A	B	C	D	E
Wafer down force (psi)	2	2	3	4	4
Spindle rotation speed (rpm)	70	110	90	70	110

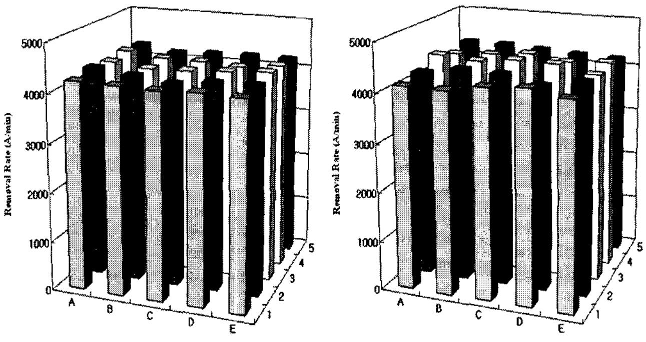
2. EXPERIMENT

For the slurry evaluation, MIT 854 pattern wafer was obtained from TSMC Co. and UNIPLA™ orbital polishing equipment and commercial pad were used. Conventional and new tungsten slurries were acquired from Cabot Microelectronic Co. and applied to polish the tungsten surface. To compare with the polishing performance of both slurries, the oxide surface on the pattern wafer was measured before and after polishing. The removal rate of the oxide surface on the pattern wafer was measured after polishing with both slurries, respectively. The center, edge and middle area of wafer were analyzed at 5 different points as shown in Fig. 1.

The removal rate was measured using OP 2600 (Thermawave Co., USA). The dishing and erosion thickness was analyzed in various pattern densities. The wafer down force and spindle rotation speed was distributed in order to find out the enhanced dishing and erosion results of new slurry at different pattern densities. Table 1 summarized the process conditions.

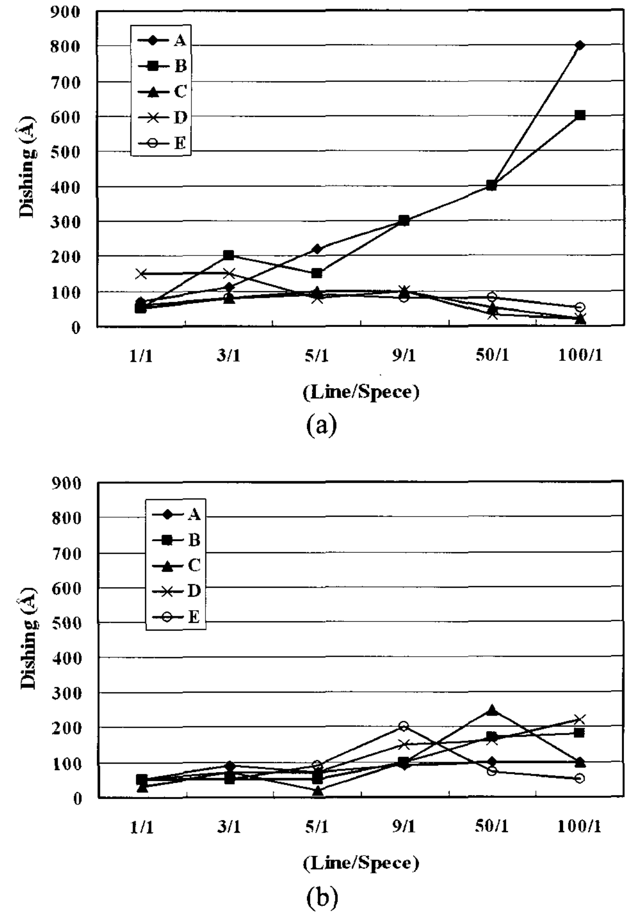
3. RESULTS AND DISCUSSION

The removal rate of conventional slurry was uniformly measured at all investigated process conditions. The new slurry has the same removal rate level. Figure 2 shows the results of the removal rate.



(a) (b)

Fig. 2. The removal rate of (a) conventional slurry and (b) new slurry.



(a)

(b)

Fig. 3. The dishing thickness change at different process with (a) conventional slurry and (b) new slurry.

Figure 3 shows the dishing thickness after polishing with conventional and new slurries. In the conventional slurry, the dishing was remarkably increased at low wafer down force condition (2 psi) as the ratio of line and space increased. However, this increase was disappeared at new slurry and the dishing under 250 Å was maintained as shown in Fig. 3(b). Although the dishing thickness was not increased distinctly, dishing thickness was slightly increased at the high ratio of line vs. space.

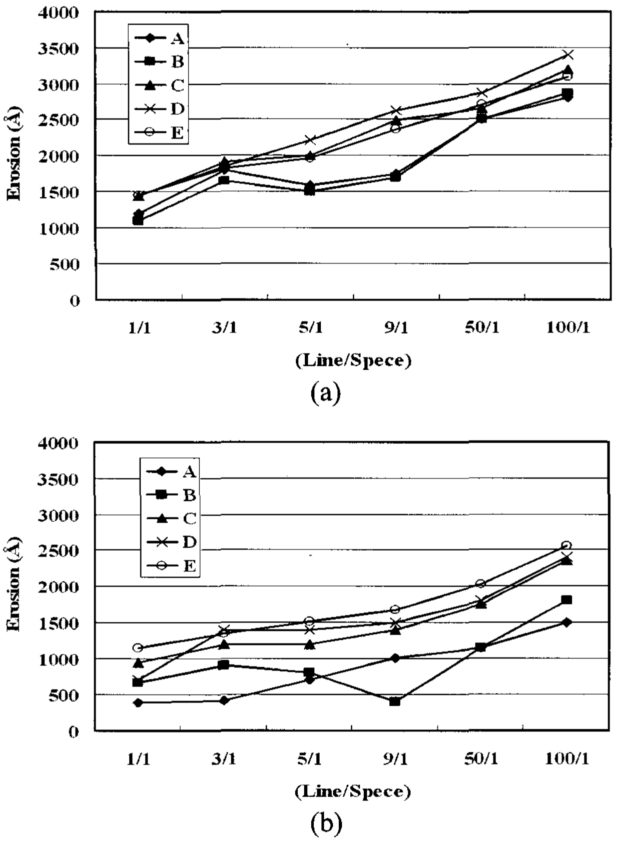


Fig. 4. The erosion thickness change at different process with (a) conventional slurry and (b) new slurry.

The erosion results are shown in Fig. 4. At the all investigated process conditions, the erosion thickness was increased from 1000 Å to 3500 Å as the ratio of line vs. space increased in the conventional slurry. On the contrary, new slurry has the slightly lower erosion thickness loss. The lowest erosion thickness loss was found at 2 psi down force. Although the erosion thickness increased at the higher down force process, spindle speed did not affect the erosion thickness increase. Therefore, erosion thickness was much influenced by down force than rotation speed. Generally, erosion thickness reduction was achieved in the new slurry.

The dishing and erosion thickness was re-measured at the various pattern densities. At the high pattern density, e.i. 0.18 μm/0.18 μm ratio of line vs. space, dishing thickness was not changed very much as shown in Fig. 5. The dishing thickness change was clearly observed at the low pattern density such as 10 μm/10 μm (line/space). This means that the dishing phenomena can be improved at low pattern density. On the other hand, erosion performance was definitely enhanced at all pattern densities investigated as shown in Fig. 6. Therefore, the new slurry can contribute the reduction of erosion thickness loss.

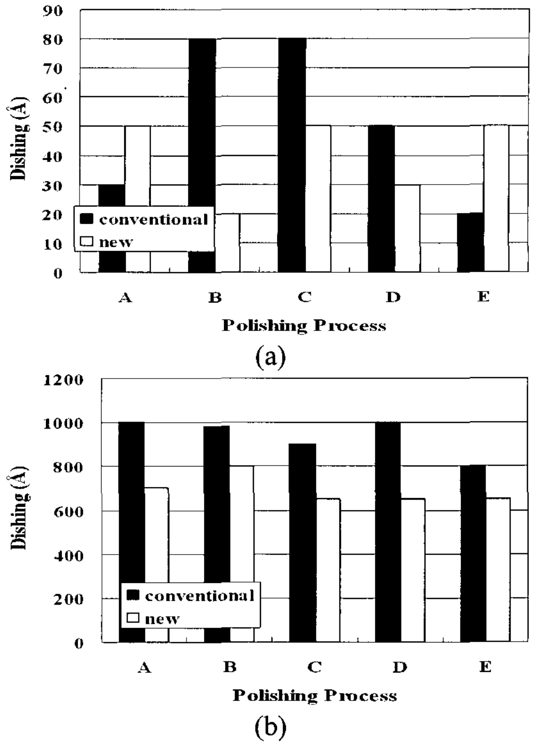


Fig. 5. The dishing thickness at (a) 0.18 μm/0.18 μm and (b) 10 μm/10 μm ratio of line vs. space after polishing with conventional (■) and new slurry (□).

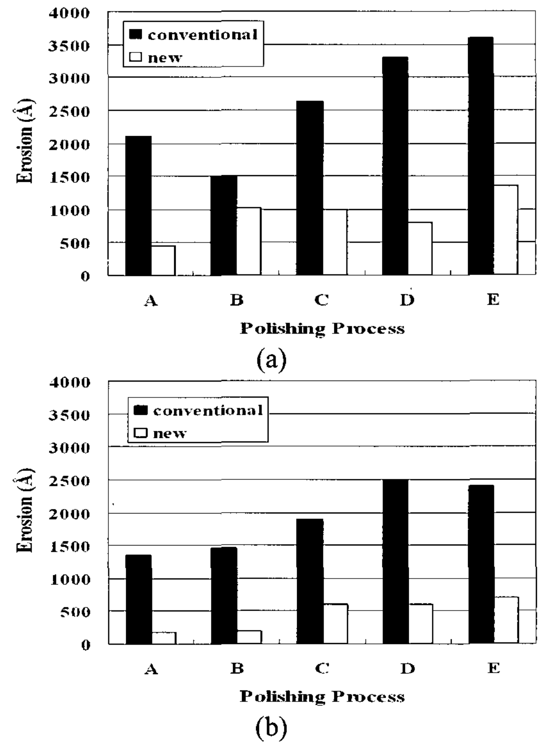


Fig. 6. The erosion thickness at (a) 0.18 μm/0.18 μm and (b) 10 μm/10 μm ratio of line vs. space after polishing with conventional (■) and new slurry (□).

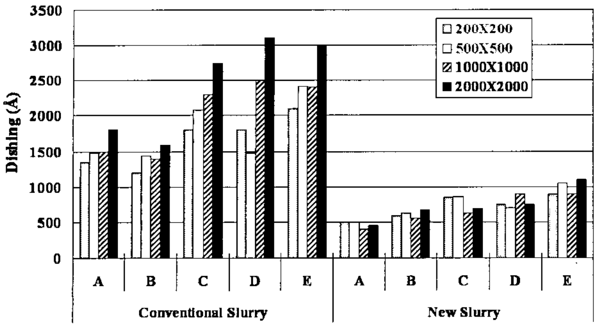


Fig. 7. The reduction of dishing thickness in the new slurry at various large pad areas.

For the more dishing evaluation at the large area, it is required to confirm the thickness loss at the large pad area. Figure 7 shows the results of dishing thickness in various area regions. As the area was increased, total dishing thickness was slightly increased. When the new slurry was applied to the polishing process, dishing reduction of maximum 1500 Å was observed. As a result, the new tungsten slurry has the good dishing and erosion characteristic.

4. SUMMARY

Conventional and new tungsten slurry was evaluated with the orbital polishing equipment. From the result of removal rate of oxide layer on the MIT pattern wafer, it was found that both slurries have the same removal efficiency. The dishing and the erosion were analyzed by thickness loss values in the different polishing pressures and spindle rotation speeds. The dishing performance was improved at the high density region and the erosion thickness was reduced as about 500 Å. At the high density region, dishing thickness was not changed very much. However, the erosion thickness loss was clearly reduced. Although the dishing performance was not enhanced at the high pattern density region, distinct thickness loss was found at the large pad area. Subsequently, the dishing and the erosion performance were improved at the new slurry.

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REFERENCES

[1] A. H. Liu, R. Solis, and J. Givens, "Development of a robust KIO_3 tungsten CMP process", Mat. Res. Soc. Symp. Proc., Vol. 566, p. 83, 2000.

[2] C. Yu, T. Myers, C. Streinz, S. Grumbine, and G. Grover, "Tungsten polishing on an orbital plaform using cabot semi-sperse W2000 slurry", PACRIM Chemical Mechanical Planarization Symposium, Seoul, Korea, p. 31, 1997.

[3] S. H. Li, H. Banvillet, C. Augagneur, B. Miller, M. P. N. Henaff, and K. Wooldridge, "Evaluation of H_2O_2, KIO_3 and $Fe(NO_3)_3$-based W CMP slurries for 8", 0.35 um CMOS Technology", CMP-MIC Conference, Santa Clara, CA, p. 165, 1998.

[4] F. Kaufman, D. B. Thompson, R. E. Boradie, M. A. Jaso, W. L. Guthrie, D. J. Peason, and M. B. Small, "Chemical mechanical polishing for fabrication W metal features as chip interconnects", J. Electrochem. Soc., Vol. 138, No. 11, p. 3460, 1991.

[5] G. S. Grover, H. Liang, S. Ganeshkumar, and W. Fortino, "Effect of slurry viscosity modification on oxide and tungsten CMP", Wear, Vol. 214, Iss. 1, p. 10, 1998.

[6] E. A. Kneer, C. Raghunath, and S. Ragahavan, "Electrochemistry of chemical vapor deposited tungsten films with relevance to chemical mechanical polishing, J. Electrochem. Soc., Vol. 143, No. 12, p. 4095, 1996.

[7] D. J. Stein, D. Hetherington, T. Guilinger, and J. L. Cecchi, "In-situ electrochemical investigation of tungsten electrochemical behavior during chemical mechanical polishing", J. Electrochem. Soc., Vol. 145, No. 9, p. 3190, 1998.

[8] E. A. Kneer, C. Raghunath, V. Mathew, S. Ragahavan, and J. S. Jeon, "Electrochemical measurements during the chemical mechanical polishing of tungsten thin films", J. Electrochem. Soc., Vol. 144, No. 9, p. 3041, 1997.