Wide Feature Dielectric Planarization using MnO2 Slurry

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Wide Feature Dielectric Planarization using MnO_2 Slurry

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Introduction

Chemical Mechanical Polishing (CMP) is investigated or used for the dielectric planarization and tungsten plug formation. In our prior work, we formed a tungsten plug using the newly developed MnO_2 slurry [1]. In this study, we tried to planarize a dielectric (SiO_2) with MnO_2 slurry for the first time. For dielectric planarization, wide feature planarization and minimal lower level dielectric removal is essential and colloidal silica slurry is widely used [2]. We found that MnO_2 slurry can planarize wide feature (2 mm x 2 mm) steps to a smaller height than the conventional slurry, while incurring less lower level dielectric removal.

Experiment

For both MnO_2 slurry and the conventional colloidal silica slurry, we examined polishing rates and the planarization ability. Figure 1 shows the polishing conditions. The speed of the head rotation is the same with that of the turntable throughout the experiments. We varied the polishing pressure from 0.21 kg/cm^2 to 0.84 kg/ cm^2 and the rotation speed from 20 to 100 rpm. The average abrasive particle size of MnO_2 was about 0.1 urn. The MnO_2 solid concentration was 7 wt%.

We formed a 0.5 um thick SiO_2 film on the six inch Si wafer by wet oxidation (Figure 2) and polished to characterize the polishing rate. Figure 3 shows a schematic cross-section of the test structure used to characterize the planarization ability. The SiO_2 film is formed using TEOS. Each region is 2 mm square and the initial step height is 0.8 um. We measured the remaining thickness of the high (T_H) and the low (T_L) and calculated the step height (=T_H - TL).

Results and Discussion

We examined the pressure dependence of the polishing rate with MnO_2 slurry and the conventional slurry which is widely used. Figure 4 shows that MnO_2 has higher polishing rate at below 0.7 kg/ cm^2 than the conventional slurry.

We examined the rotation speed dependence of the polishing rate at pressures

0.56 kg/ cm^2 and 0.21 kg/ cm^2, respectively. At 0.56 kg/ cm^2, the polishing rate of both slurries increased for higher rotation speeds (Figure 5). At 0.21 kg/ cm^2, the polishing rate of MnO_2 slurry increased for higher rotation speeds, whereas the polishing rate of the conventional slurry did not (Figure 6).

At a pressure of 0.21 kg/ cm^2, MnO_2 slurry planarizes a 2 mm x 2 mm region step to a height of less than 0.1 um after 5 minutes of polishing. The conventional slurry planarizes the step to a height of over 0.35 um after 12 minutes of polishing. This is because the conventional slurry cannot achieve a sufficient removal rate at 0.21 kg/ cm^2 pressure (Figure 7). Despite the lower pressure, the upper level is more selectively removed [3], the conventional slurry cannot be used appropriately at 0.21 kg/ cm^2.

Therefore, we planarized the step at 0.21 kg/ cm^2 with MnO_2 and 0.56 kg/ cm^2 with the conventional slurry. We controlled the rotation speed to get the same polishing rate (120 nm/min). Figure 8 shows that the step height decreases and the lower level oxide removal increases as the polishing time increases. However, MnO_2 slurry reduces the step height faster and the final step height is less than the conventional slurry. To clarify the planarization efficiency, we plotted the relationship between the step height and the lower level oxide removal of both slurries (Figure 9). MnO_2 slurry can reduce the step height with less lower level oxide removal. Moreover, it can achieve a smaller height.

Figure 10 shows an SEM image of the planarized dielectric after MnO_2 polish applied to interconnect pattern. A completely planarized surface is achieved. We also developed the cleaning method for post MnO_2 polish (Figure 11). We can get the same level of cleanness with the reference by adding the HC1+H_2O_2+ H_2O (1:1:48) solution (at RT) supply before scrubbing.

Conclusion

We used the MnO_2 slurry for the dielectric planarization. We found that MnO_2 slurry has an ample removal rate at a low polishing pressure, whereas the conventional slurry does not. Therefore, the MnO_2 slurry can planarize dielectric more completely, with less lower level removal than the conventional slurry.

Acknowledgements

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(2) S. Sivaram et al., Solid State Technology, p. 91 (1992),
(3) P. Renteln et al., VMIC Proc., p. 57 (1990).

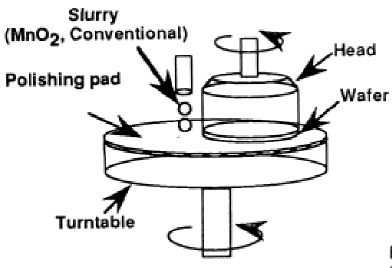

Fig. 1. Polishing conditions.

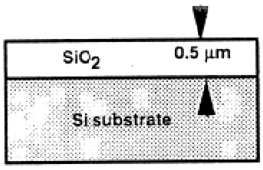

Fig. 2. Polishing rate measurement test structure.

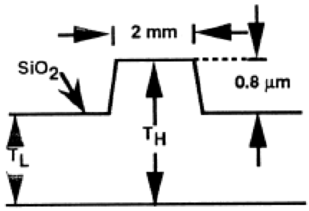

Fig. 3. Planarization ability test structure and measured spots.

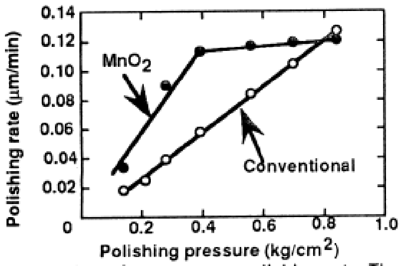

Fig. 4. Effect of pressure on polishing rate. The rotation speed is 40 rpm for MnO_2 and conventional slurries.

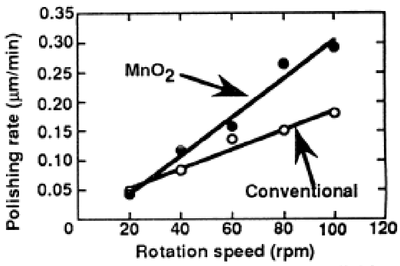

Fig. 5. Effect of rotation speed on polishing rate at pressure 0.56 kg/cm^2.

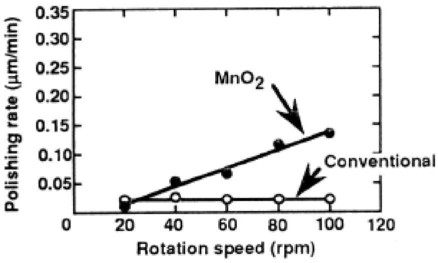

Fig 6 Effect of rotation speed on polishing rate at pressure 0.21 kg/cm^2.

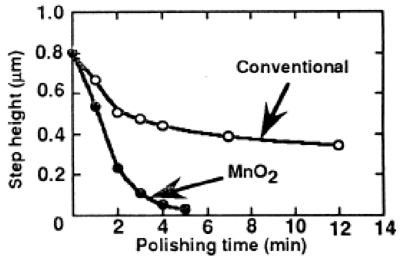

Fig. 7. Planarization trial at pressure 0.21 kg/cm^2 with MnO_2 and conventional slurries. The rotation speed is 40 rpm.

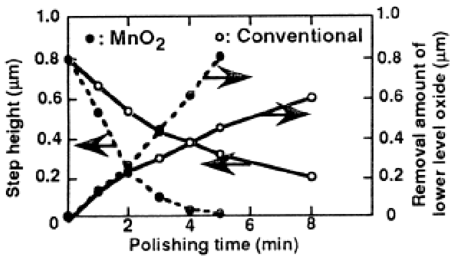

Fig. 8. Planarization ability comparison between MnO_2 and conventional slurry at the same polishing rate. The pressure is 0.21 kg/cm^2 and 0.56 kg/cm^2 with MnO_2 and conventional respectively.

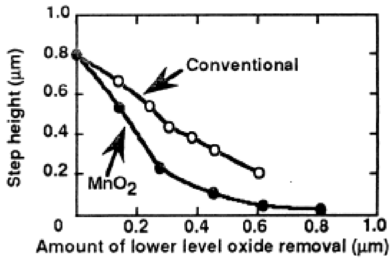

Fig. 9. Planarization efficiency comparison between MnO_2 and conventional slurry at the same polishing rate.

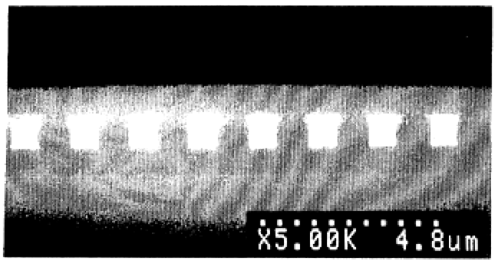

Fig. 10. Cross-sectional view of dielectric after CMP with MnO_2.

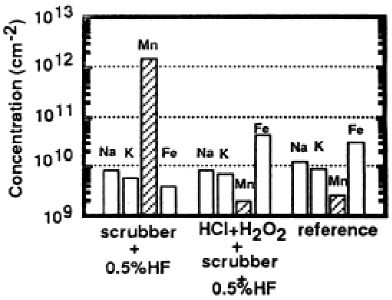

Fig. 11. Cleaning method improvement.