Effect of alkaline slurry on the electric character of the pattern Cu wafer*

Hu Yi(胡轶), Liu Yuling(刘玉岭)†, Liu Xiaoyan(刘效岩), He Yangang(何彦刚), Wang Liran(王立冉), and Zhang Baoguo(张保国)

Institute of Microelectronics, Hebei University of Technology, Tianjin 300130, China

Abstract: For process integration considerations, we will investigate the impact of chemical mechanical polishing (CMP) on the electrical characteristics of the pattern Cu wafer. In this paper, we investigate the impacts of the CMP process with two kinds of slurry, one of which is acid slurry of SVTC and the other is FA/O alkaline slurry purchased from Tianjin Jingling Microelectronic Material Limited. Three aspects were investigated: resistance, capacitance and leakage current. The result shows that after polishing by the slurry of FA/O, the resistance is lower than the SVTC. After polishing by the acid slurry and FA/O alkaline slurry, the difference in capacitance is not very large. The values are 0.1 nF and 0.12 nF, respectively. The leakage current of the film polished by the slurry of FA/O is 0.01 nA, which is lower than the slurry of SVTC. The results show that the slurry of FA/O produced less dishing and oxide loss than the slurry of SVTC.

Key words: resistance; capacitance; leakage current; alkaline slurry; chemical mechanical polish (CMP)
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1. Introduction

As interconnect circuits are scaled down to the deep submicron regime, interconnect delay becomes increasingly dominant over intrinsic gate delay. To reduce the RC delay time, changes in the interconnections are inevitable as the manufacturing technologies. Because longer interconnect wires result in high resistance, while the reduced interline spacing causes a significant increase in coupling capacitance and cross talk. In order to assure the performance of the high-speed circuits, continuous efforts have been devoted to incorporating copper or low-dielectric constant (low-k) materials into multilevel interconnections to reduce the major part of circuit delay, cross talk, and power consumption[1−3]. The implementation of today's copper low-k interconnects is strongly impacted by the acquired understanding of their overall reliability, both for metals and for dielectrics. For integrating Cu and low-k materials into integrated circuits (ICs), the Damascene technique[4, 5] with chemical mechanical polishing (CMP)[6, 7] is the most suitable approach towards using copper in a multilevel metallization scheme. Although a lot of studies have been focused on the planarization and topography of multilevel interconnection after the CMP process[8], little attention has been paid to the dielectric properties after the metal CMP process, especially for the influence of CMP slurries. In this experiment, the electric character of the films is tested to see whether it will degrade after polishing by the alkaline slurry.

2. Experiment

Experiments were performed in two parts: one was the process of CMP, and the other was the test of the electric character of the films. The wafers were 8 inch pattern Cu wafer which was 100 nm node. There were two kinds of slurry. One was acid slurry provided by the SVTC, which was in America, and the other one was FA/O alkaline slurry purchased from Tianjin Jingling Microelectronic Material Limited, which contains various chemical additives, such as abrasives, oxidizer and chelating agent. There were three wafers in the experiment, marked as wafers 1, 10 and 12. The three wafers were bought from the ADVANTEC Company, and the thickness of the Cu film was 700 nm. Wafer 1 was polished by the slurry of SVTC, and wafers 10 and 12 were polished by the slurry of FA/O. CMP was performed by a rotary type polisher, AMAT Mirra, using a standard Rohm Haas IC 1000 window pad. The window pad is used for an AMAT CMP tool with an end point detector. There is not any difference except there is a sensor on it. The platen speed was fixed at 35 rpm for the pattern Cu wafer. The speed of the carrier was 29 rpm. The membrane pressure was 2 psi. The flow rate of the slurry was 175 mL/min, and the polishing time was 160 s. The compound of slurry made by SVTC involved adding 1650 mL H_2O_2 into 18925 mL slurry, as the pattern Cu wafer slurry. The mixture of FA/O alkaline slurry was achieved by adding 176 mL H_2O_2 into 4000 mL slurry.

Then we investigated the effect of electric character of the films polished by the two kinds of slurry. We tested resistance, capacitance and leakage current by TEL P12XL prober with an Agilent 4073C tester. If you use different slurries, you should make sure that there is no metal residual on the wafers before you send them for e-test. If you check for polish rate or roughness, you don't need to remove them completely.

3. Results

E-test result for pattern wafers of mask 454 (100 nm). At the same pressure, the polishing rate is 2655 Å/min with acid slurry and 3871 Å/min with alkaline slurry. And the result of dishing and erosion is shown in Table 1.

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† Corresponding author. Email: lyl@hebut.edu.cn
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Table 1. Result of dishing and erosion.

Wafer	Dishing (nm)	Erosion (Å)
#1	156	604
#10	49	603
#12	90	526

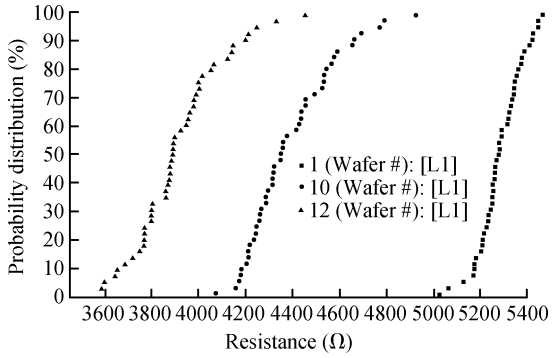

Fig. 1. Resistance of 0.1 μm line/0.1 μm space.

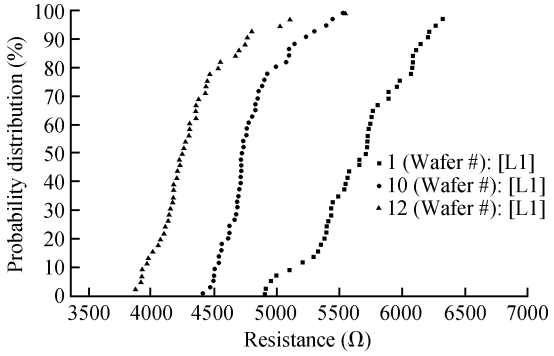

Fig. 2. Resistance of 0.1 μm line/0.5 μm space.

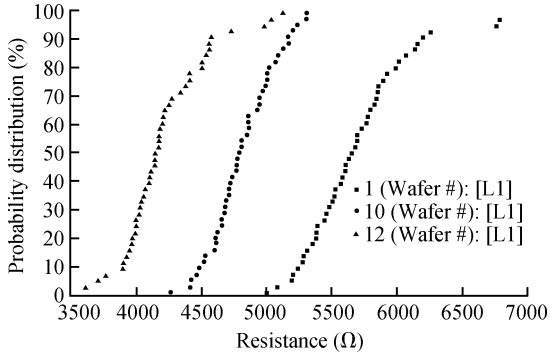

Fig. 3. Resistance of 0.1 μm line/10 μm space.

3.1. Results of resistance test

By means of the test results as shown in Figs. 1–3, we knew that the resistance of films polished by the slurry of FA/O is smaller than the slurry of SVTC. This leads to the conclusion that the films polished by FA/O alkaline slurry produced less dishing than the slurry of SVTC.

We can see from Figs. 1 to 3 that in the same line width 0.1 μm, and different spaces (0.1 μm space, 0.5 μm space, 10 μm space), the same results on the figures. Lines of triangles and circles represent the results of wafers 10 and 12, and the line of squares represents the results of wafer 1. The results of wafers 10 and 12 are better than those of wafer 1. As for wafers 10 and 12, it is very hard to judge the difference.

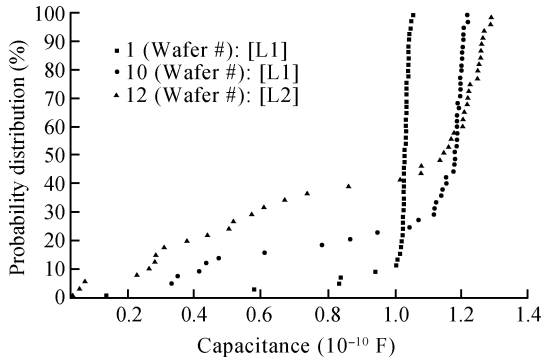

Fig. 4. Capacitance of 0.1 μm line/0.1 μm space.

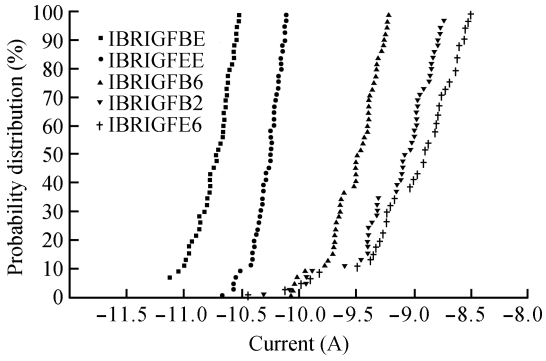

Fig. 5. Current of wafer 1 at 5 V.

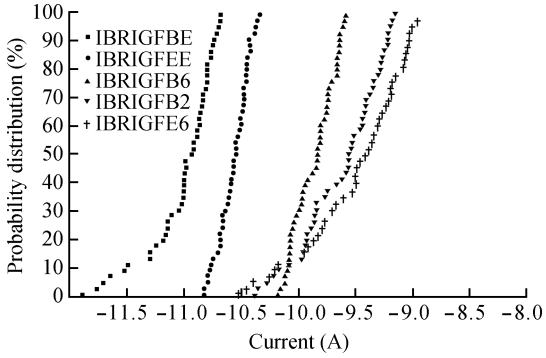

Fig. 6. Current of wafer 10 at 5 V.

3.2. Result of the capacitance test

After polishing by the two kinds of slurry, the difference in capacitance is not very large. The result in Fig. 4 is 0.12 nF, where the films are polished by the FA/O alkaline slurry. And the value is 0.1 nF for the SVTC. In contrast to this value is 0.04 nF before experiment, so we can see that the change is not very large.

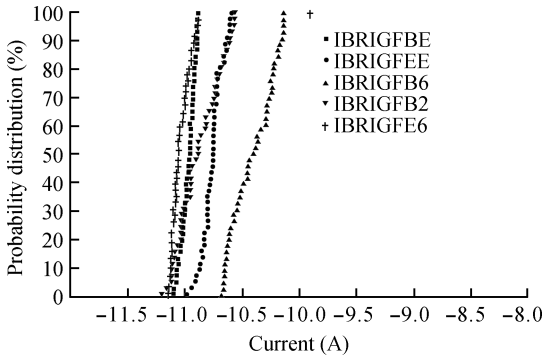

Fig. 7. Current of wafer 12 at 5 V.

3.3. Results of the leakage current test

The leakage current of films polished by the FA/O alkaline slurry is 0.01 nA, which is lower than the slurry of SVTC. The results are shown in Figs. 5 to 7. Thus, we can deduce that the FA/O alkaline slurry produced less dishing and oxide loss.

On each wafer we select five dots to test the leakage current, and we can see the five lines on the figures represent the results.

4. Conclusion

It will be fatal if the copper ion and other metal ions are left on the surface for electronic character and integrated circuits. It can make large leakage current and then breakdown. So it is very clear that we must wipe off the ions left in the circuits. The chelating agent in the FA/O alkaline slurry is very effect to get rid of the copper ion and other metal ions. According to the e-test of the electrical character, the results showed that FA/O alkaline slurry is activity on the dishing. And it produced less dishing and oxide loss at the same polishing parameter.

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