Extended Abstracts of the 1996 International Conference on Solid State Devices and Materials, Yokohama, 1996, pp. 142-144

Reconditioning-Free Polish for Inter-Layer-Dielectric Planarization

K. Nakamura, S. Kishii, and Y. Arimoto

Fujitsu Laboratories Ltd.
10-1 Morinosato Wakamiya, Atsugi 243-01, Japan
Tel: +81-462-50-8237
Fax: +81-462-48-3473

Abstract

In CMP (Chemical Mechanical Polishing) using a colloidal silica slurry with a pH of 10-11 for ILD (Inter- Layer-Dielectric) planarization, the removal rate drops off rapidly because of the pad surface degradation. Thus we must recondition the polishing pad surface in order to maintain a constant removal rate during the pad's life.

We clarified that this degradation was caused by the KOH solution in a conventional slurry. We also found that our newly developed MnO_2 slurry could avoid that degradation for reconditioning-free CMP.

1. Introduction

We investigated using CMP for planarizing the dielectric, to develop a practical global planarization system for ILD films in multi-level interconnections.[1,2] In the CMP process for ILD planarization, we generally use a colloidal silica slurry. This slurry has a pH of 10-11 and has added K^+ (920 ppm), because K^+ (an alkaline metal) greatly increases the oxide removal rate.[3]

When we use this slurry, the removal rate rapidly drops off during the polishing process due to pad surface degradation.[4,5] This degradation is regarded as the physical deformation of the pad surface caused by applied shear forces during the polishing process.[6] Thus we must recondition the polishing pad surface in order to maintain a constant removal rate during the pad's life.

In a pad reconditioning process, the polishing pad is ground by a diamond file. This reduces the polishing pad's life, and also generates dust, which reduces yield by increasing the number of defects caused by particles.

In this paper, we will show that the polishing pad degradation was mainly caused by the KOH solution in the conventional slurry. We also demonstrate our newly developed MnO_2 slurry[7,8] to avoid the pad surface degradation for reconditioning-free CMP.

2. Clarification of the pad surface degradation factor

Figures 1 and 2 show the surface roughness of a virgin pad (IC1000). The removal rate decreases when the pad surface becomes smooth. The RMS (Root Mean Square) roughness parameter of this pad's surface was 10.5 μm, and there were no flat regions.

However, after a 75 minute polish using a conventional slurry containing KOH, the pad surface became smooth, as shown in Figures 3 and 4. In this experiment, we polished wafers with a thermal oxide film at 0.56 Kg/cm^2 and the rotation rates of both regions where the wafer and the polishing plate were 60 rpm. In Figure 3, the glazed areas show the regions where the surface roughness has been worn-out. The RMS roughness parameter of this surface was 5.07 μm.

After a 75 minute polish *with only a KOH* solution that does not contain any abrasive, we examined the pad surface condition. Figure 5 shows a photograph of this pad surface. The glazed area in Figure 5 is larger than that in Figure 3, because the pad surface of Figure 3 is ground by the silica particles in the slurry.

Figure 6 shows a photograph of the pad surface after a 75 minute polish *with only water*. There were almost no glazed areas on this pad's surface.

Thus, the degradation of a polishing pad's surface is mainly due to a change in the pad material surface morphology due to interaction with the KOH solution, not to the physical deformation of the pad's surface caused by the applied shear forces during the polishing process.

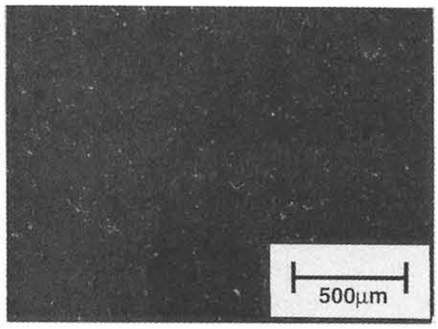

Figure 1. Photograph of a virgin pad surface.

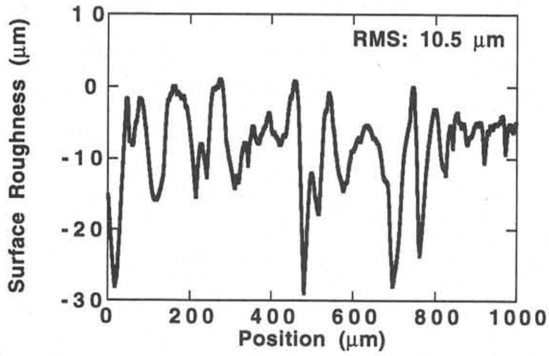

Figure 2. Surface roughness profile of a virgin pad. The RMS is 10.5 μm and the maximum peak-to-valley height is about 30 μm.

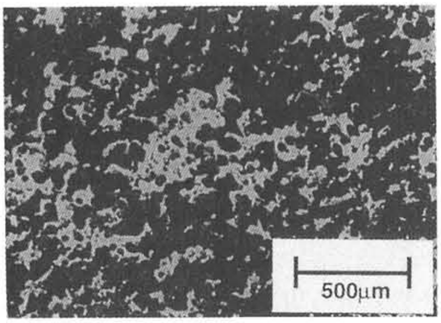

Figure 3. Photograph of a pad surface after a 75 minute polish with a conventional slurry containing KOH. The glazed areas show the regions were the roughness has been worn-out.

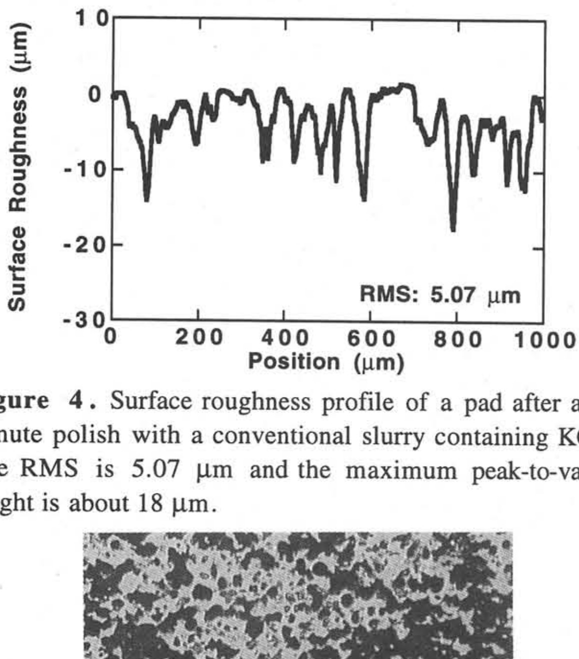

Figure 4. Surface roughness profile of a pad after a 75 minute polish with a conventional slurry containing KOH. The RMS is 5.07 μm and the maximum peak-to-valley height is about 18 μm.

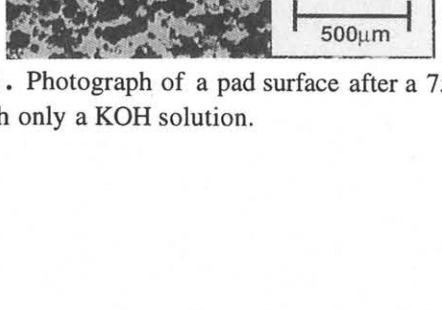

Figure 5. Photograph of a pad surface after a 75 minute polish with only a KOH solution.

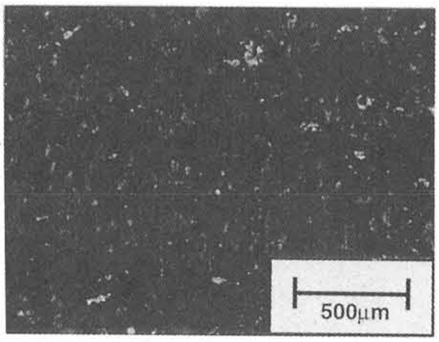

Figure 6. Photograph of a pad surface after a 75 minute polish with water.

3. Reconditioning-free polish with MnO_2 slurry

Figure 7 shows a photograph of the pad surface after a 75 minute polish with a conventional slurry with light polishing pressure. In this experiment, we polished wafers with a thermal oxide film at 0.21 Kg/cm^2 and the rotation rates of both the wafer and the polishing plate were 80 rpm. This is the same polishing condition that we polished wafers with a thermal oxide film using an MnO_2 slurry. When we polish using a light weight, we also see the deformation of the polishing pad's surface. The glazed area for the light-pressure polish was as large as that in Figure 3, and we confirmed that the removal rate dropped off rapidly as we expected. This means that the polishing pad degradation is independent of the polishing pressure, and depends on the KOH solution added to a conventional slurry.

Figures 8 and 9 show the pad surface condition after a 300 minute polish with an MnO_2 slurry. In this experiment, we polished wafers with a thermal oxide film at 0.21 Kg/cm^2 and the rotation rates of both the wafer and the polishing plate were 80 rpm. There were almost no glazed areas, and the RMS of this pad's surface was 7.39 μm. KOH is not added to an MnO_2 slurry, so the glazed areas of the polishing pad are formed by a frictional force between the wafer and the polishing pad. The polishing pad is also ground by the MnO_2 particles in the slurry, so that small roughness regions are generated. Thus, polishing with an MnO_2 slurry has a self-reconditioning effect on the pad.

Figure 10 shows the removal rates of the thermal oxide film, using a conventional slurry and an MnO_2 slurry. In this experiment, we polished wafers with a thermal oxide film at 0.21 Kg/cm^2 with an MnO_2 slurry and 0.56 Kg/cm^2 with a conventional slurry. The rotation rates of both the wafer and the polishing plate were 80 rpm with the MnO_2 slurry, and 60 rpm with the conventional slurry. The pressures and rpm rates were chosen to achieve the same polishing rates (both 120 nm/min.). In this experiment, we did not recondition the polishing pad surfaces. The removal rate for the conventional slurry dropped off rapidly, but that of the MnO_2 slurry did not drop off until after about 570 minutes (190 wafers). This means that we do not need to recondition the pad's surface until after 570 minutes of polishing using an MnO2 slurry.

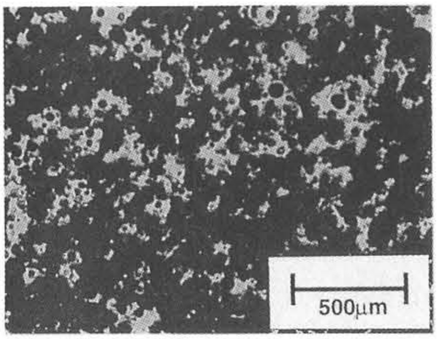

Figure 7. Photograph of a pad surface after a 75 minute polish with water using light polishing pressure.

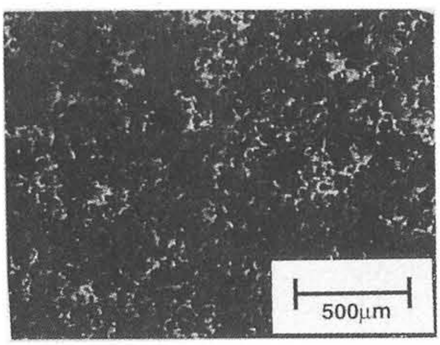

Figure 8. Photograph of a pad surface after 300 minute polish with an MnO2 slurry.

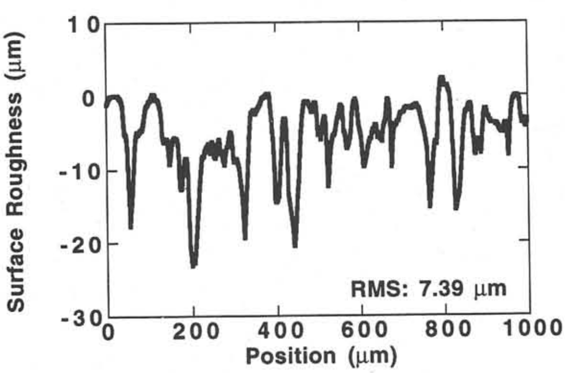

Figure 9. Surface roughness profile of a pad after a 300 minute polish with an MnO2 slurry. The RMS is 7.39 μm and the maximum peak-to-valley height is 18 μm.

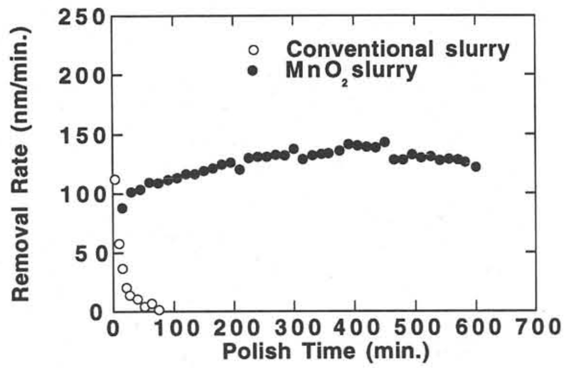

Figure 10. Removal rates of thermal oxide films, using a conventional slurry containing KOH and an MnO2 slurry, without surface reconditioning. Polishing pressures and rotation rates were adjusted to achieve same polishing rates (120 nm/min.).

4. Conclusion

We found that polishing pad's surface degradation was primarily caused by the KOH solution in a conventional slurry. By using our newly-developed MnO2 slurry we avoided the surface degradation. Using MnO2 slurry, we were able to polish wafers for about 570 minutes (190 wafers), without pad surface reconditioning. Our MnO2 slurry realizes a reconditioning-free polishing system, which extends the useful life of the polishing pad. This also prevents dust generation, which improves the yield due to the reduced number of defects caused by particles.

Acknowledgements

The authors wish to thank Y. Kiyokawa, A. Hatada, N. Sasaki and T. Itoh for helpful discussions and their support during this work.

References

1) B. Davari et al., IEDM Tech. Dig. (1989) 61.
2) W. J. Patrick et al., J. Electrochem. Soc. **138** (1991) 1778.
3) L. M. Cook, J. Non-Cryst. Solids **120** (1990) 152.
4) S. Sivaram et al., Proc. Mat. Res. Soc. Symp. **260** (1992) 53.
5) R. Jobe, Proc. ISMIC (1996) 265.
6) R. Jairath et al., Solid State Technology (1994) 71.
7) S. Kishii et al., IEDM Tech. Dig. (1995) 465.
8) S. Kishii et al., 1996 VLSI Symp., to be published.