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Dishing and Erosion in Chemical Mechanical Polishing of Electroplated Copper

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Polishing of copper, a process called copper chemical mechanical polishing, is a critical, intermediate step in the planarization of silicon wafers. During polishing, the electrodeposited copper films are removed by slurries; and the differential polishing rates between copper and the surrounding silicon dioxide leads to a greater removal of the copper. The differential polishing develops dimples and furrows; and the process is called dishing and erosion.

In this work, we present the results of experiments on dishing and erosion of copper-CMP, using patterned silicon wafers. Results are analyzed for the pattern factors and properties of the copper layers. Three types of pads – plain, perforated, and grooved – were used for polishing. The effect of slurry chemistries and pad soaking is also reported.

Keywords: chemical mechanical polishing, planarization, dishing, erosion, copper

1. Introduction

CMP is an important intermediate step in IC fabrication. Copper-CMP is a process by which an electroplated copper film is polished so that only the electrical interconnect remains. It is especially difficult because of differential polishing rates and uncertainty of how parameters influence rates. Location and extent of dishing and erosion is still not well characterized and this paper will present how some of the parameters are influenced by processing conditions.

2. Prior Results on Pressure Measurements

CMP is essentially a tribological phenomenon whereby the contact pressure at the wafer/pad interface is of importance. Prior work at Georgia Tech has shown that suction pressures exist at the interface between a rigid flat simulating the wafer, and the polishing pad. The magnitude of this suction pressure can be as high as the applied load that could mean added contact pressure between the wafer and the pad. This might result in a higher removal rate than predicted.

It was found [1] that the magnitude of this suction pressure is dependent on the relative speed between the wafer and the pad, the elastic modulus of the pad, the roughness of the pad etc. Results have also shown that the length of the soaking time of the pad in water has an affect on the pad modulus, which in turn can affect the suction pressure. It was also discovered that when plain and perforated Rodel IC1000 pads used, there exist suction pressures; but this suction pressure cannot be detected when k-grooved IC1000 pad is used. Figure 1 shows a typical pressure profile from the leading edge of fluid entrainment to the trailing edge, obtained from experiments.

3.Mask Design and Electrodeposition of Copper

Before copper-CMP can be carried out, patterned wafers have to be fabricated, and a mask for photolithography needs to be designed and made. The single chip layout of the mask design is shown in Figure 2. The chip occupies an area of 19.45mm x 19.45mm and is repeated in a square array over the 5" mask. On the mask, windows are opened for making lines or trenches on the wafers. The pattern consists of groups of copper lines with different line widths and pattern densities, and other features. These variations will be helpful in understanding how the suction pressure can affect dishing and erosion in the various combinations of line width and pattern density.

The 4" patterned wafers were fabricated using standard cleanroom techniques like thermal oxidation, photolithography, reactive ion etching, sputtering etc. After etching the trenches into the silicon dioxide, the wafers underwent electroplating whereby copper is grown from the copper seed sputtered onto the wafer earlier on. The process will fill up the trenches with copper.

The electroplating solution consists of a mixture of hydrochloric acid, sulphuric acid and copper sulphate. The parameters used in the process are shown in Figure 3. The electroplating facility consists of a bath whereby the temperature of the solution can be varied. The wafer can be rotated at chosen speeds and the anode can be made to swing side-to-side at selected speeds during the process. The flow rate of the solution between the wafer and the anode can be varied by adjusting the pumping speed. The current and type of pulse can be adjusted also. Figure 4 shows an image of the copper surface obtained.

The polishing is done using a commercial bench top polisher with a 300mm platen. The slurry is supplied by EKC Technology. It consists of Phase I for bulk copper removal and Phase II for the final polishing. Some initial results from the polishing experiments are shown in Figures 5 and 6. Figure 5 shows 1um micron wide copper lines on a wafer after polishing. Figure 6 shows a cross section of the 1um line with a dishing in the copper.

4. Conclusion

The mask design and fabrication of the patterned wafers have been carried out. The copper electroplating process was also optimized to produce good copper films on the wafer. The initial polishing experiments were also successful in the removal of excess copper from the wafer. We will report on how the suction pressure variation within the wafer/pad contact area can affect the dishing and erosion distribution of the wafer; and how the line width and pattern density come into play.

5. Acknowledgements

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6. References

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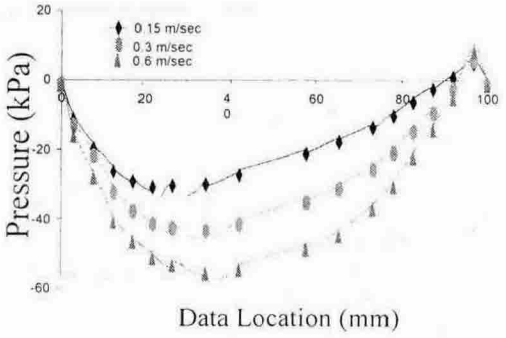

Figure 1 Interfacial fluid pressure profile.

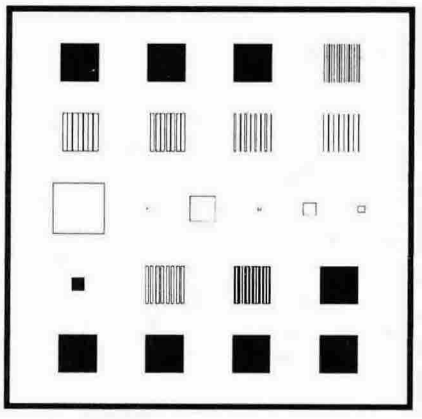

Figure 2 Single chip layout of mask.

Temperature	20 deg C
Wafer Rotation Speed	8 (arb. Unit)
Anode Agitation Speed	5 (arb. Unit)
Pumping Speed	5 (arb. Unit)
Applied Current	5.3 mA/cm^2
Current Pulse Interval	0.1 / 0.1 ms

Figure 3 Copper electroplating parameters.

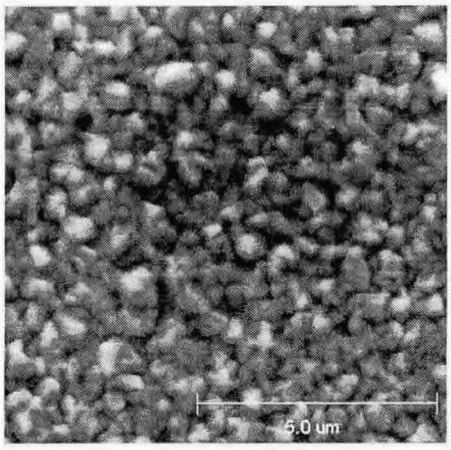

Figure 4 SEM image of an electroplated copper surface ready for polishing.

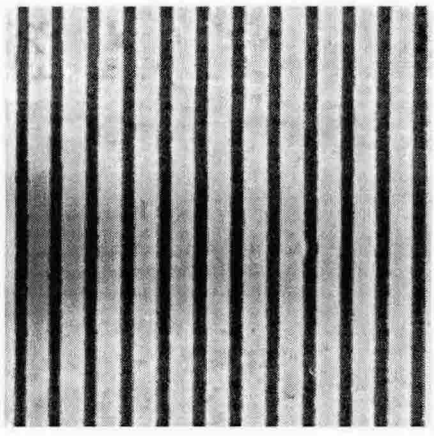

Figure 5 Polished wafer surface. The lighter color lines represent 1um wide copper lines.

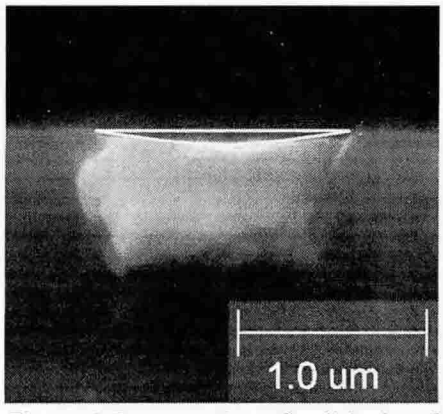

Figure 6 Cross section of polished wafer showing the dishing of a 1um copper line.