Title
Pad Contact Area Characterization in Chemical Mechanical Planarization

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Publication Date
2004-05-31

PAD CONTACT AREA CHARACTERIZATION IN CHEMICAL MECHANICAL PLANARIZATION

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ABSTRACT

There are many elements affecting CMP performance such as slurry, pad, process parameters and pad conditioning. Among these, the pad is considered as one of the most important parts because of its deterioration during polishing. However, a special purpose pad design has not been tried yet. In this paper, a fabrication process and prototype are detailed using micro molding technology. These are applied to pad design optimization

Keywords: Chemical mechanical polishing (CMP), micro molding, pad design.

INTRODUCTION

Chemical Mechanical Planarization (CMP) is considered to be one of the most versatile IC fabrication technologies capable of achieving planar surfaces that are essential for very large scale integrated circuits (VLSI). During the CMP process, a wafer is placed face side down on a pad under high pressure, both rotating simultaneously. High pressure, rotational speed, and chemical-mechanical reactions enhanced by chemical slurry result in a planarized surface (Yu et al., 1993).

Generally, the pad surface has numerous independent pores that temporarily hold fresh slurry. The pores are separated by polyurethane wall structures that contain micro asperities. As these micro asperities provide space for reactions between wafer and pad, deterioration occurs continuously during the process (Oliver et al., 2000). The real contact area increases when the asperities make direct contact with the wafers and this results in reduced real contact pressure. As a result, the material removal rate drops (Oliver et al., 2000). To achieve constant removal rate and uniformity, it is required to maintain a constant real contact area. This is ensured by the use of a diamond grit conditioner that regenerates the peaks and valleys on the pad.

Since the real contact area plays an important role in CMP, pad surface characterization has been thought of as being very essential, but the pad surface deterioration mechanism has yet to be fully understood.

The deterioration of the pad surface in CMP is investigated in this paper using pads made with different geometries, which provide different deterioration mechanisms, wear and deformation. These design and fabrication of these pads (using micro molding technology) is described.

PAD DETERIORATION MECHANISMS

Although the pad degrades during CMP, it is hard to establish an appropriate mechanism due to the inherent wet nature of the process. Wear and deformation are two candidate mechanisms explored in this paper and either one can theoretically explain the observed increase in real contact area. Until now, wear based on Greenwood and Williamson (1996) and deformation on polymer erosion have been suggested (Barteney and Lavrentev, 1981). The wear mechanism increases the number of contact points without changing the unit size of contact. Deformation, on the other hand, increases the contact area instead of the contact number. Figure 1 shows the two different pad deterioration mechanisms.

PAD DESIGN BASED ON CHARACTERIZATION

To understand the pad deterioration mechanism, it is necessary to characterize the pad surface topography. In this work, a VSI-based laser interferometer, WYKO NT3300, is used to measure pad surface topography. To improve reflectance, the pad is coated with 25 nm gold layer.

Generally a pad is made of polyurethane foam and has a surface of peaks and valleys after conditioning in an initial step.

From a top view analysis, the surface is covered with pores (diameter: 40-60 μm) separated with wall structures (width: 10-30μm). The density of pores is known to be 30-50% (Figure 2 (a)).

Using surface profile analysis, a correlation between pad geometry and the conditioner is found. That is, there is a functional frequency in pad peaks and valleys. Based on this investigation, the side view of a pad can be divided into 3 regions, namely the reaction region, the transition region and the reservoir region (Figure 2(b)). The reaction region is the

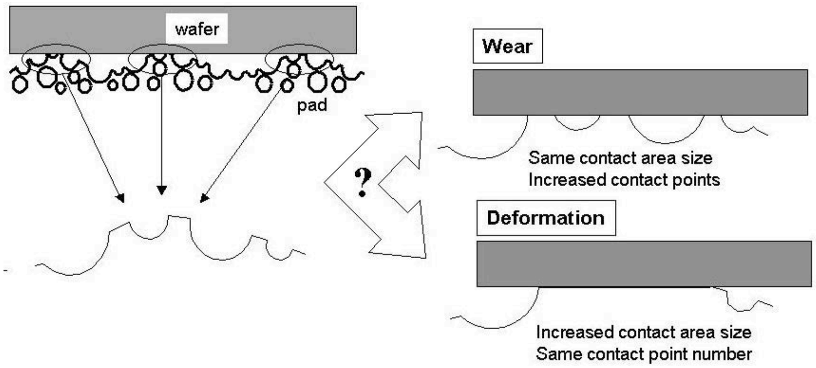
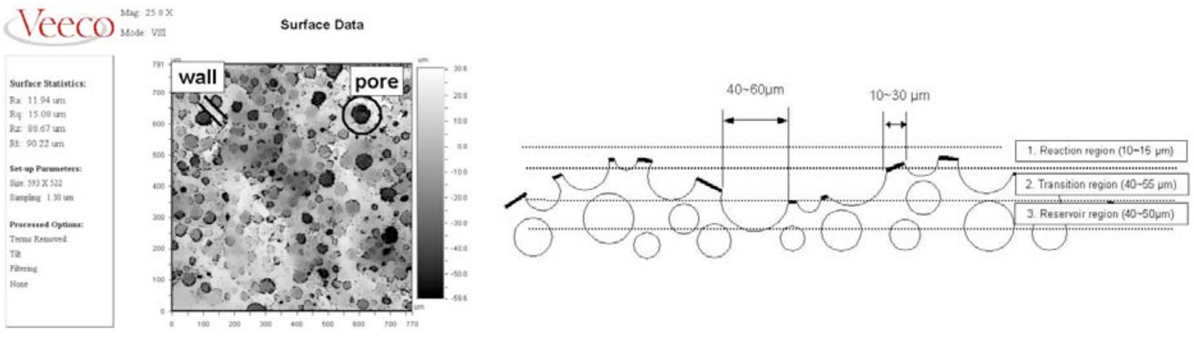


FIGURE 1. PAD DETERIORATION MECHANISMS.



(a) TOP VIEW

(b) SIDE VIEW

FIGURE 2. PAD SURFACE ANALYSIS.

space where pad and wafer have multiple direct contacts with abrasives. The transition region is for slurry transportation from the reservoir region to the reaction region. Fresh slurry supplied to the pad can be held temporarily in the reservoir region and flows through the transition region to the reaction region. As the degradation mechanism is limited to the reaction region, the discussion in this paper is restricted to that area. The transition and reservoir regions will be discussed later.

By using bearing ratio analysis, the data is acquired for the ratio of the area along the z-axis to the whole surface. Pad deformation along the z-axis is measured to be 10-12µm when the pressure is 500 g/cm^2. The ratio of the area 10µm from the top to the whole surface is found to be 3-5% on average. A ratio of 3.2% is chosen for the initial state in pad design. The size of the contact area is measured to be 20-50 µm on each side. The distribution of each contact area is considered to be uniform. According to this analysis, the initial contact area is characterized as a series of units, each consisting of 5 individual squares (20x20 µm for each square) within a larger square region of 250x250 µm.

Two types of pads are designed and fabricated to simulate the two pad degradation mechanisms. The wear mechanism can be captured suitably by increasing the number of contact points of the designed pad. Pads with increased contact area but identical numbers of contact point can mimic the effects of the deformation mechanism. Experiments are performed with pads that simulate these two conditions. The ratio of real contact area to pad surface area is maintained when investigating the two different mechanisms to enable a direct comparison of results. Pads used in the experiment are fabricated using micro molding technology. Figure 3 shows the design of the pad.

PAD FABRICATION

To verify wear and deformation theories, a micro molding technology is used in fabrication of the pads. A silicon wafer is etched with deep reactive ion etching (DRIE) process. The contact area is left unetched with a step height of 20µm. This etched wafer is used as a master and replicated by silicone rubber in a molding process. Then the silicone rubber is used as the mold for the pad. Figure 4 details the indirect casting process.

After manufacturing the pad, the dimensions of the etched wafer, silicone rubber, and pad are measured. In the etched wafer, the step height is 19.6µm. This is precisely copied to a silicone rubber mold with a step height of 19.7µm. Using this mold, the pad is fabricated with a step height of 19.1µm. The Precision of the micro molding process is better than 1µm. Figure 5 details the fabricated features and the results of the measurement.

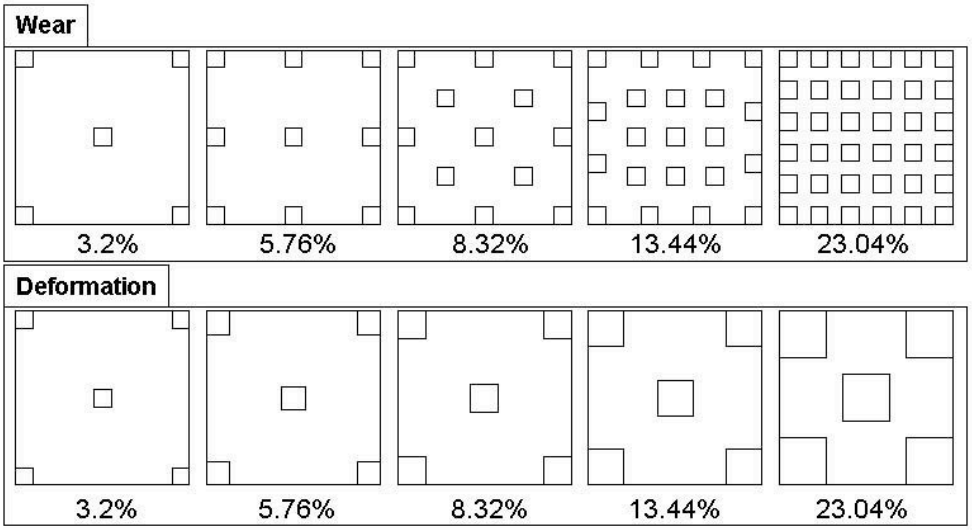


FIGURE 3. PAD DESIGNS.

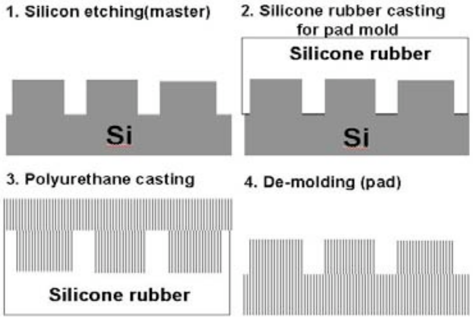
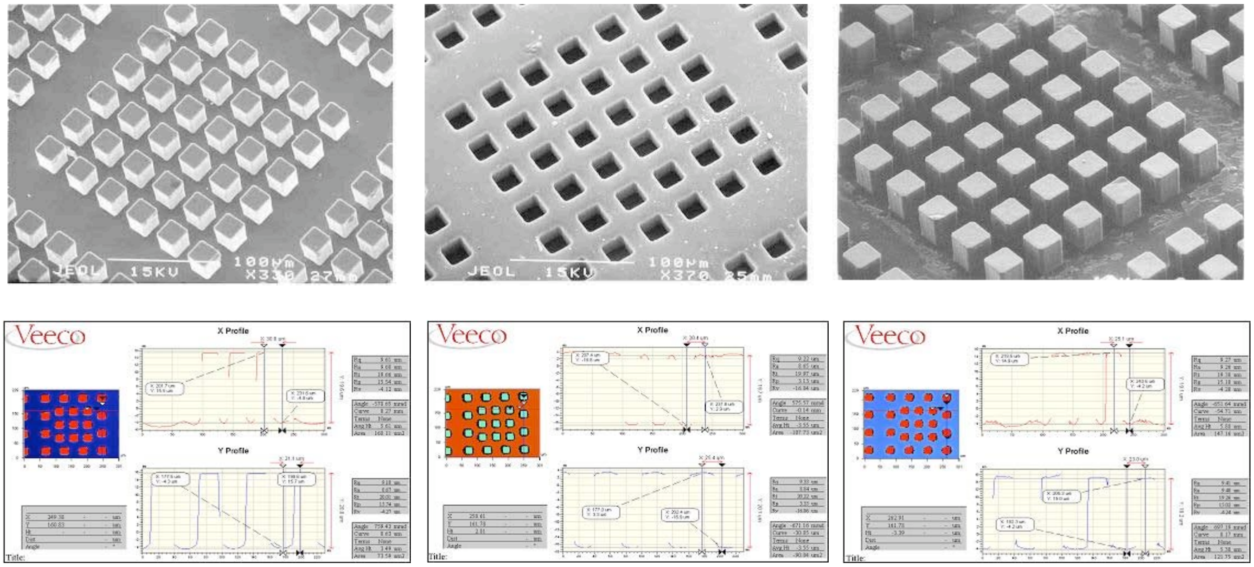


FIGURE 4. PAD FABRICATION PROCESS.



(a) ETCHED WAFER (MASTER) (b) SILICONE RUBBER (MOLD) (c) POLYURETHANE PAD

FIGURE 5. DIMENSION MEASUREMENTS.

CONCLUSION & FUTURE WORK

To characterize the pad deterioration mechanism, pads with different geometries are fabricated using micro molding technology. The dimensional accuracy is far superior compared to other molding methods. CMP experiments are being planned, in order to clarify the pad degradation mechanism, and will be reported on later.

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