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The Effect of Mechanical Properties of Polishing Pads on Oxide CMP (Chemical Mechanical Planarization)

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The purpose of this study was to investigate the effect of micro holes, pattern structure and elastic modulus of pads on the polishing behavior such as the removal rate and WIWNU (within wafer non-uniformity) during CMP. The regular holes on the pad act as the superior abrasive particle's reservoir and regular distributor at the bulk pad, respectively. The superior CMP performance was observed at the laser processed bulk pad with holes. Also, the groove pattern shape was very important for the effective polishing. Wave grooved pad showed higher removal rates than K-grooved pad. The removal rate was linearly increased as the top pad's elastic modulus increased.

Keywords : CMP (Chemical Mechanical Planarization), Pad, Holes, Groove pattern, Elastic Modulus

1. INTRODUCTIONS

Chemical Mechanical Planarization (CMP) is widely used for planarizing both metal and inter-level dielectric layers in the fabrication of integrated circuits to achieve adequate planarization necessary for the stringent photo-lithography depth of focus requirements and the formation of novel damascene interconnection structures [1]. CMP can be performed by pressing a rotating wafer against a moving polishing pad on which suitable slurry containing chemicals and abrasive particles is dispensed. Planarization of the wafer results from the synergistic action of the mechanical shear forces and the chemical action of the slurry [2]. Hence, the chemical and mechanical properties of polished films have respectively great influence on the wear and chemical mechanism during CMP process.

In the case of the wear mechanism, the reaction between polishing pad and abrasive particles in the slurry was important. All commercially available polishing pads are relatively complex composite materials, and have micro pores in it [3]. These pores on pad act as reservoirs for abrasive particles in the slurry and help to polish substrates effectively. They are very irregular in size and distribution can be easily deformed during polishing and conditioning. This deformation can cause the non-uniformity in removal rate and planarity. The role of grooves on pad is well known to facilitate the transportation of the reactant slurry and the product residues across the pad surface during polishing. Even though the hardness, pore density and pattern structure of pad are very important factors in determining the polishing performance, not much studies have been reported on pad. The purpose of this study is to investigate the effect of hardness, pore density and pattern structure of pads on the polishing behavior such as the removal rate, WIWNU (within wafer non-uniformity) and friction efficiency during CMP.

2. EXPERIMENTAL PROCEDURES

All polishing experiments were carried out using a UNIPLA NS-110, SEMICONTECH. Both the carrier and platen speeds were set at 30rpm. The down pressure and retainer ring pressure of carrier was respectively 7psi, 9psi and the flow rate of slurry was 200ml/min. The polishing and pad conditioning time were set for 2 min and 1min, respectively. Fumed silica based alkaline slurry (Hanhwa oxide slurry, HS-1200) was used for the polishing experiments. PECVD TEOS 6" wafers were used for the oxide polishing. The micro holes were made on rigid bulk pad without any pores on it by a laser process. The bottom soft pad was attached on the laser processed PU (polyurethane) pad. The size and density of pores can be changed flexibly. These pads with these micro holes can keep the original pad topography and hole shape after the continued polishing and pad conditioning process. To determine the removal rate, non-uniformity and the TEOS film thickness were measured using a Nanospec optical film thickness measurement apparatus (Nanometrics AFT Model 200).

3. RESULTS AND DISCUSSIONS

The micro pores on conventional pad were shown in Figure 1a. Also, the micro holes were made on rigid bulk pad without any pores by a laser process, as shown in Figure 1b. The irregular pores and regular micro holes can be observed through the SEM and optical microscopy images, respectively. In the case of the conventional pads, they have very irregular micro pores and their distribution.

Figure 2 shows the removal and non-uniformity of conventional pad (RODEL IC1400) and bulk pad with laser process. The slightly higher removal rate can be observed at the conventional pad. However, the higher non-uniformity value (16.4%) was observed in comparison with the value (11.6%) of the rigid bulk pad by a laser process. It is noted that the irregular pores and distribution can be deformed during polishing and conditioning process, and they caused the non-uniformity in removal rate and non-planarity. In the CMP process, the planarity and uniformity efficiency were very important factors in determining the polishing performance.

Figure 3 shows the removal rate and non-uniformity with and without holes on bulk pads, respectively. K-groove pattern was made on the rigid bulk pad. The higher removal rate and better non-uniformity on oxide were observed on pads with holes. It indicates that the holes act as abrasive particle's reservoir and enhance the contact time and area between slurry and wafers.

Figure 4 shows the dependency of groove patterns on pad on the removal rate and non-uniformity. Conventional circular type K-grooves and modified wave grooves were used for the experiments. The superior CMP performance of the higher removal rate and lower non-uniformity was observed when the wave groove pad was used. It was expected that wave groove pad had the longer slurry residence time than K-groove pad during polishing due to the larger groove areas.

Figure 5 shows the removal rate as a function of elastic modulus of pad. The removal rate was linearly increased as the top pad's elastic modulus increased. The pad deforms itself according to its modulus values and exerts different pressures on the TEOS films which result in the different removal rates.

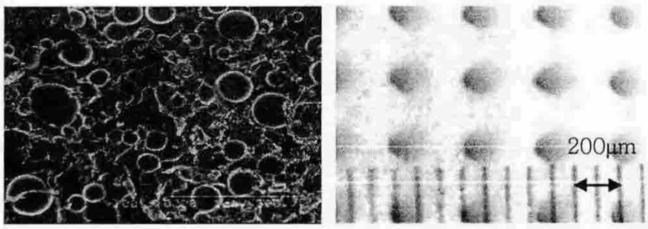
4. SUMMARY

In this study, the laser processed polishing pads were evaluated in terms of the removal rate, non-uniformity. The effects of parameters such as micro holes, groove pattern structure and elastic modulus of the top pad were evaluated. The formation of uniform arrays of holes on the pad enhanced the removal rate with better wafer uniformity. These holes act as the abrasive particle's reservoir during polishing.

The pattern shape was also very important in determining the CMP perfomance. Wave type grooved pads showed higher removal efficiency than K-grooved pad. The higher removal rate and lower non-uniformity might be due to the better contact of slurry with wafers with wave groove pad.

The removal rate was linearly increased as the top pad's elastic modulus increased. The elastic modulus might determine the contact area of slurry on wafers i.e. the pressure of pad.

5. FIGURES



(a) (b)

Fig. 1 . (a) Micro-pores on conventional pad, (b) micro holes of the top view in pad produced by laser process

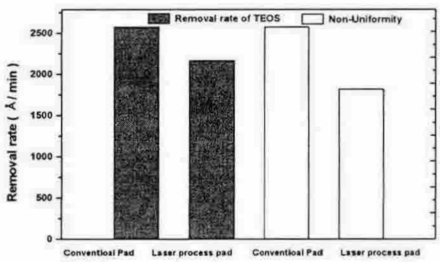


Fig 2. The removal rate and non-uniformity between conventional, RODEL IC1400 pad and laser processed bulk pad

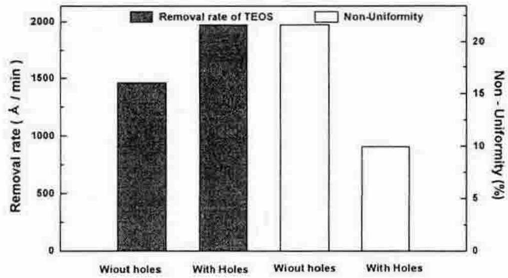


Fig 3. The removal rate and non-uniformity with and without holes on bulk pad

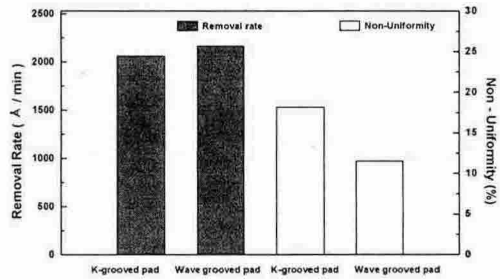


Fig 4. The removal rate and non-uniformity of K-grooved pad and wave grooved pad

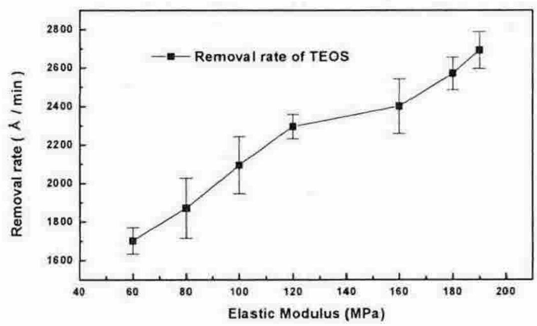


Fig 5. The removal rate and non-uniformity as function of elastic modulus of pads

6. REFERENCES

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