Development of Multiple CMP Monitoring System for Consumable Designs

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Consumables used in Chemical Mechanical Polishing (CMP) have been played important role to improve quality and productivity. Since the properties of consumables constantly change with various reasons, such as shelf time, manufactured time, lot to lot variation from supplier and so on, CMP results are not constant during the process. Also, CMP process results are affected by multiple sources from wafer, conditioner, pad and slurry. Therefore, multiple sensing systems are required to monitor CMP process variation. In this paper, the authors focus on development of monitoring system for CMP process which consist of force, temperature and displacement sensor to measure the signal from CMP process. With monitoring systems mentioned above, complex CMP phenomena can be investigated more clearly.

Keywords : Multiple CMP monitoring, Friction, Temperature, Pad profile

1. INTRODUCTION

Consumables used in Chemical Mechanical Polishing (CMP) have been played important role to improve quality and productivity. Since the properties of consumables constantly change with various reasons, such as shelf time, manufactured time, lot to lot variation from supplier and so on, CMP results are not constant during the process. Also, CMP process results are affected by multiple sources from pressure, velocity, pad, slurry, pH, temperature, wafer topography, etc, Since CMP process depends on numerous complex factors such as it is difficult to research the fundamental mechanism, development of consumables, and so forth. Therefore, various approaches have recently been developed to understand the fundamentals of CMP process. So, multiple systems are required to monitor CMP process variation.

In this paper, sensing the authors focus on development of monitoring system for CMP process which consist of force, temperature and displacement sensor to measure the signal from CMP process.

The friction sensor converts friction force from the interface between pad and wafer. Therefore, the change in signal resulting from variation of consumable condition can be detected and analyzed based on dynamic interpretation of the signal. Also, the temperature sensor is used in order to monitor the change of temperature during CMP process. Laser displacement sensor is used in order to monitor the pad profile variation before and during the process. Therefore, the profiler is designed to scan a pad in radial direction to acquire pad thickness variation during CMP process. With monitoring systems mentioned above, complex CMP phenomena can be investigated more clearly. The developed monitoring system is shown in Fig. 1.

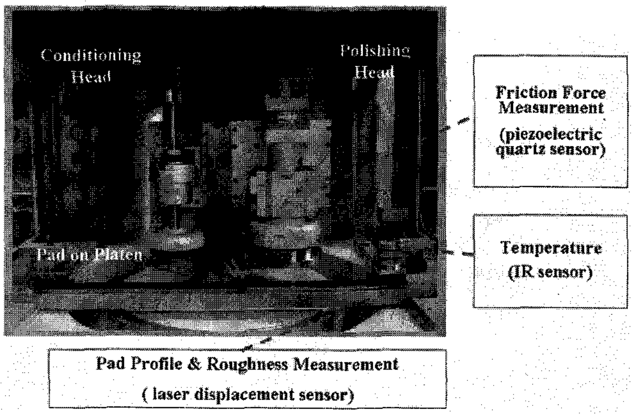

Fig. 1. CMP equipment with multiple monitoring systems.

2. INSTRUMENTAL AND RESULT

2.1 Friction force sensing system

An experiment was designed to acquire the data for deriving the relationship between the friction force and the CMP characteristics. The direction of friction force is perpendicular to the axes of rotation. the piezoelectric quarts sensor was embedded in GNP POLI 500 polisher (G&P Technology, Korea) to monitor the friction force during the CMP process. Friction force monitoring system is designed to measure a high frequency dynamic friction force accurately. The Piezoelectric quarts sensor's type is 9230B, it was made in KISTLER. Figure 2 shows the principal of the friction force calculation.

Friction force was calculated from a moment balanced objection. Figure 3 shows the algorithm of the friction force sensing. This system consists of piezoelectric sensor, A/D converter, and analysis software. The piezoelectric sensor attached on polishing head gives dynamic friction signal with voltage, and this signal is amplified and converted by A/D converter. The resolution of friction force measurement is 0.001 mV and the software program calculates the electric signal value in kgf according to the sensor calibration. And then, CMP analysis software displays friction force signal on the monitor during process.

$$R(v)\bullet a = F\bullet b \qquad (\Sigma Mo=0) \tag{1}$$

Table 1 shows the experimental condition. Removal rate was measured by AUTO-ELTM(RUDOLPH), and measurement pattern is the 19 point diameter scan with 5 mm edge exclusion. Within wafer non-uniformity (WIWNU) was calculated by standard deviation uniformity of America Society of Testing Materials (ASTM). Figure 4 and Fig. 5 show that the velocity and pressure affects the friction force and friction energy.

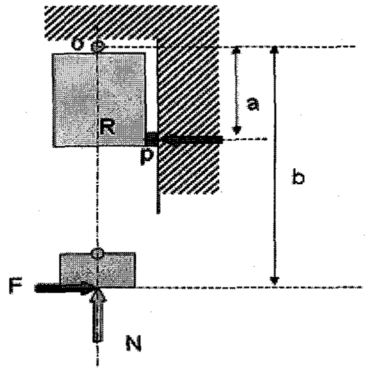

Fig. 2. The theory of friction force calculation.

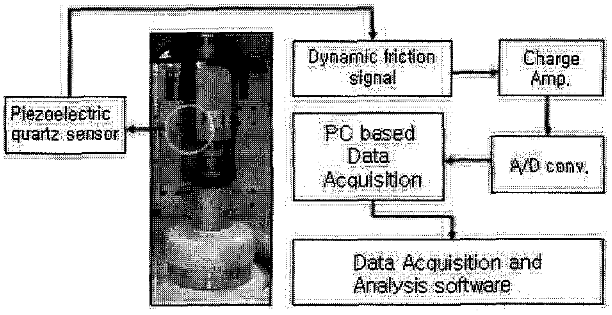

Fig. 3. The schematic algorithm of friction force measurement.

As the velocity increase, the friction energy also increase, whereas, the friction force decrease.

But, as the Velocity increases, the friction energy and the friction force also increase. Therefore, controlling CMP process is essential for CMP results.

Table 1. Experiment condition.

Pressure	100 ~ 800 g/cm2
Velocity	Head and Table : 30 ~ 110 rpm
Slurry	ILD1300™
Pad	IC1000/Suba400 stacked™ Suba400™
Slurry flow rate	150 cc/min
Temperature	24 ℃
Wafer	4 inch thermal oxide wafer
Polishing time	1 min

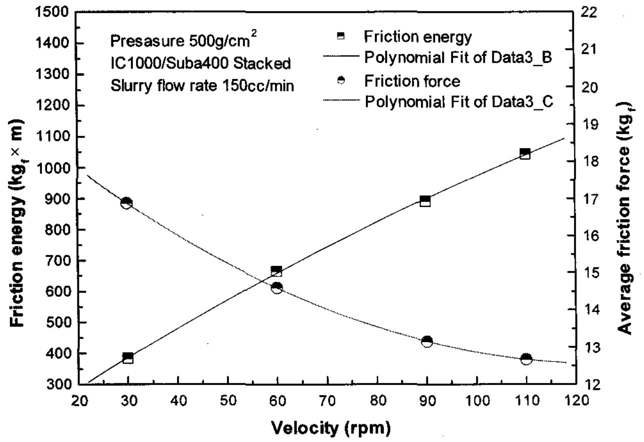

Fig. 4. Friction energy and average friction force as a function of velocity.

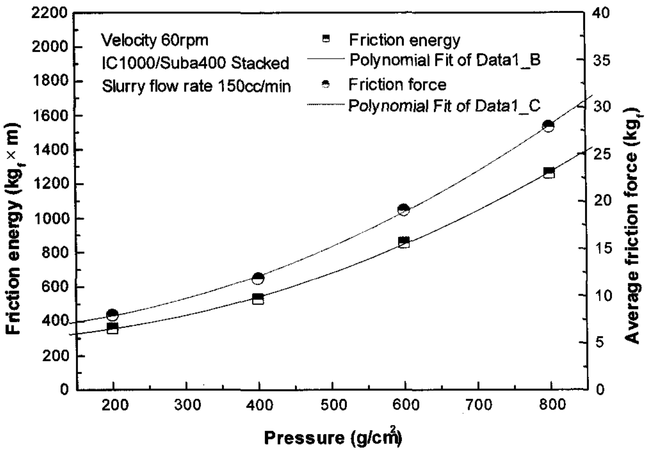

Fig. 5. Friction energy and average friction force as a function of pressure.

2.2 Temperature sensing system

An experimental for temperature sensing system was established on the GNP POLI 500 polisher. Temperature sensor is ES1-LP3 IR sensor which is embedded over the pad. Chemical reaction rate summary the elements with frequency is defined with product of the probability which will pass over a reaction activation energy. When the temperature increases in the CMP process, chemical reaction by the kinetic energy increase of the element the probability which will pass over the reaction activation energy barrier comes to be high. According to the Arrhenius, reaction constant (K) becomes larger. Therefore, it is important that the change of the temperature from the CMP process condition.

$$K = A\exp(-E_a/RT) \qquad (2)$$

A : Arrhenius constant, E_a : active energy, R : vapor constant, T : temperature

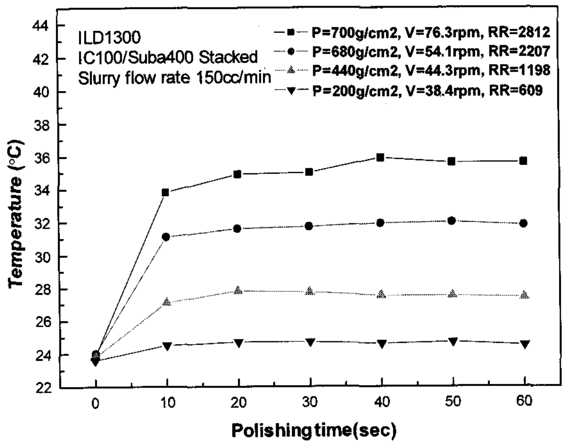

Fig. 6. Temperature as a function of polishing time at the different removal rates.

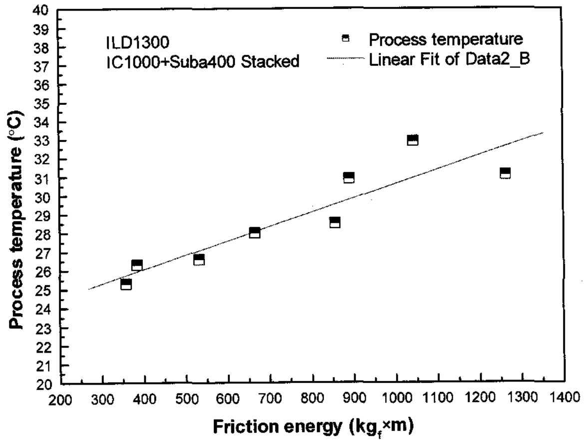

Fig. 7. Average process temperature as a function of friction energy.

Figure 6 shows temperature as a function of polishing time at the different removal rates. Figure 7 show average process temperature as a function of friction energy. As increases friction energy, process temperature also increase lineary.

2.3 Pad profile sensing system

An experimental for pad profile sensing system was established on the GNP POLI 500 polisher. Acquiring to pad profile signal, used laser displacement sensor. It is Z4M-W which is embedded overpass on the pad. It was driven by linear motor. Fig .8 shows amount of pad as distance on pad. In this case, as the change of R and distance on pad, amount of pad wear was irregularly changed. The change of pad wear will be affected CMP results, furthermore, the change of slurry and wafer etc will be occurred another result. So, it is required more experiment of another consumables.

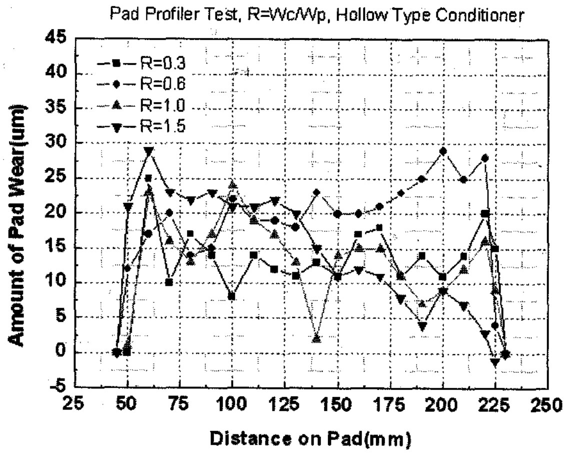

Fig. 8. Amount of pad wear as distance on pad.

3. CONCLUSION

In this paper, suggested multiple CMP monitoring system. Multiple CMP monitoring systems are able to detect friction, temperature, pad profile from CMP process as the type of consumables. In the case of identical consumables condition, friction energy is dominated by input energy caused by pressure and relative velocity of table and head. The change of temperature is also caused by change in friction characteristic during polishing time. As detecting of temperature, the temperatures are related as a function of polishing time at the different removal rates and average process temperature as a function of friction energy. In addition, pad profile can be detecting as different conditions of CMP. Consequently, it is necessary to strength for the effective monitoring systems which increase the efficient control of consumables and the characteristic of CMP process. In conclusion, the monitoring system will contribute to research and development of CMP process for fabrication of semiconductor device and silicon wafer.

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