Friction force monitoring system in post-CMP cleaning for correlations with process issues

Woonki Shin[1], Joonho An[1], Hobin Jeong[1], Seongsoo Kim[1] and Haedo Jeong[1,#]

1 Graduate School of Mechanical Engineering, Pusan National University, San 30, Jangjeon-dong, Gumjeong-gu, Busan, Republic of Korea, 609-745
Corresponding Author / E-mail: hdjeong@pusan.ac.kr, TEL: +82-51-510-3210, FAX: +82-51-518-8442

KEYWORDS : CMP (Chemical Mechanical Polishing), Post-CMP cleaning, Particle adhesion, PVA brush, Friction force

CMP (Chemical Mechanical Polishing) is a material removal process performed by complicated chemical reaction and mechanical abrasion. However, CMP process leaves a lot of abrasive particles on the wafer surface, which should be removed in post-CMP cleaning process. This paper investigated the relation among the force and efficiency to remove the adsorbed particles and the generated damage on the wafer surface during a post-CMP cleaning. Particle adhesion force can be different from the chemical bonding and interfacial reaction of the various materials. To confirm the force and efficiency to remove the particles on the wafer, PVA brush cleaner having a force detecting sensor was systemized. The friction force between the wafer surface and PVA brush were measured by this system during a brush scrubbing simultaneously. The experimental results showed that if the friction force was increased, the particle removal efficiency was higher however the rate of generation of the defect such as a scratch was increased. The particle removal force was analyzed by detected friction force and the surface defects were verified by AFM. Therefore, this paper suggests the optimization of PVA brush cleaning condition associated with cleaning efficiency and surface defect from the contact and friction force.

Manuscript received: January XX, 2011 / Accepted: January XX, 2011

1. Introduction

Chemical Mechanical Polishing (CMP) has emerged as a critical technology for achieving global planalization in advanced integrated circuit manufacturing. As device features continue shrinking, post-CMP cleaning technique to remove the submicron particles becomes more and more important. Particulate matter on a semiconductor wafer can cause circuit defects and thus yield loss in the final product. Brush scrubbing is one of the most effective physical cleaning methods. Its mechanism of particle removal is based on direct contact between a soft polyvinyl alcohol (PVA) brush and the wafer surface. The brush asperities engulf the wafer surface contamination while the brush rotates; friction force is cause between the brush and the wafer [1]. It means that the brush cleaning efficiency can be improved by mechanical particle removal that is controlled the brush pressure, rotating speed and friction. This paper addressed the relationship between particle removal efficiency and mechanical condition of the brush coupled with friction force associated with the process.

2. Experimental

Post-CMP cleaning requires an understanding of particle adhesion, which is imperative to remove particles efficiently. The adhesion force can be explained by the Derjaguin-Landau-Verwey-Overbeek (DLVO) theory, chemical bonding, and interfacial reactions such as diffusion, condensation, and diffusive mixing [2]. Especially, the interaction force between the wafer surface and particles can be calculated based on DLVO force, which is a combination of the Van der Waals force and electrostatic force. However, it is difficult to obtain the exact particle adhesion force due to complex and diverse variables. During the brush scrubbing, the high-frequency friction force was simultaneously measured by using a force sensor (Figure 1). When the sensor was loaded during brush scrubbing, it generated an electrical charge that was directly proportional to the applied force [3]. The voltage from the sensor was amplified by utilizing a charge amplifier and then transferred for data acquisition.

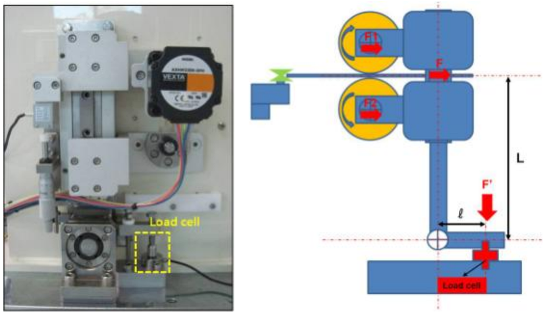
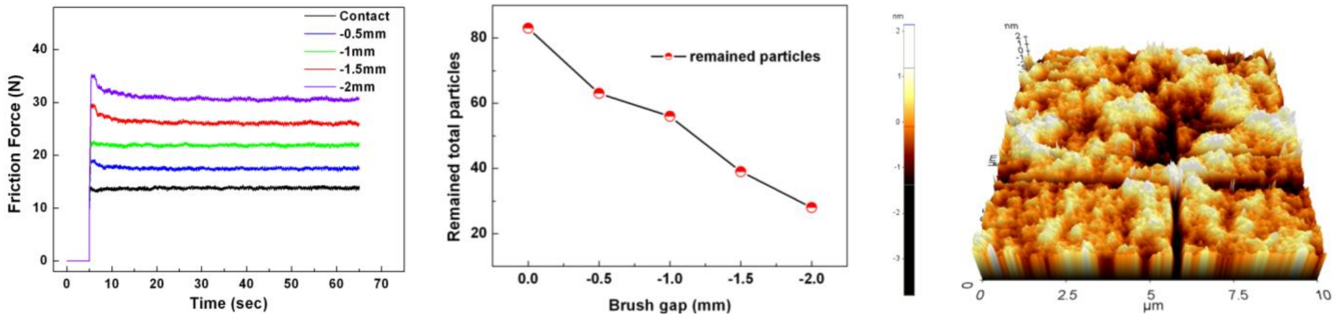


Fig. 1 Friction monitoring system of brush cleaner



(a) (b) (c)

Fig. 2 (a) Friction signal during cleaning process, (b) Cleaning efficiency and (c) AFM image after cleaning process

3. Results and Discussion

During brush scrubbing, the primary removal mechanism is contact rotational torque of the brush. When the brush makes contact with the wafer, the contact friction signal was measured by friction force monitoring system, the gap was defined zero. Fig. 2(a) shows that the friction force increases with decreasing the gap between the brush and wafer. By decreasing the gap gradually, the brush is compressed, not only the contact area between the particle and the brush but also the friction force is increased. The cleaning efficiency according to the friction is shown in Fig 2(b). On the surface that was cleaned by brush scrubbing, the particles remained the most at a gap of zero. The results show that high removal efficiency can be obtained under higher friction force. Figure 2(c) is an AFM image of scratch induced by brush scrubbing under a high friction force. The increase in the friction force caused the particle to be embedded in the wafer surface; then, the particle was driven by rolling and sliding. When the friction force was increased, the particle removal efficiency was higher, but the result was the poorest in term of defectivity.

4. Conclusions (Times New Roman 10pt)

As the CMP and post-CMP cleaning process becomes more sophisticated, process monitoring is essential in order to have reliable process results. For this purpose, cleaning process monitoring systems should provide not only the measurement of force to remove adsorbed particles on a wafer surface but also reliable process monitoring capability during post-CMP cleaning. To confirm the force to remove particles from the wafer, the friction force monitoring system was developed. The experimental results showed that if the gap decreased, the friction force and the particle removal efficiency increased. However, when a high friction force caused scratches, the total defect increased according to the increase in the friction force. Therefore, the friction monitoring system would be helpful to investigate the brush cleaning process without surface damage.

ACKNOWLEDGEMENT

This work supported by the second phase of the Brain Korea 21 programs in 2011. This research was supported by NCRC(National Core Research Center) program through the National Research Foundation of Korea funded by the Ministry of Education, Science and Technology (2010-0001-226).

REFERENCES

1. Busnaina, A., Lin, H., Moumen, N., Feng, J., Taylor, J., “Particle Adhesion and Removal Mechanisms in Post-CMP Cleaning Processes”, IEEE Transaction on Semiconductor Manufacturing, Vol. 15, No. 4, pp. 374-382, 2002.

2. Jeong, H., Kim, D., Dornfeld, D., “Multi-Sensor Monitoring System in Chemical Mechanical Planarization (CMP) for Correlation with Process Issues”, Annals of the CIRP, Vol. 55, No. 1, pp. 325-328, 2006.

3. Philipossian, A., Mustapha, L., “Effect of Mechanical Properties of PVA Brush Rollers on Friction Forces during Post-CMP Scrubbing”, Journal of the Electrochemical Society, Vol. 151 No. 9, pp. 632-637, 2004.