

The CMP by Polishing with GiP Dressed by BODD

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Abstract. Due to the continual improvement of CMP technologies, and the need for polishing delicate wafers at high speed, graphite impregnated pads (GiP) dressed by brazed organic diamond disks (BODD) can double the throughput of wafer-pass at the reduced cost of ownership (CoO). The increased polishing rate is due to the act of nano graphite particles that absorb slurry. The nano graphite particles coated with chemical and abrasive can achieve high removal rate without causing scratches on the wafer. In addition, nano graphite particles do not stick to wafer surfaces, so they can be cleaned easily. BODD can uniquely dress GiP to create slurry channels so the pore free pad is not bottlenecked by slurry supply. This paper also demonstrated the low stress polishing by applying ultrasound during the CMP process.

Introduction

The industrial CMP pads are made of porous polyurethane (e.g. IC1010 manufactured by Rohm Haas of Dow Chemical). The pores are incorporated into pad in order to reduce the contact area between wafer and pad during the polishing process. The pores can increase the contact pressure between protruded ridges on wafer surface and taller asperities on pad surface. In addition, the pores serve as reservoir for storing slurry that contains both chemical for softening wafer surface and abrasives for removing the softened materials.

There are other CMP pads that contain no pores, such as Cabot's w7300 promoted by Thomas West, Inc. (TWI) for polishing the W layer on wafers. Due to the lack of pores, the contact pressure of dressed asperities is not high enough to polish the wafer sufficiently fast. Worse still, the pad surface is lack of slurry channels to supply chemical and abrasive to the polishing sites. As a result, TWI pads require longer time per wafer pass that is not desirable.

SKC produced several graphite-impregnated pads (GiP) under the JDA with Dr. James C. Sung. The first generation incorporated natural graphite of about 20 microns in size. A series of tests were performed that demonstrated the comparable performance of wafer removal rates and within wafer non-uniformity. There was no scratch problem for polishing oxide, but numerous micro scratches were present on polished copper layer. In order to avoid the scratches on soft copper, the second generation of GiP makes use of 0.5 micron sized nanographite particles. The performance of this new type of GiP is the focus of present study.



Fig. 1: Black GiP versus conventional white pad.

Major properties among IC1000 pad as the CMP industrial standard, TWI poreless pad for W CMP, and SKC's new GiP are compared below.

Table 1: Physical Properties of CMP Pads

Pad Type	GiP	IC1000	TWI
Density (g/cm ³)	1.09	0.76	1.2
Hardness (Shore D)	61~63	55~57	63~65
Compression Recover ratio (%)	14.2	34.6	36.2
Compression ratio (%)	3.3	3.5	4

It is clear that TWI's poreless pad is harder than the pore ridden IC pad. GiP is intermediate between the two types of pads, but it is more plastic than either pad due to the presence of nano graphite particles.

Hydrophilic Pads

One of the advantages of poreless pad is the uniformity of the pad material can be improved as pores are intrinsically segregated in polyurethane due to the density difference. However, the monolithic pad has no pore for storing slurry that is required for polishing wafers. Consequently, the hydrophilicity of the pad is very important for poreless pad. The wetting of pads can allow the pad asperities to be coated with slurry. GiP has the smallest contact angle with water, and hence it can absorb slurry due to the capillary force of graphite particles.

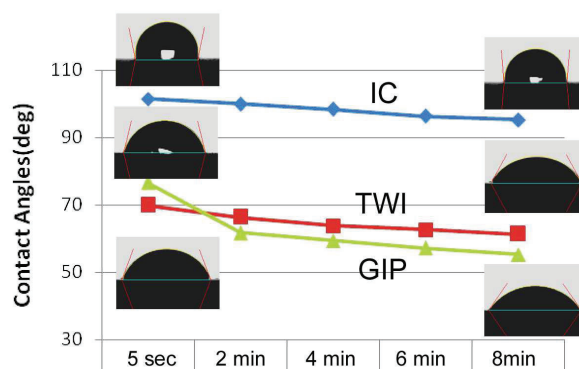


Fig. 2: The contact angle of water on different pads at different times.

Another feature of GiP is the pad-dressing rate that reflects the pad consumption rate. Due to GiP's plasticity, it is cut slower with a diamond dresser. Moreover, when impregnated graphite particles are coated with slurry due to the capillary force, the diamond grits cannot cut the pad deep.

Hence, the consumption rate of GiP can be less than IC during the CMP operation.

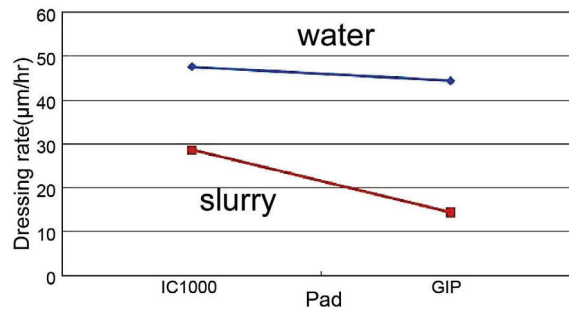


Fig. 3: The lower pad consumption rate of GiP compared to IC.

Low Stress CMP

The key attribute of GiP is in its ability to polish wafer faster than ever. This is due to the higher frictional force at the interface between oxidized wafer and GiP.

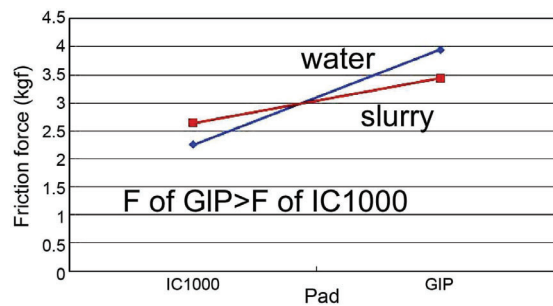


Fig. 4: The increased dragging force between wafer and GiP can allow a higher wafer removal rate compared to IC pads.

Although the grip of wafer is firmer on GiP than IC, the polishing force is relatively uniform during the CMP process. This implies that the removal rate of wafers can be steady, and hence more predictable and easier for control.

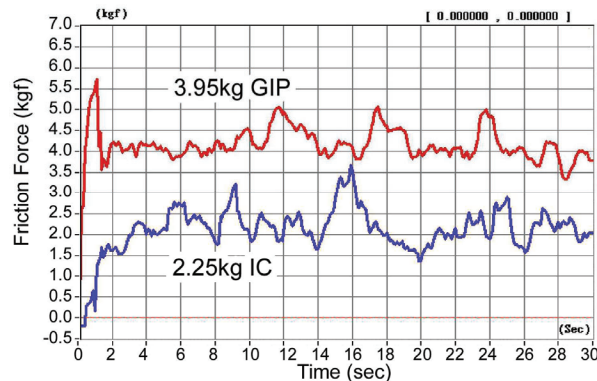


Fig. 5: Nano graphite particles can avoid the stick slip polishing of wafers, even at higher down force. This implies the contact stress is lower during the CMP process.

High Throughput CMP

Due to hydrophilic nature of GiP, and the fact that nanographite particles can act as nano abrasive, the wafer-polishing rate on oxide is more than doubled that of IC pads. Hence, the wafer-pass throughput using GiP may be at least doubled the industrial standard.

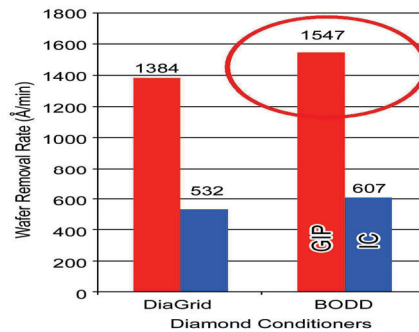


Fig. 6: The dramatic increase of polishing rate during oxide CMP by using the black GiP pad compared to conventional white IC pad. The advantage of using GiP is further enhanced by using BODD as the diamond dresser.

Slurry Saving CMP

Another benefit of using GiP is to save slurry consumption. Due to the presence of nano graphite particles that act as abrasive, the slurry consumption can be cut significantly. Slurry consumption is the largest CoC item so using GiP can reduce much consumable cost.

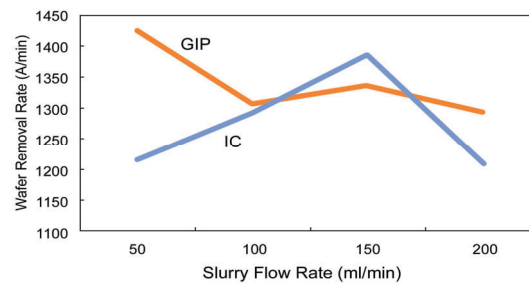


Fig. 7: The oxide removal rate as a function of slurry flow rate. Note that at 50 ml/min, GiP can polish wafer faster than IC even the latter was with 3X of slurry consumption.

In summary, GiP may double wafer removal rate at half of slurry consumption, this would translate into a significant lower CoO of CMP per wafer.

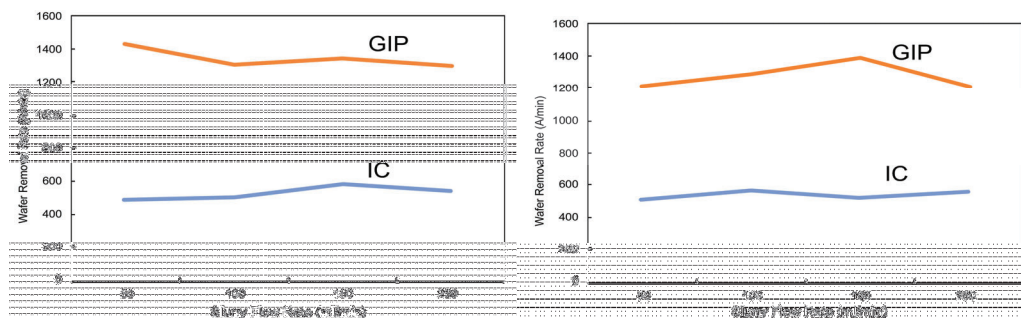


Fig. 8: The enhanced wafer removal rate at reduced slurry consumption with the black GiP pad compared to white IC pad.

Mosaic Diamond Disk

In order to improve further the performance of CMP, the design of diamond dresser has been changed from a monolithic design to mosaic design. In particular, the pallets of brazed diamond disk (BDD) is mounted on a common platform by attaching them with a firm epoxy (organic binder), hence the nickname BODD is applied to such a mosaic design.

BODD is very versatile so different types of diamond grits (size and shape) can be employed on

different pallets. This will allow the dresser to roughen the pad and level the asperities independently by having different types of pallets on the same substrate. The conventional diamond disk cannot compromise the requirements of roughening the pad to achieve a certain removal rate, and at the same time, leveling asperities that assure wafer uniformity. Moreover, scratching wafer by "killer asperities" may be avoided at high wafer throughput. BODD was used to dress TWI pads with uniform polishing of wafers.

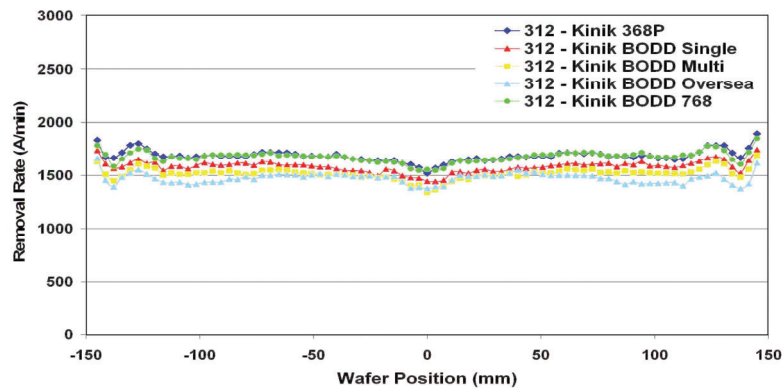


Fig. 9: The uniform profiles of polished wafer by CMP with BODD dressed poreless pad.

Ultrasonic CMP (uCMP)

Another breakthrough in the CMP technology is to use ultrasonic vibration to agitate slurry coated pad during the polishing process. The ultrasound not only moves around the chemical and abrasive in slurry, but also breaks the agglomerates of abrasive particles so the polishing sites by individual particles can increase significantly. Additional effect of ultrasound is to smear coating the asperities top with chemical and abrasive. This is particularly effective when water absorbing graphite particles are present in the pad of GiP.

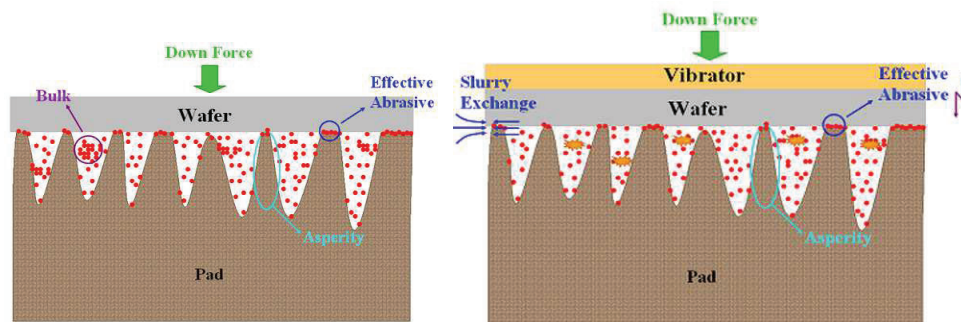


Fig. 10: The illustration of ultrasonic effects on the dispersion of slurry in the asperities of pad surface.

As the result of applying the ultrasound during CMP, not only the removal rate is increased, but also the wafer smoothness is improved. This means that wafer can be polished fast without being damaged, that cannot be achieved by conventional CMP means.

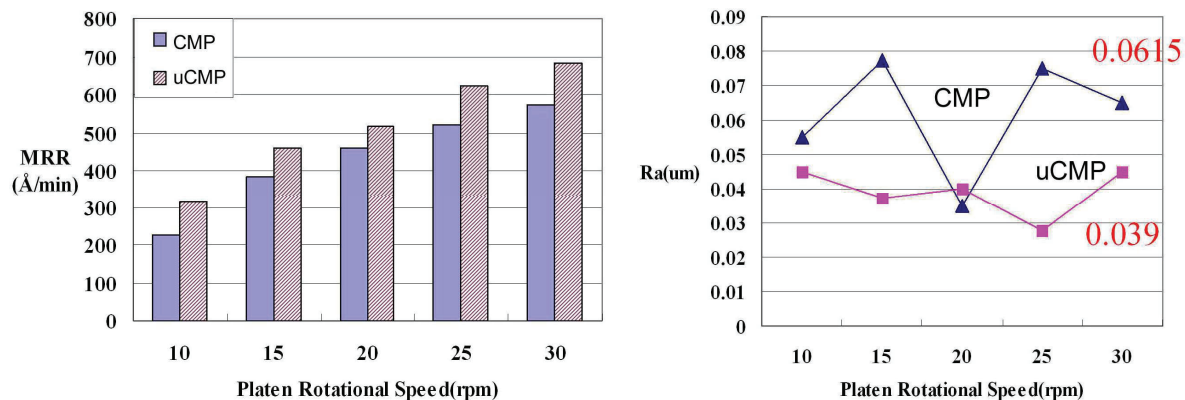


Fig. 11: The increase of wafer removal rate and the decrease of wafer surface roughness can be both achieved by implementing ultrasound CMP (uCMP) at a wide range of platen's rotational speed.

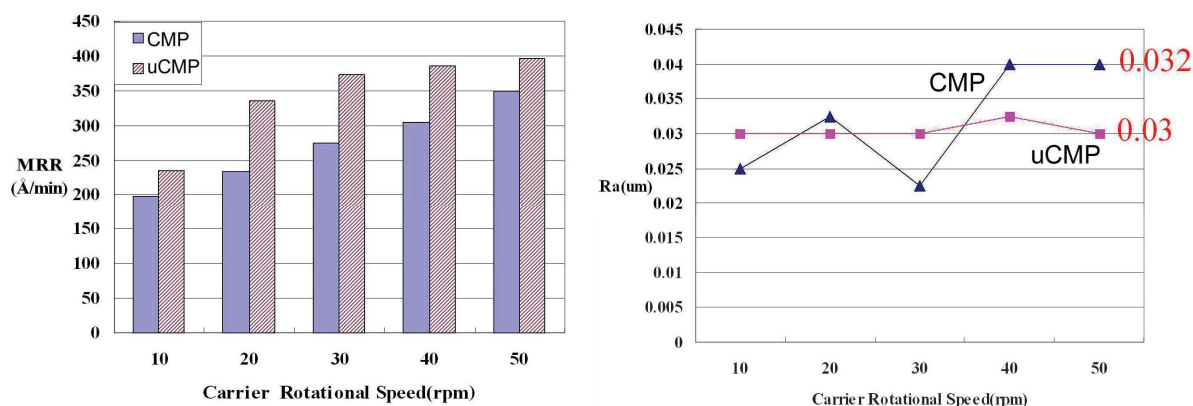


Fig. 12: The increased wafer removal rate at different wafer rotational speed by inducing ultrasound during CMP.

Conclusions

In summary, GiP can absorb slurry so it can polish wafers fast. BODD can roughen the pad surface without introducing killer asperities, so CMP with BODD dressed GiP would be the best choice for the CMP industry. In addition, ultrasound can further enhance the above benefits by allowing the low stress polishing at high down force of the wafer. The combination of GiP, BODD and ultrasound can make the CMP most effective and efficient.

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