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The Black Pad with Graphite Impregnation for CMP

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CMP has been practiced by polishing wafers with white polyurethane pads that contain pores. These pores may reduce the contact areas at the interface so the polishing rate is increased by enhanced pressure. Moreover, the pores also serve as the reservoir for storing excess slurry that can replenish the consumed abrasive particles at the polishing site from time to time.

A new design of black pads has eliminated the need of built in pores. Instead, submicron graphite particles are impregnated in polyurethane matrix. The graphite particles can be plucked off at the polishing site so the contact pressure at the polishing site is increased as if pores are present. Furthermore, graphite particles are hydrophilic so slurry can be retained better than that in water repelling white pad. The wetting can also lubricate the polishing site and allow faster polishing of the wafer without damaging the local circuitry. This reports summarizes various features of the black pads including their CMP performance compared to conventional white pads.

The Black Pad

During a CMP operation, excess material on the coated thin film (e.g. copper) on wafer is removed by abrasion with nano abrasive particles. These particles are suspended in a chemical slurry that perch on the top of pad asperities. In order to enhance the contact pressure at the polishing site, pores of tens micron across are dispersed in the polyurethane pad. These pores also serve as the reservoir for the slurry that can ooze out by squeezing with the wafer. As the IC interconnects are trending toward 32 nm and beyond, hard contact at the interface between wafer and pad must be avoided. Consequently, softer pads are designed to avoid the spiky rise of contact pressure. However, due to the global planarization requirements, the pad is relatively stiff on macro scale, but soft in local contact.

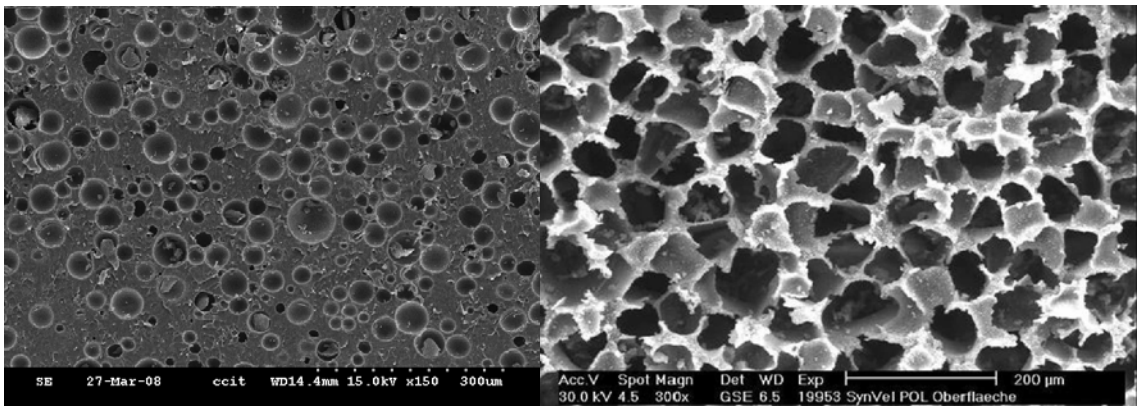

Figure 1. The hard pad with enclosed pores (left diagram) and the soft pad (right diagram) with partitioned pores.

A new type of pad is made by impregnating microscopic graphite particles in a polyurethane matrix. The pad so formed appears black that is in stark contrast with the white pad adapted by the CMP community.

Figure 2. The black pad versus the white one.

The presence of graphite particles can achieve the following functions that are absent in white pads.

1. Graphite particles are soft in contact as if pores are present.
2. Graphite is hygroscopic, so the black pad can be wetted by slurry.
3. Graphite is a solid lubricant, it can reduce the heat generated at the polishing site.
4. Graphite is a hest spreader, it can avoid hot spots formed locally on the pad surface.
5. Graphite particles can also polish the wafer so the removal rate may be increased.
6. Nano graphite is used for polishing so scratches on copper are avoided.

The Dressibility

The dressibility of a black pad was compared with the white one by cutting with a diamond pad conditioner. It was noticed that graphite impregnation in the pad yielded a smoother surface than pore ridden pads.

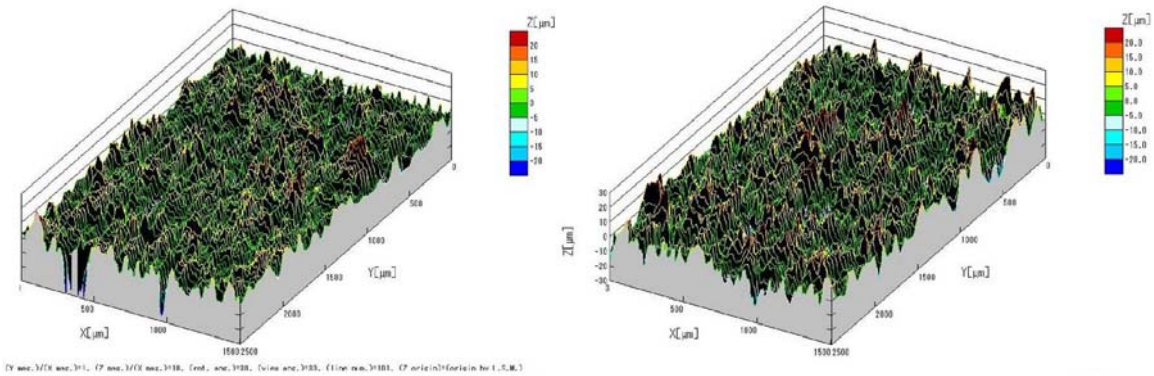

Figure 3. The dressed surface between black (left) and white (right) pad.

The leveling of pad asperities is critical for polishing delicate wafers because scratches may ensue during the encountering of "killing asperities". It was found that the black pad, after dressing, possessed no asperities that are protruding much higher than the rest.

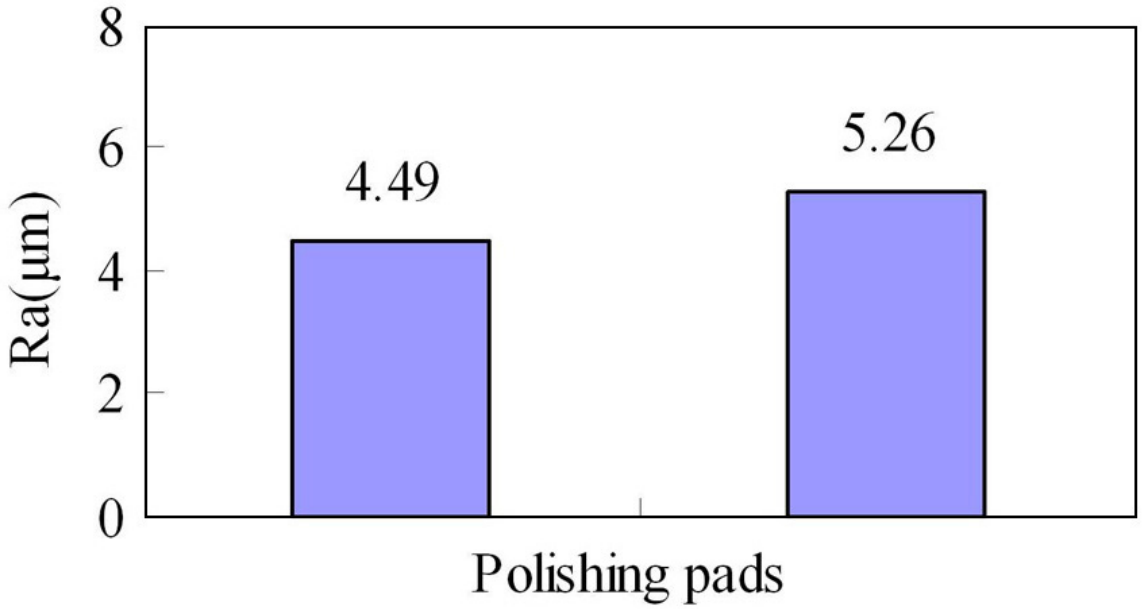

Figure 4. The black pad (left) had a smoother surface than the white one (right).

Although the asperities on the black pad were better leveled, the valleys of these asperities were more diversified than the white pad. The slurry can now move across the mesh of pad asperities more efficiently by channeling in valleys of various depth.

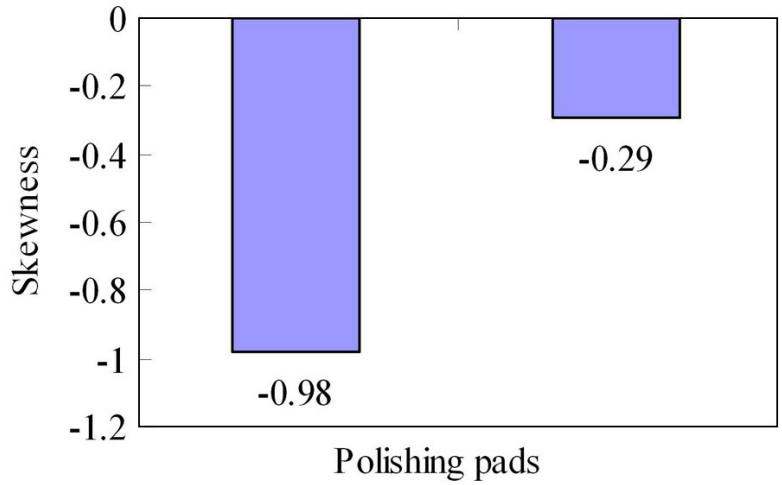

Figure 5. Black pad (left diagram) had deeper valleys than white pad (right diagram) for faster transport of slurry.

Another feature of the black pad is its ability to suck slurry by capillary force. This is important to avoid the dry spots during the polishing process. Dry spots can raise the temperature and destruct the delicate interconnects of expensive wafers.

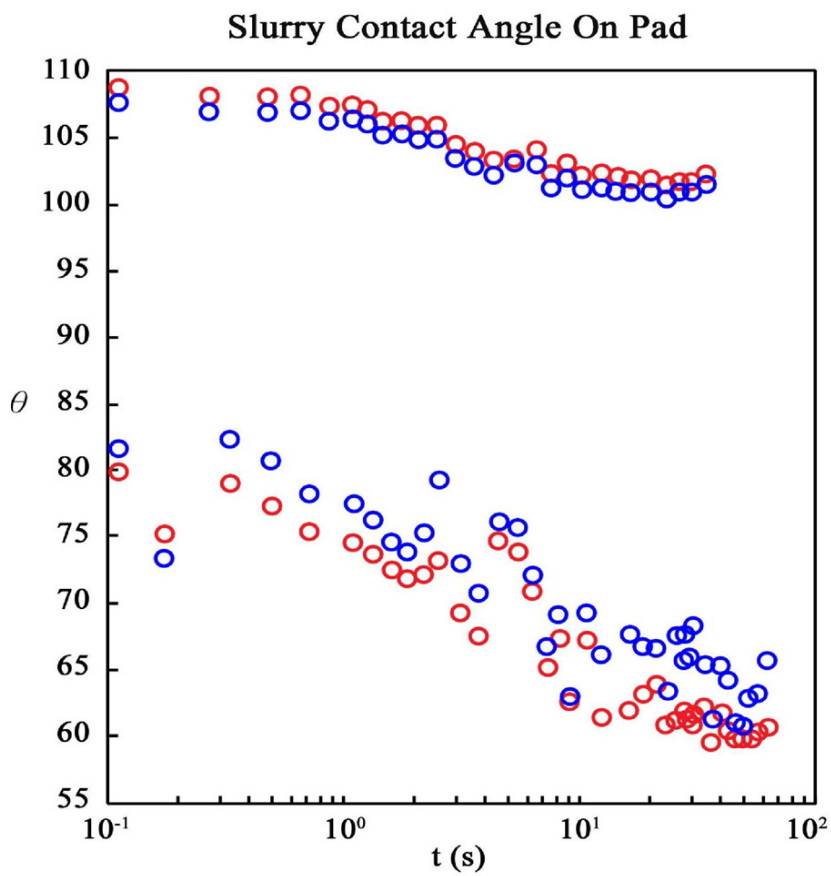

Figure 6. The hydrophilicity of the black pad (lower circles) versus the white one (upper circles).

The CMP Performance

The CMP performance for polishing an oxide layer was compared between black pad and white pad. The polishing rate was much higher with the black pad when the same slurry was used.

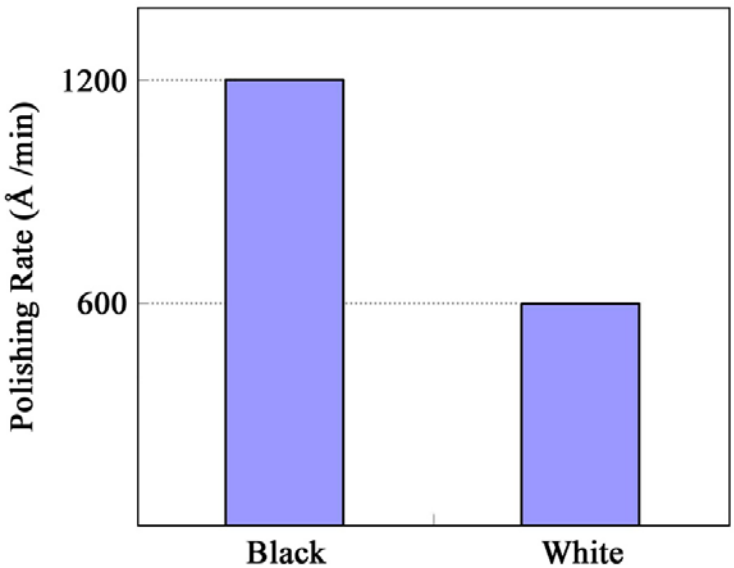

Figure 7. The removal rate of oxide was twice when the wafer was polished by the black pad compared with white one.

The polishing rate was monitored for consistency. It was found that the CMP performance with the black pad was steady.

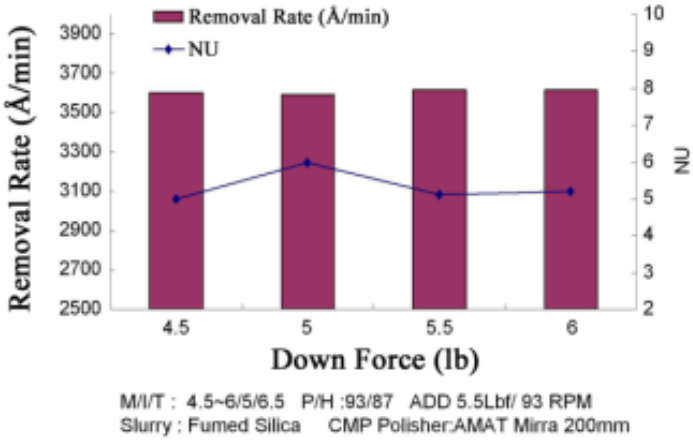

Figure 8. The removal rates of the black pad under the same polishing conditions (Courtesy of SKC, Korea).

The CMP performance for polishing copper layer was compared between the two types of pads. The results confirmed that the polished wafer profiles were comparable between black pad and white pad. However, the black pad provided a more uniform polishing than white one.

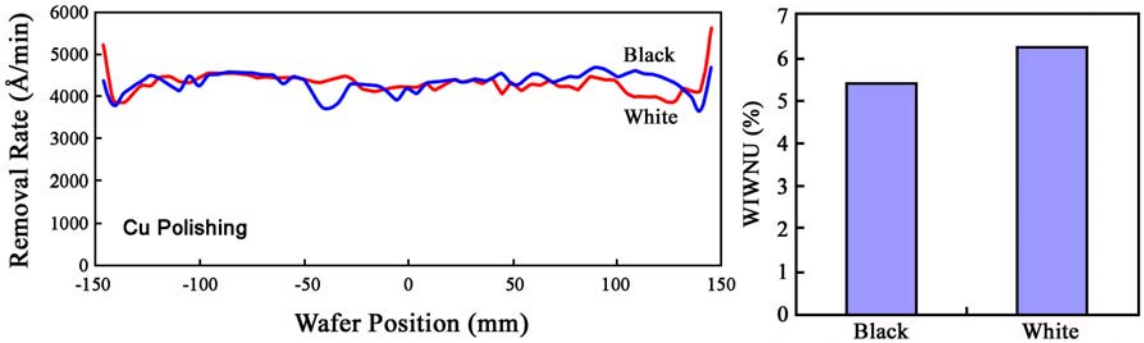

Figure 9. The comparable CMP performance between black pad and white pad (Courtesy Rohm Haas).

The consistency of copper polishing by black pads was evaluated on polishing of different wafers. The steady performance of black pad was confirmed again.

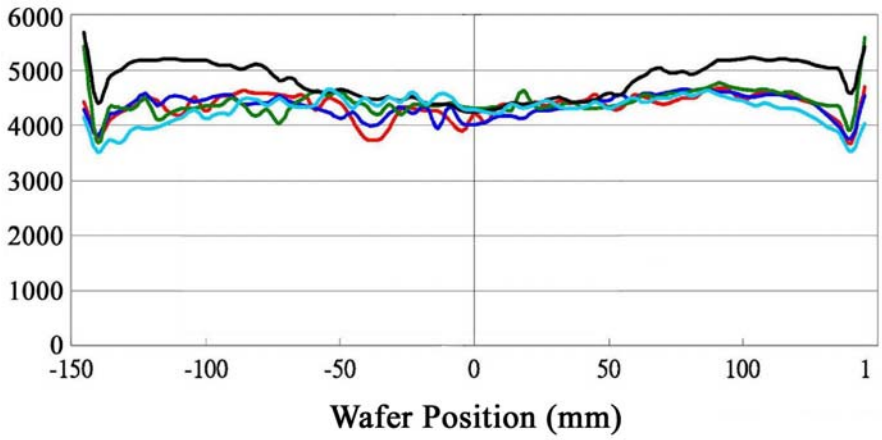

Figure 10. The consistent polishing performance of copper by the black pad.

Summary

The polishing rate of oxide was faster on pore free graphite impregnated pads than conventional pore ridden pads. The polishing profiles of copper layers were comparable between black pads and white pads. With the Moore's law trending toward sub-virus feature sizes (e.g. 22 nm) and the scheduled (2012) introduction of pizza-sized (450 mm) IC wafers, the in-situ lubrication and the real time wetting may be critical for CMP to avoid the presence of hot polishing spots. Consequently, the black pad may be more attractive than the white ones for polishing future generations of IC interconnects.

References

[1] Chien-Min Sung, “CMP Consumables with Taiwan’s Innovations”, International Conference on Planarization / CMP Technology (ICPT) 2008, Hsinchu, Taiwan, p.87.

[2] Chien-Min Sung, Ying-Tung Chen, Wei-Huang, Kyle Chang, Michael Sung, “Polycrystalline Disk Dressers for the CMP of Terabytes Hard Drives”, International Conference on Planarization / CMP Technology (ICPT) 2008, Hsinchu, Taiwan, p.264-271.