ECS Transactions, 18 (1) 523-528 (2009)
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Polycrystalline Diamond (PCD) Shaving Dresser: The Ultimate Diamond Disk (UDD) for CMP Pad Conditioning

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All conventional pad conditioners dress the CMP pad with discrete diamond grits of random orientation. With the advent of polycrystalline diamond (PCD) dressers, the pad conditioning can be performed with an unprecedented regularity. The result is a total elimination of "killer asperities" that may scratch the soft copper layer or porous dielectric layer. Moreover, the PCD dressers may be constructed to form a blade shaver so pad disruption during conditioning can be minimized. As a result, the original pad polymers can be preserved for polishing wafers. This ultimate diamond disk (UDD) has transformed stick slipping pad destruction to smooth shaving pad construction. UDD is particularly suitable for dressing CMP pads for polishing 22 nm interconnects, in particularly, with the anticipated debut of 450 mm pancake wafers scheduled for 2012.

PCD Cutter

Instead of penetrating the pad surface with a brutal force of diamond grits, advanced diamond disk (ADD) is made by carving a disk of sintered polycrystalline diamond (PCD) layer to form cutting tips of predetermined shape and distribution. The tailor made cutting tips with sharper angle can be formed with higher regularity than conventional diamond disks.

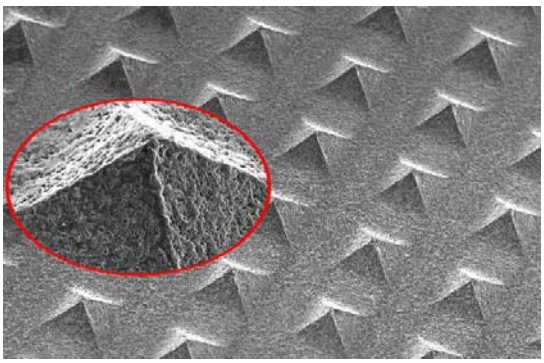

Figure 1. The ADD cutting tips bonded monolithically in PCD matrix material.

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As a result of improved leveling of cutting tips of ADD, the contact points on pad during dressing increases by more than tenfold compared to BDD, the conventional brazed diamond disks.

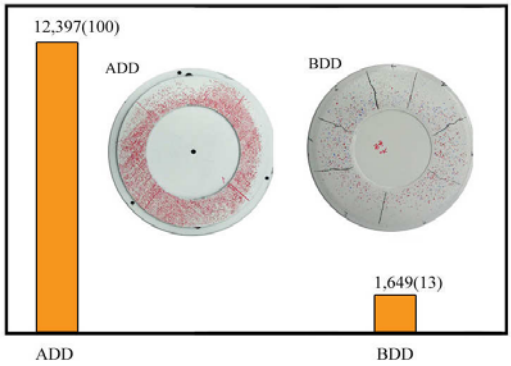

Figure 2. The comparison of working crystals (darkened dots) between ADD and BDD after dressing the pad (IC1000). Both disks have about the same number of cutting tips to begin with the test.

Tender Polishing versus Brutal Polishing

Due to the same depth of cutting, ADD is uniquely capable to form uniform asperities on CMP pads. Moreover, the highly protruded killer asperities are eliminated. The uniform loading of pressed wafer can allow fast removal of IC layer (e.g. copper) at high pressure without causing damages (e.g. scratches) due to the low stress contact.

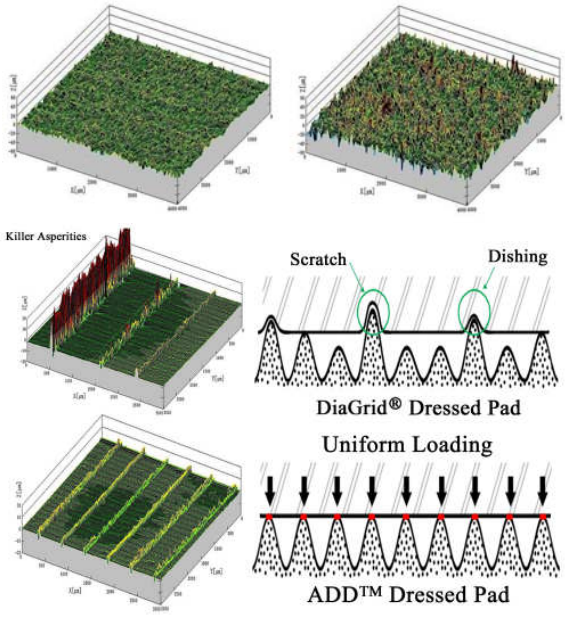

Figure 3. The uniform pad dressing of ADD can avoid the formation of killer asperities that may destruct delicate IC wafers. In the above legend, DiaGrid® refers to BDD pad conditioner.

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The CMP with ADD Performance

It has been demonstrated that ADD dressed pad could polish TEOS wafers at a higher removal rate with a better uniformity than that polished with BDD dressed pad.

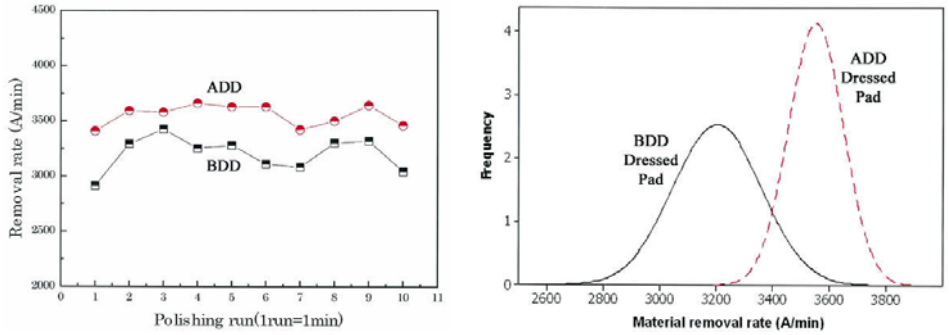

Figure 4. The PCD cutters dressed pad could polish wafer faster with more uniform loading than diamond grits.

The uniform asperities can not only polish wafer with low contact stress, but they are more readily wetted by slurry. As a consequence, the slender asperities can be permeated with abrasive impregnated solution of chemicals so the polishing is performed without dry spots. The abrasion of dry spots would generate both high stress and high temperature; so delicate IC could be damaged.

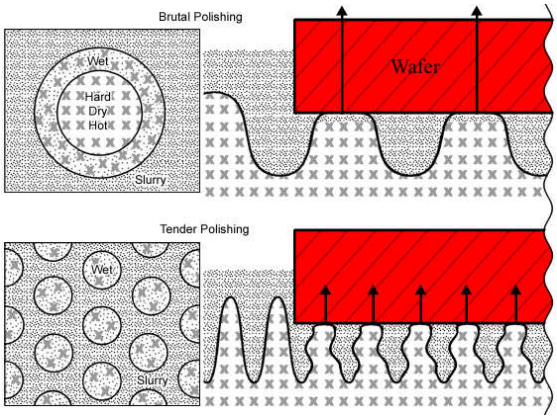

Figure 5. The contrast between brutal polishing with BDD dressed pad and tender polishing with ADD dressed pad.

Soft Landing CMP

In addition to enable high pressure CMP with low stress polishing, ADD's sharp teeth are uniquely capable to cut resilient pads (e.g. Rhom Haas's EV4000) without causing excessive tearing. The resilient pads are designed to reduce local contact stress during polishing. However, due to the presence of bouncing polymers in the matrix, diamond grits cannot cut the pliable pad effectively. In contrast, the rugged PCD cutting tips can break the soft surface and allow the resilient pad to polish wafers consistently.

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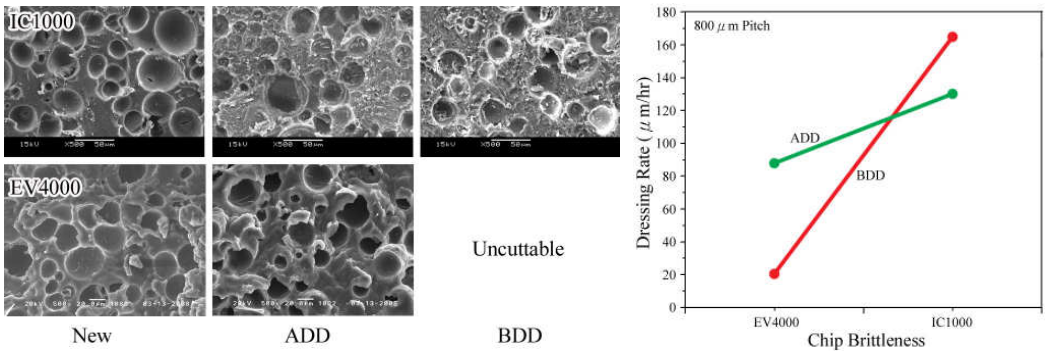

Figure 6. BDD can dress brittle pad materials that may scratch wafer surface. However, ADD can dress resilient polymers to ensure soft landing of delicate IC during CMP.

The Ultimate Diamond Disk (UDD)

Although PCD is shaped on surface to form ADD patterns, there is a better design with PCD sliced to form cutting blades. In this way, the blade can be arranged to make an optimized penetration angle that has not been achievable even with ADD.

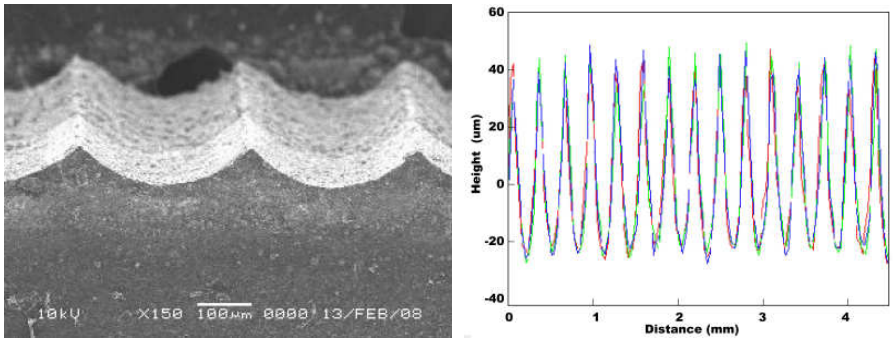

Figure 7. The PCD blade with cutting teeth that can be fully leveled. Note that the cutter tips are leveled within a few microns compared to conventional range of 50 to 100 microns for highest points of discrete diamond grits.

The blades are then arranged in a predetermined pattern and cast in epoxy to form a strange looking diamond disk that is totally out of conventional wisdom.

Figure 8. The UDD with the design of sliding blades. Multiple design features can be accommodated with number of blades and tilt angles.

Figure 9. Additional variations of UDD in blade patterns. The left diagram shows "Chaos Disk", and the right diagram "Sun Disk".

The pad asperities profile formed by UDD is intermediate between ADD and BDD. However, this may be misleading due to the fact that UDD is uniquely capable to cut pad under tension while all other pad conditioners may only drag the pad during cutting. This means that UDD dressed pad surface can retain the most original pad material features of all diamond disks.

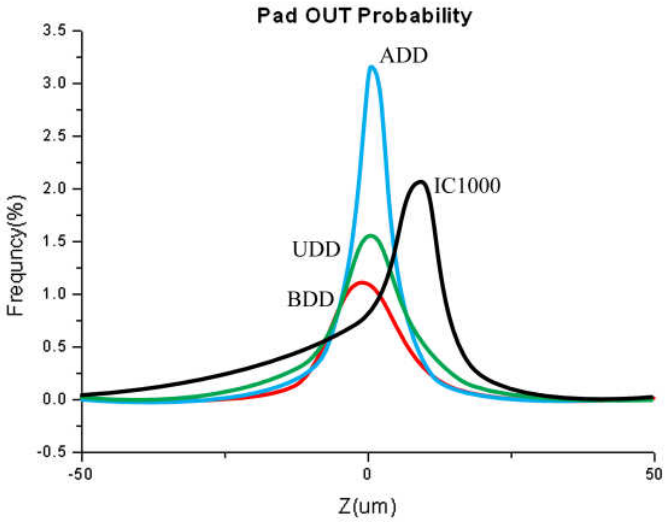

Figure 10. The pad asperities distributions after dressing with ADD, BDD and UDD. Note that the unused pad (IC 1000) was fully leveled on the tips of asperities due the slicing by a sharp steel knife. ADD has the best leveled tips after the pad was dressed with more working crystals. Both UDD & BDD had fewer working crystals so the dressed pad had uneven heights of asperities. In general, the leveling of asperity tips allows uniform and consistent polishing of wafers.

Tensile Shaving Versus Compression Grooving

As UDD is made of arranging cutting blades, many new design concepts previous unachievable can now be entertained. For examples blades with straight edge or with teeth can be bundled to achieve special effects. Straight edges are efficient to scrape clean glazed layer. The cutting tips are best in shredding soft polymers.

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The most important feature of PCD blade is that it can reduce the drag force on the pad and begin to shave polymer. For conventional brittle IC pads, the plastic deformation is not excessive so dull monodiamond grits can still penetrate the polymer. But even so, the polymer is over heated and the chains disrupted. For soft landing pad (e.g. EV4000 of RHEM), not only plastic deformation is large, but also elastic deformation is significant. In this case, monodiamond grits can only deform the pad with minimal penetration. The PCD blade is uniquely capable to avoid the compression of the polymer before penetrating. In fact, the polymer is under tension and it is severed by sharp edge.

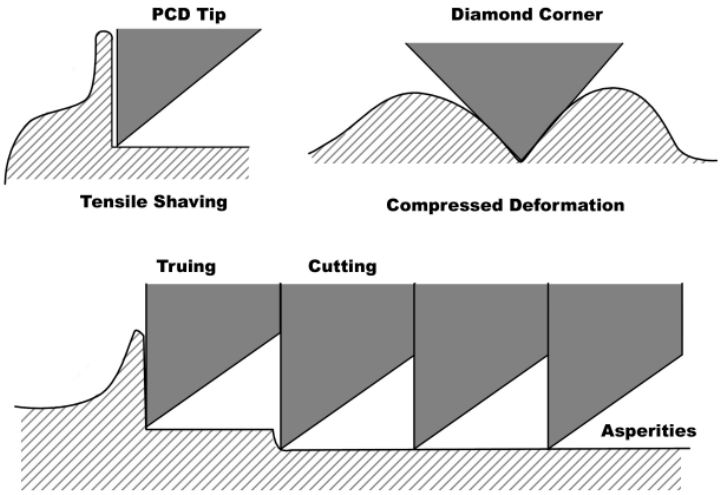

Figure 11. The shaving by tension versus the deforming by compression (top diagram). The blade train that can true the pad before grooving (lower diagram).

Conclusions

PCD dressers are a revolutionary design for CMP pad conditioning. Due to the sculpturing capability, the cutting pyramids can be shaped with high symmetry. The unprecedented tight leveling of the cutting tips can avoid wafer-destructing asperities. Moreover, the PCD can be sliced to make cutting blades. By arranging many blades on a common plane, the ultimate diamond disk can be made. UDD can shave the pad instead of smearing cutting that is prevailing by dressing pad with conventional pad conditioners. The tensile shaving of the pad can preserve the original polymer for polishing IC wafers clean. The following references documented the CMP performance of wafer polishing.

References

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