International Conference on Planarization/CMP Technology · October 25 – 27, 2007 Dresden
VDE VERLAG GMBH · Berlin-Offenbach

The Organic Diamond Disk (ODD) for Dressing Polishing Pads of Chemical Mechanical Planarization

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Diamond pad conditioners can determine the efficiency of CMP processes and the quality of polished wafers. The polishing rate of a wafer is dependent on the amplitude (height) of pad asperities. The polishing uniformity is controlled by the frequency (density) of such asperities. Current diamond pad conditioners cannot dress the pad to produce microns sized asperities at high density. This is because the tips of diamond grits cannot be leveled to the same height so the grooved pad top is uneven with excessive asperities that may ruin the wafer and under sized asperities that is easily glazed.

New designs of diamond pad conditioners have markedly improved the leveling of diamond tips. Organic diamond disks (ODD) are manufactured by reverse casting of polymers. Due to the uniform spacing of diamond grits and their controlled tip heights, none of the diamond grits will be overly stressed. Moreover, all diamond grits are sharing the dressing work. Consequently, the number of working grits of ODD is significantly higher than conventional designs. Moreover, because no diamond will cut pad unnecessarily, the pad life is greatly lengthened. Furthermore, due to the uniform distribution of pad asperities, the slurry will be held efficiently so the run off is avoided. As a result, the slurry usage is reduced. ODD is therefore a significant savor of CMP consumables for semiconductor manufacture.

Keywords: CMP, Diamond Dresser, Pad Conditioner, Epoxy

1. Organic Diamond Disks

Conventional CMP pad conditioners are made by bonding individual diamond grits with a metal matrix on a flat metal substrate. Due to the variation of grit sizes and diamond orientation, the tip height distribution is intrinsically large (50-100 microns). Hence, the cutting depth of the pad varies significantly. The deep grooving of the tall grits cannot only overly consume the pad, but also the diamond will be excessively stressed. The diamond may be chipped by such impact force, particularly if it was thermally damaged during the manufacturing process, as in the case of vacuum brazing or hot pressing. Even if the diamond is not weakened by heating, the high stress may pullout the diamond from the matrix, particularly if the bonding strength is weak, as in the case of electroplated pad conditioners.

A new design by reversing the diamond attaching process is made with an organic matrix (e.g.

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epoxy). The diamond grits are first leveled to a mold surface. Subsequently, they are cast by covering with a polymer. Due to the pre-leveling of the diamond tips, their height variation is within 20 microns. This organic diamond disk (ODD) will dress pad uniformly without excessive cutting. The result is a significant increase of pad life. In addition, the reverse casting process allows the use of larger diamond so the buried portion in the matrix is many times more than the protruded one. As no diamond grit is overly stressed, there is no risk of falling out grits. Because the fabrication process is at ambient temperature so the diamond strength is fully preserved to avoid chipping during the dressing process.

ODD disks are very light (e.g. 70 grams) and they can be transparent or color-coded. This versatility can make their inspections easier (e.g. to check the loss diamond) and also for the color management of CMP manufacture with different recipes (e.g. red disks for copper removal and black ones for oxide polishing). In contrast, conventional pad conditioners are made of heavy (e.g. 430 grams) metal and their appearances are the same for various designs.

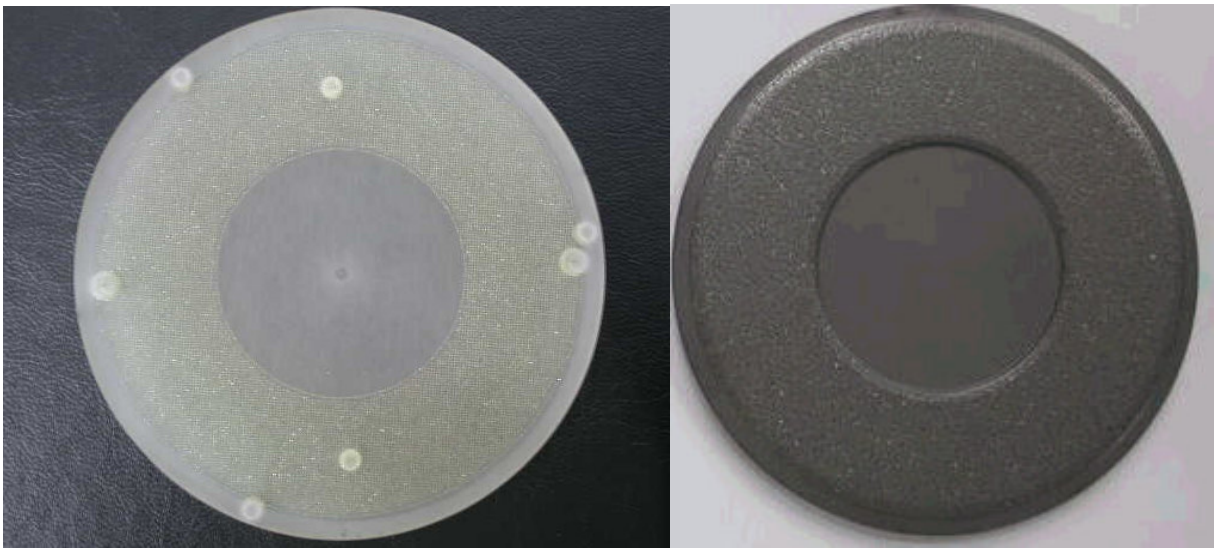

Fig. 1: The monolithic ODD (left diagram) and the layered metal pad conditioner (right diagram).

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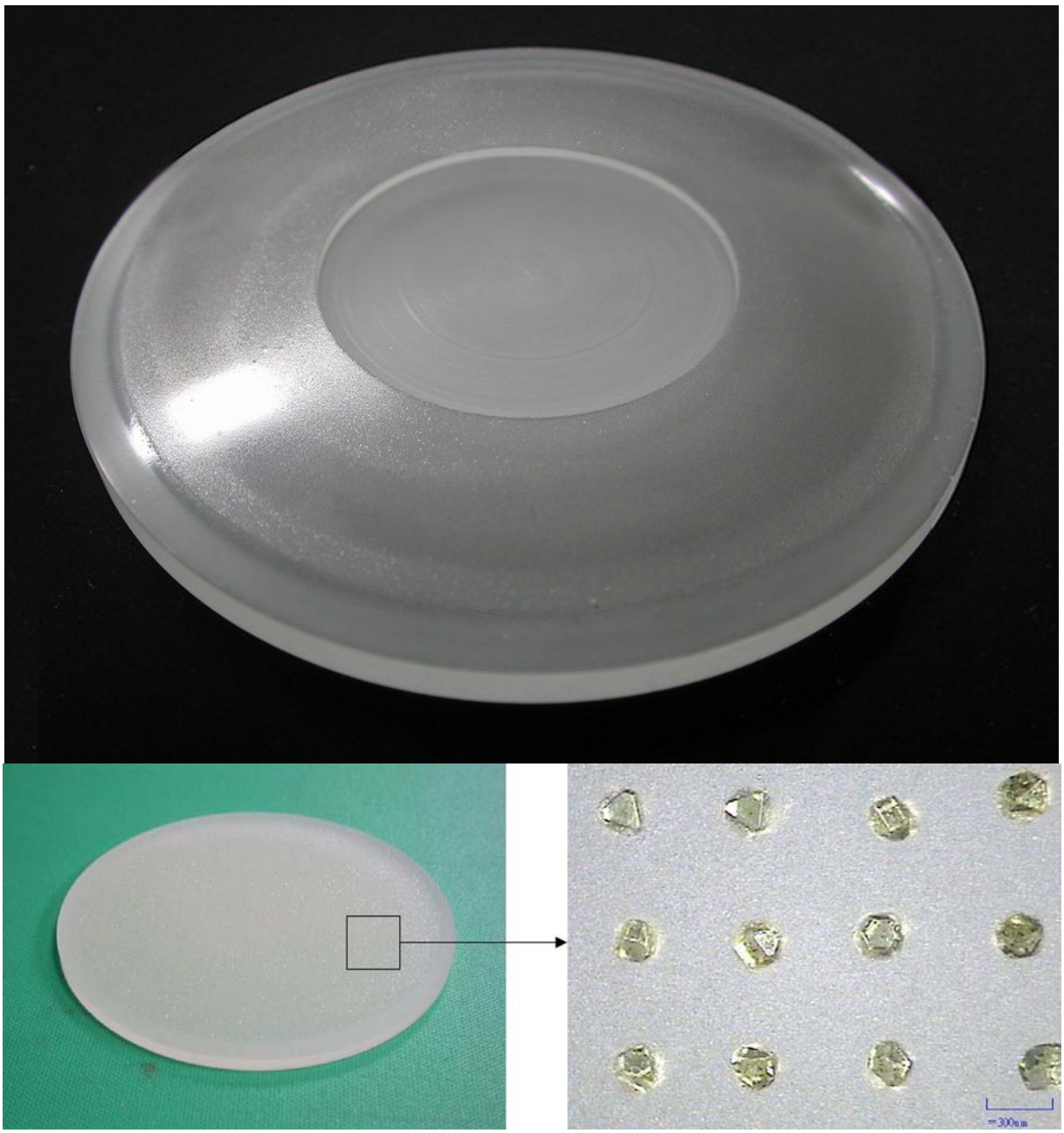

Fig. 2: Transparent ODD can allow defects (e.g. missing diamond) be spotted with naked eyes.

2. The Design Features

The bonding of diamond by epoxy resin is weak compared to metal bonding. However, because the diamond tips are leveled to a much tighter range, the distribution of the dressing stresses is much more uniform. Mover over, the burial depth for each diamond is about twice that of the exposed portion. Consequently, the risk of plucking away a diamond from the matrix during dressing the pad in minimal.

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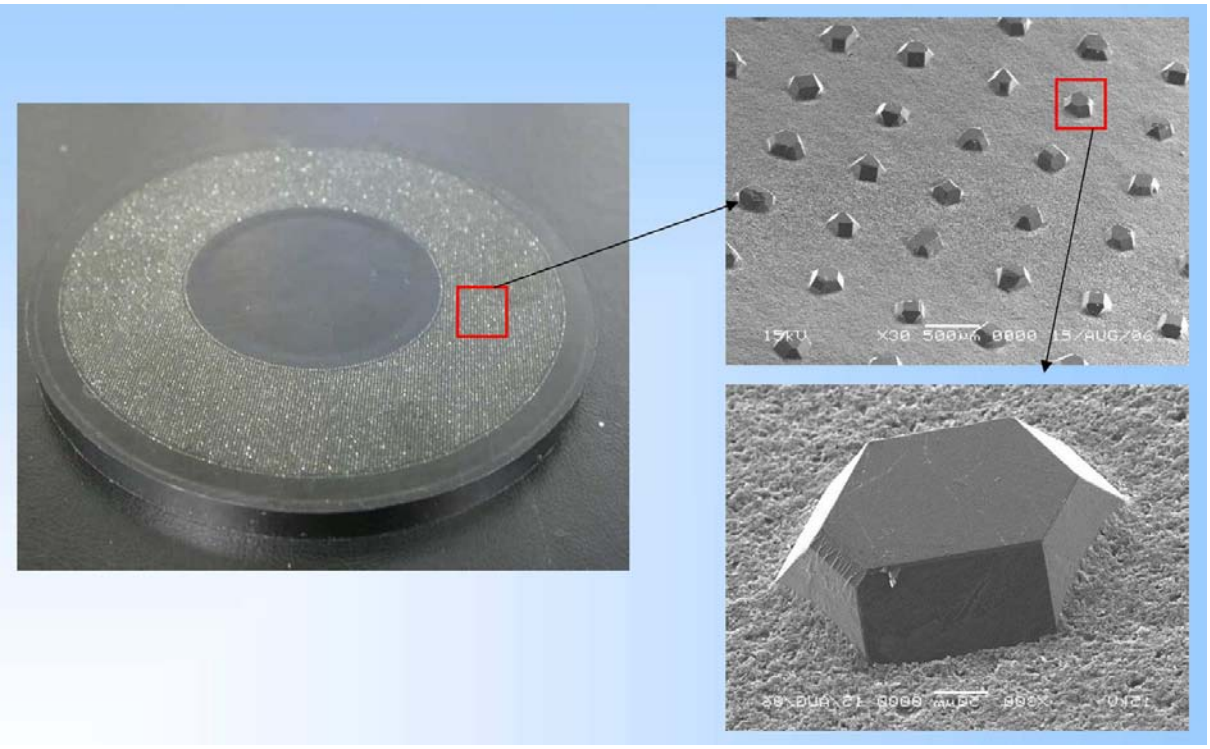

Fig. 3: The bonding conditions of diamond in the epoxy matrix.

The dressing rate of the pad for ODD can be controlled by diamond to diamond separation, the higher the separation, the deeper the penetration to the pad, and the higher the dressing rate. Moreover, if shapes are less regular, the sharp cutting tips can increase the dressing rate. Furthermore, if more diamond tips are oriented facing the pad, the dressing rate can also be enhanced.

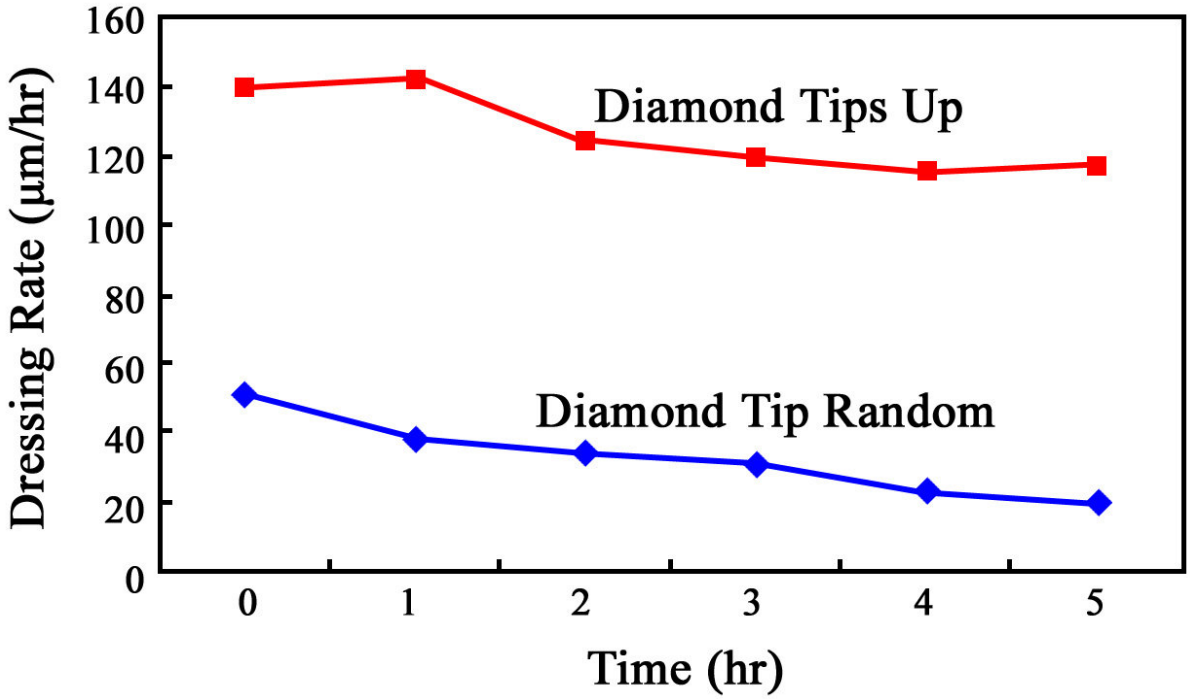

Fig. 4: The diamond orientation effect on the dressing rate of ODD.

The long dressing performance of ODD is comparable to the standard DiaGrid® pad conditioners made by brazing diamond with Ni-Cr alloy, although the decay rate may be slower.

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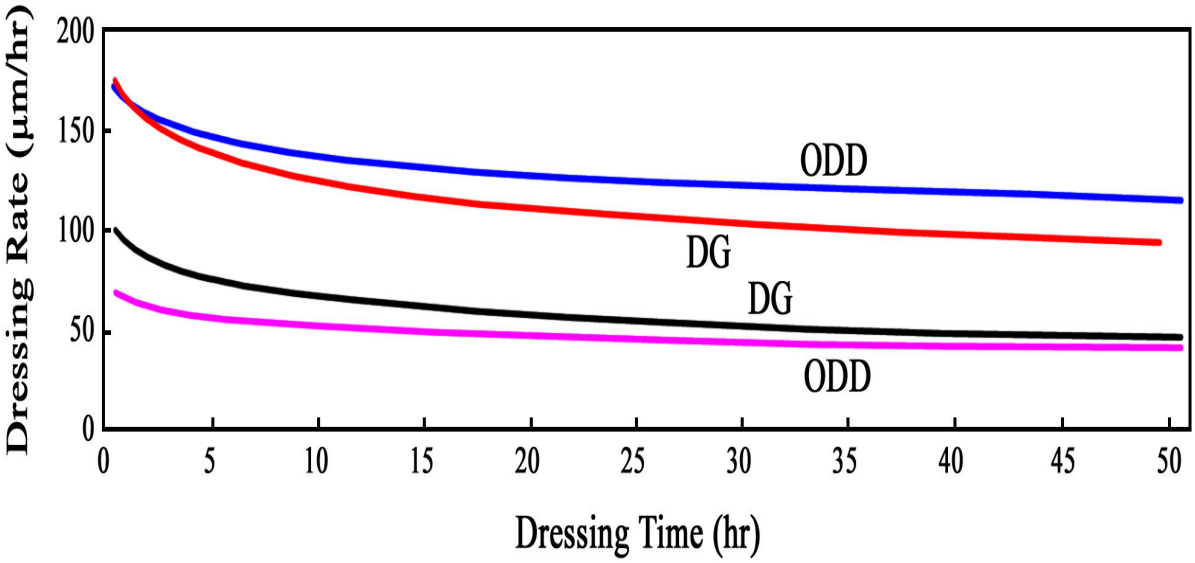

Fig. 5: The dressing rate of ODD is controllable and its decay rate is less than DiaGrid® pad conditioners (DG).

3. Preliminary Results

The prototype ODD samples were tested at Rohm-Haas, the leader of CMP consumables. The result indicate that the polishing performance of oxide wafer is comparable between ODD and the standard DiaGrid® pad conditioners. However, the asperities on the pad dressed by ODD are much more uniform.

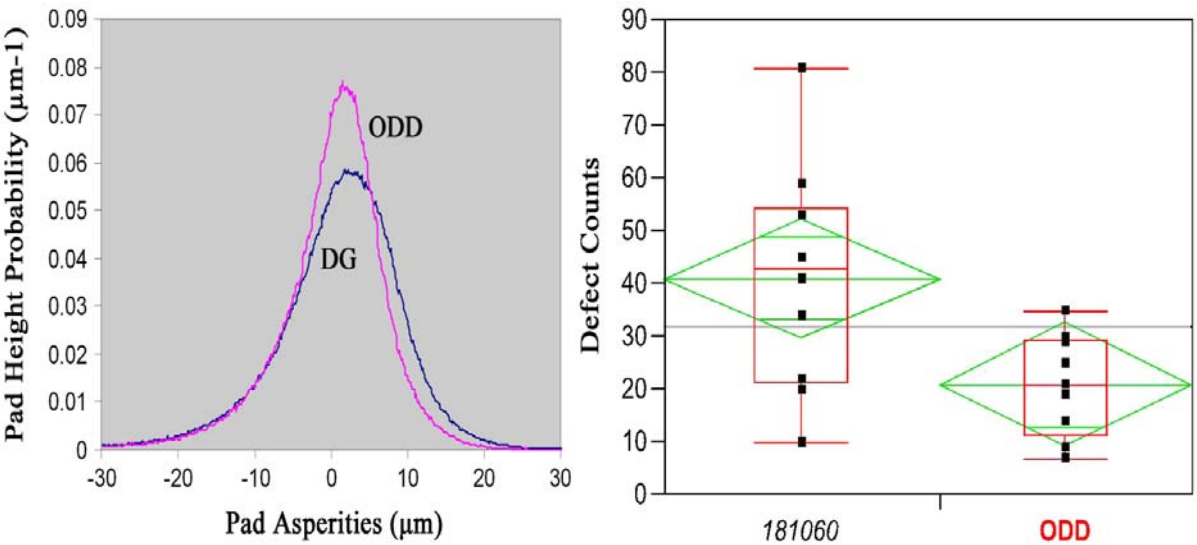

Fig. 6: The contrast of pad asperities distributions. Note that the spread of asperities heights of ODD was narrower than DiaGrid® pad conditioner (courtesy of RHEM-CMPT).

The more benign dressing of ODD can result in much longer pad life that may reduce significantly the cost of consumables.

The ODD and DiaGrid® samples were also compared with the wafer profiles when polished at different conditions. The results confirmed that ODD was fully capable to replace DiaGrid® pad conditioners for CMP manufacture of semiconductors.

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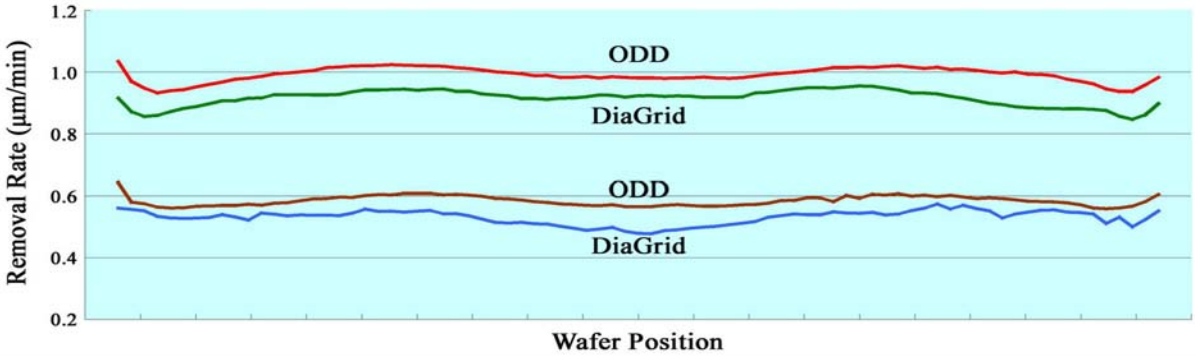

Fig. 7: Wafer (200 mm) profiles of ODD (upper curves) versus DiaGrid® pad conditioners (lower curves) for two different polishing conditions (courtesy of Eternal).

Additional data has confirmed at semiconductor fabs that the pad dress rate is half or less for achieving the same wafer removal rate. Moreover, the dressing time can be shortened by about 1/3 to restore the polishing effectiveness of the pad after polishing the wafer. These results imply that the CMP production pads will be consumed much less and the throughput of wafer passes can be increased significantly.

4. Conclusions

The major concern of using an organic matrix to hold diamond is that the adherence strength is weaker, about 5 times lower compared to a metallic matrix. However, this deficiency is made up by the tight height control of diamond tips. Conventional diamond disks are fabricated by laying diamond on a flat substrate so the diamond tip heights are dependent on the size distribution. In order to minimize the variation of diamond tips, smaller diamond crystals are used. As a result, the burry depth of small diamond is shallow. In contrast, ODD can bury deep without altering the tip positions, so the weak bonding strength is more than made up by increasing the bonding area. Moreover, because the tip heights are under stringent control, the loading of diamond tips is below the threshold limit that may pluck out a diamond. Consequently, it is less like to loss a diamond from an ODD dresser than a conventional metallic disk. Furthermore, ODD is processed at room temperature so its diamond is not thermally degraded. In contrast, the brazed diamond disks contain vulnerable diamond grits that may break during the CMP process.

ODD has much higher count of working crystals so its life is significantly longer. Moreover, being benign in dressing, ODD is actually a pad saver. In addition, ODD can create densely populated pad asperities that can polish wafers fast but with high uniformity. Hence, ODD cannot only reduce the CMP cost, but also improve the wafer quality.

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