

Cermet Ceramic Coating on Diamond Dresser for In-Situ Dressing of Chemical Mechanical Planarization

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ABSTRACT

In recent years, copper circuitry has been replacing aluminum wires and tungsten via as the dominant interconnections. The polishing of copper circuitry requires using highly acidic solution (e.g. pH = 4) and with strong oxidizing agent (e.g. hydrogen peroxide). In order to withstand the corrosive reactions, the bonding metal of the CMP pad conditioners must be corrosion resistant. Otherwise, it will be dissolved in the acidic slurry that may contaminate the delicate circuitry. Ideally, the diamond pad conditioner is best shielded from contacting with the acidic slurry. The chemical shield must be made of a hard substance so it can withstand the polishing action of the slurry. In addition, this hard substance ought to be highly inert so it will not react with the chemicals in the slurry.

The best chemical shield is diamond-like carbon (DLC) and the second best is ceramic coating. Kinik Company pioneered diamond pad conditioners protected by DLC barrier (DiaShield[®] Coating) back in 1999 (Sung & Lin, US Patent 6,368,198) and there has been no follower since then. Kinik's offered two varieties of DiaShield[®] Coatings: ultrahard amorphous diamond and superhard hydrogenated DLC. Recently, Kink also evaluated Cermet Composite Coating (CCC or C³, patent pending). C³ is unique that the coating composition grades from a metallic (e.g. stainless steel) under layer to a ceramic (e.g. Al₂O₃ or SiC) exterior. The metallic under layer can form metallurgical bond with metallic matrix on the diamond pad conditioner. The ceramic exterior is both wear and corrosion resistant. The gradational design of C³ coating will assure its strong adherence to the substrate because there is no weak boundary between coating and substrate.

By dipping diamond pad conditioners of various designs in acidic solution (e.g. copper cleaning solution) for extended period of time (e.g. 50 hours) the chemical inertness of various matrix materials are determined with the decreasing ranking as: hydrogenated DLC > C³ coating > amorphous diamond > sintered nichrome > brazed alloy > electroplated nickel.

Keywords: DLC, cermet, CMP, coating

1 The IN-SITU DRESSING OF CMP

Chemical mechanical planarization (CMP) is the must step of flattening wafer and smoothening its surface for the manufacture of sophisticated integrate circuitry (e.g. ULSI). During the process a coated wafer is pressed against a rotating polyurethane pad (e.g. IC1010 manufactured by Rohm Haas Electronic Materials) and it is gradually polished. The pad top is permeated with a slurry that contains both dissolved chemicals (e.g. hydrogen peroxide) and suspended abrasives (e.g. fumed silica). The chemical is used to react with the wafer coating; and the abrasive is employed to remove the reactant, as well as other protruded part.

The CMP process cannot be sustained because the pad surface will be deposited with polishing debris. Moreover, the pad top itself will be polished by the wafer so it becomes smooth. The dirt loaded smooth pad cannot polish the wafer effectively. A diamond dresser, also known as pad conditioner, is used to scrape off the debris from the pad top. At the same time, the diamond grits on the dresser will cut into the pad top (e.g. 20 microns) and carve out the texture required for holding the slurry and for abrading the

wafer surface.

The diamond dresser is made by attaching diamond grits (e.g. 200 microns) on a substrate (e.g. stainless steel). In general, the diamond grits are embedded in a metal matrix (e.g. nickel alloy) that either bonds to diamond or locks up the grit in place. The metal matrix can be applied by either brazing or electroplating. The former process is more desirable as the matrix is once in a molten state that can wet diamond and form strong chemical bond at the interface. In this case, diamond grit will not be pulled out during the polishing process. Moreover, the molten matrix will form a wetting profile that rises toward diamond but recesses away from diamond. The rise will reinforce the support of diamond; and the recess will facilitate the flow of slurry, as well as the removal of the debris.

It is preferably to dress the pad in-situ, i.e. while the wafer is polished. In this case, the pad top can be cleaned in real time and its surface texture can be maintained continually. However, for polishing metallic circuitry (e.g. copper), the slurry used is acidic (e.g. pH = 3) and the chemical is corrosive. As a result, the metal matrix of the dresser may be dissolved. Without the adequate support of the metal matrix, the diamond grit will soon fall out. The detached diamond grit may be embedded in the pad and cut deep in the wafer that cannot be tolerated by CMP operation.

In order to prevent the dissolution of the metal matrix, the diamond dresser is removed from the pad when the slurry is used in polishing wafer. After the wafer reaches the end point of polishing, it is taken away and the slurry feeding is temporarily suspended. Only at this stage, the diamond dresser is used to dress the pad. This ex-situ dressing operation can result in significant loss (e.g. 1/4) of CMP throughput. Moreover, because the pad texture is not optimized for polishing wafer, the polishing rate will decline substantially and the wafer thickness may not uniform either.

In order to protect the metal matrix from the attack of the slurry, a diamond-like carbon (DLC) coating is applied to the surface of diamond dresser. DLC is superhard so it can resist the abrasion of the slurry. In addition, DLC is highly inert and it is non-reactive to almost all chemicals and acids. Consequently, a DLC coated diamond dresser can be used to dress the polishing pad in-situ. As the result, the CMP productivity can be increased, so is the wafer quality.

2 CERMET CERAMIC COATING (C³)

Although DLC is an ideal chemical barrier that may protect the metal matrix from corrosion, it suffers several drawbacks that may offset its advantage for coating diamond dressers. Firstly, DLC, in addition to deposit on the metal matrix, it will also adhere onto diamond grits. The DLC will wrap around diamond grits so their sharp cutting tips become blunt. The dull diamond tip can no longer penetrate the pad effectively, as a result, polishing rate of the wafer will decline.

Secondly, the adhered DLC on diamond grits may flake off during the dressing action. The separated DLC shreds may mix with the polishing debris that can scratch the expensive wafer.

Thirdly, because DLC is very different from metal in physical characteristics (e.g. thermal expansion) and chemical properties (e.g. reaction compatibility), their interface is weak. The poorly adhered DLC may also flake off the metal matrix. The detached DLC may scratch the wafer. Moreover, the exposed metal matrix is likely to be etched by the corrosive slurry.

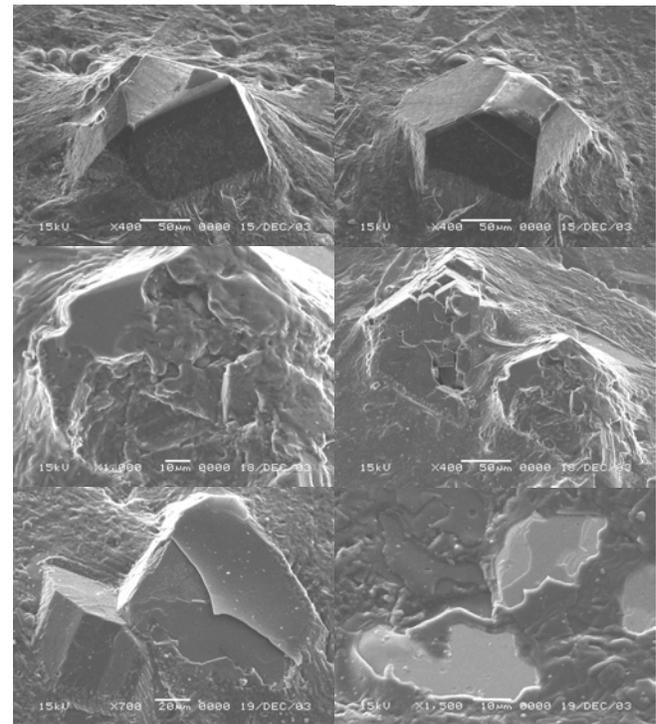


Figure 1: The coating of DLC on diamond grits and the metal matrix and its detachment after CMP polishing. The top diagram shows the flaking of DLC coating from the surface of euhedral diamond crystals; and the middle diagram, the flaking from grits of irregular shapes. The bottom diagram shows the peeling of

DLC from the metal matrix.

In order to improve the adherence of the coating material on the metal matrix and prevent it from coating onto diamond grits, a new coating technology is developed. This time, a metal film (e.g. stainless steel) is deposited first so it can form metallurgical (diffusion) bonding with the metal matrix. The metal film cannot adhere to diamond grits, however. While the metal atoms are showering onto the diamond dresser, a plasma of ceramic material (e.g. Al_2O_3) is also introduced in the atmosphere. Moreover, the concentrations of metal and ceramic are adjusted in such a way that metal underlayer can grade into ceramic top surface.

The above described cermet (ceramic-metal) composite coating (CCC or C^3) has several advantages. Firstly, its base is metal so it can adhere firm to the metal matrix of the diamond dresser. Secondly, because the metal grades into ceramic, there is no boundary in the coating. In other words, the vulnerable weak interface is eliminated. Thirdly, the ceramic is acid proof and it is corrosion resistant. Moreover, the composition of the ceramic as well as metal can be changed to suit specialty requirements (e.g. silicon carbide may be used instead of alumina as the top surface).

The CCC has been applied to diamond dressers and the effect is apparent. The metal underlayer does not adhere to diamond grits so the risk due to the loss of CCC there is minimized. Moreover, because the sharp edges of the diamond are exposed, their dressing ability is maximized. Hence, the pad dressing can be effective, and the CMP polishing may be efficient.

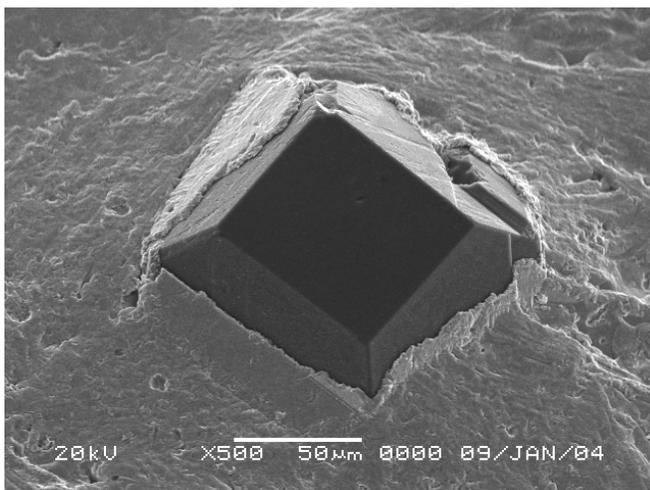


Figure 2: The diamond grit on the dresser that is coated with CCC is free from over coating after being rubbed

against a pad. The exposure of the fresh diamond can also penetrate the pad top easily and hence it can create the optimal texture for efficient polishing of wafer.

The CCC can adhere firm on the metal matrix so the used diamond dresser shows no sign of coating loss. Because the metal matrix is covered during entire period of CMP operation, it is not etched.

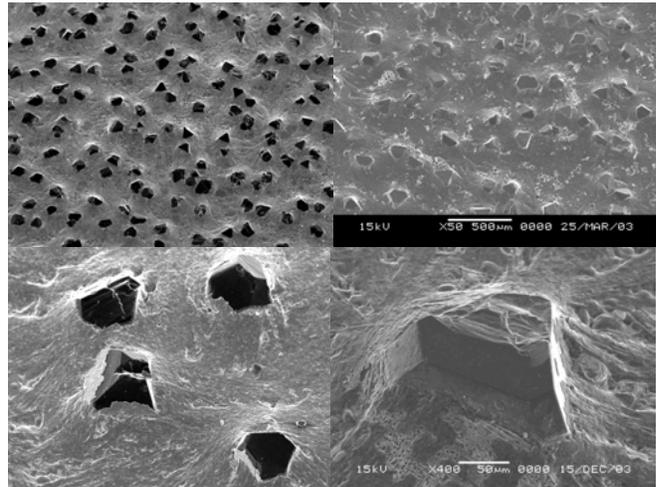


Figure 3: The intact appearance of CCC after a diamond dresser went through a CMP process (left diagram). In contrast, the peeling is serious with a DLC coated diamond dresser (right diagram).

In summary, the CCC is more preferred over DLC coating for protecting diamond disks. The advantage of CCC is in its selective ability to adhere metal matrix and not diamond grits. Moreover, CCC is versatile as its geometry (e.g. thickness) and composition can be engineered. It can be specifically designed to meet the in-situ dressing in caustic environment (e.g. copper CMP).

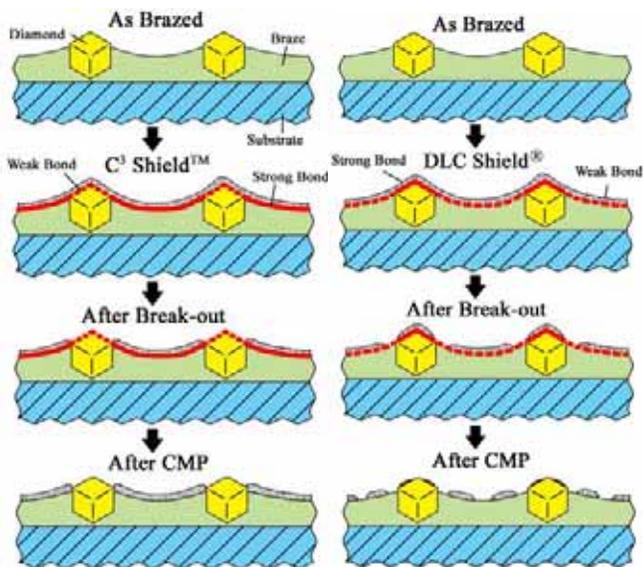


Figure 4: The contrast of CCC and DLC coating on diamond dresser. The CCC can adhere firm on metal matrix but it can be removed from diamond grits (left diagram). DLC coating is just the opposite, it will flake off from both metal matrix and diamond grits (right diagram).

REFERENCES

- [1] Sung, C. M., U. S. Patents 6,039,641, 6,286,498 and 6,679,243.
- [2] Sung, C. M. and Frank S. Lin, U. S. Patent 6,368,198.