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Novel Vitrified-Bond Ultra-Fine Grinding Technology for SiC Polishing

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Abstract. The present paper shows a new fixed abrasive bond-grit formulation aimed for best-in-class, low-cost and high-quality finished SiC wafer surfaces. Grinding wheels manufactured with this technology can accomplish ultra-smooth SiC (Ra = 0.55 nm and TTV < 1 µm) surfaces due to their unique bonding structure and their tailored grit size. Additionally, SiC wafers ground with these wheels exhibit reduced sub-surface crystal damage, mirror-like polished surface and improved wafer geometry while both the grinding forces and the wheel wear are kept low.

Introduction

The obtention of high-quality finished surfaces in Silicon Carbide (SiC) wafer thinning is essential in the pursuit of mass production of novel power semiconductor devices [1]. State-of-the-art SiC wafers are pre-processed via several cycles of lapping or mechanical diamond polishing followed by Chemical Mechanical Polishing (CMP) [2], processes which entails many steps and high machining costs due to the associated slow material removal rate [3]. To enable a reduction of consumable costs, grinding with a consolidated diamond abrasive technology has been investigated as an alternative to lapping and diamond polish over the last years [4-5]. Thus, modern ultra-fine grinding wheel technologies have achieved sub-nm surface roughness (Ra) and sub-µm Total Thickness Variation (TTV) values despite the well-known hardness, stiffness and strength of monocrystalline SiC [6-7].

Experimental Procedure

In this study, numerous 6” SiC wafers were ground using standard backgrinding equipment. A representative close-up region from one of the grounded 6” SiC wafers is illustrated in Fig. 1. As it can be observed from the 3D analysis (Fig. 1c), the surface profile is extremely homogeneous and grinding lines are nearly prevented. This is confirmed with the subsequent area and surface roughness measurements shown in Table 1 and Table 2, respectively. The corresponding wafer exhibits an Arithmetic Mean Height (Sa) of 0.85 nm in combination with a Total Height (Rt) of 3.78 nm. Interestingly, a sub-nm Root Mean Square Deviation (Rq) value is obtained, which correlated with the expected high surface quality shown in Fig. 2. It should be noted that more wafer regions and extra SiC wafers were considered, and nearly identical results were achieved.

At the heart of Meister Abrasives’ novel grinding technology, capable of producing SiC surfaces with the mentioned quality, is the proprietary bond-grit formulation. It features bonding structures, which are abrasive grains bond in a vitrified matrix system. With this approach, the same number of grains are active in the work zone. When material removal takes place on the substrate, new, sharp diamond grains are introduced by the matrix system. Meister Abrasive’s bond-grit formulation offers several advantages over competing technologies. As the diamonds employed in the wheels are specifically selected to the grinding process applications, the benefits include enhanced cutting behaviour, excellent self-dressing behavior and improved cooling. By developing new bond-matrixes, specifically tailored for each grit size, Meister offers a single bond for each wheel technology, leading to reach longer lifetime and lower grinding forces.

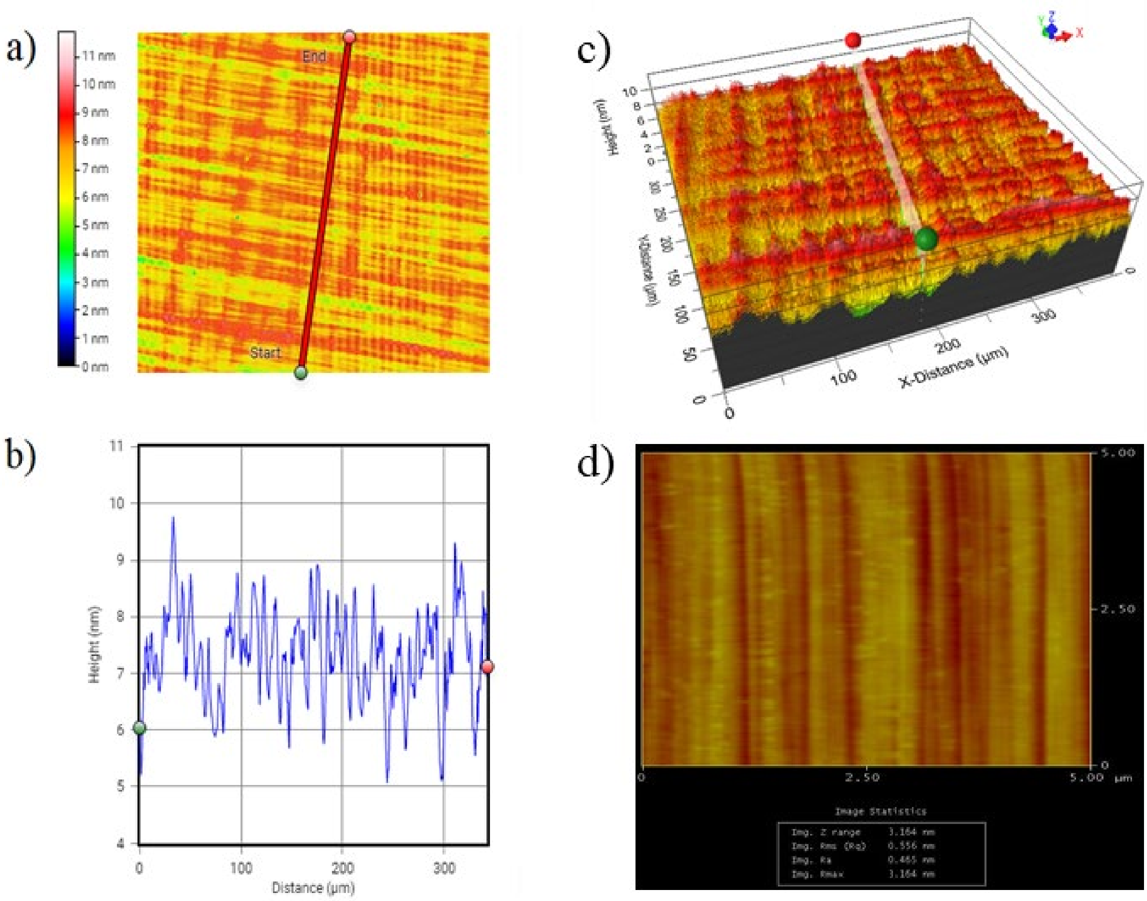

Fig. 1. Selected region (400 x 350 µm) from our UF6 grounded SiC wafer: a) contour topographic analysis of top view; b) line profile of diagonal represented in a); c) 3D view of identical area; and (d) Atomic Force Microscopy (AFM) scan of a 5 µm by 5 µm area (note the Z-scale is 3.16 nm).

Table 1. Area roughness parameter measurements of Fig. 1 obtained with Filmetrics Profilm3D via WLI (White Light Interferometry).

Parameter	ISO 4287 Amplitude (nm)
Peak Height (Sp)	4.56
Valley Depth (Sv)	7.36
Maximum Peak to Valley Depth (Sz)	11.91
Arithmetic Mean Height (Sa)	0.85
Root Mean Square Height (Sq)	1.03
Skewness (Ssk)	-0.07
Kurtosis (Sku)	2.75

Table 2. Line roughness parameter measurements of Fig. 1 obtained with Filmetrics Profilm3D via WLI.

Parameter	ISO 4287 Amplitude (nm)
Maximum Peak Height (Rp)	1.56
Maximum Valley Depth (Rv)	1.46
Maximum Height (Rz)	3.02
Total Height (Rt)	3.78
Arithmetic Mean Deviation (Ra)	0.55
Root Mean Square Deviation (Rq)	0.66
Skewness (Rsk)	0.13
Kurtosis (Rku)	2.46

A key feature of Meister unique bonding technology is its highly porous open structure (see Fig. 3, which illustrates that the porosity). This enables low force grinding processes that besides decreasing surface roughness, improve wafer geometry, in terms of total thickness variation (TTV), bow and warpage. Using Meister Abrasives' solutions, grinding process engineers can produce wafers with a TTV below 1 µm while keeping the grinding forces very low and steady. This smooths processing conditions, helps to avoid production breaks associated with overcurrent warnings.

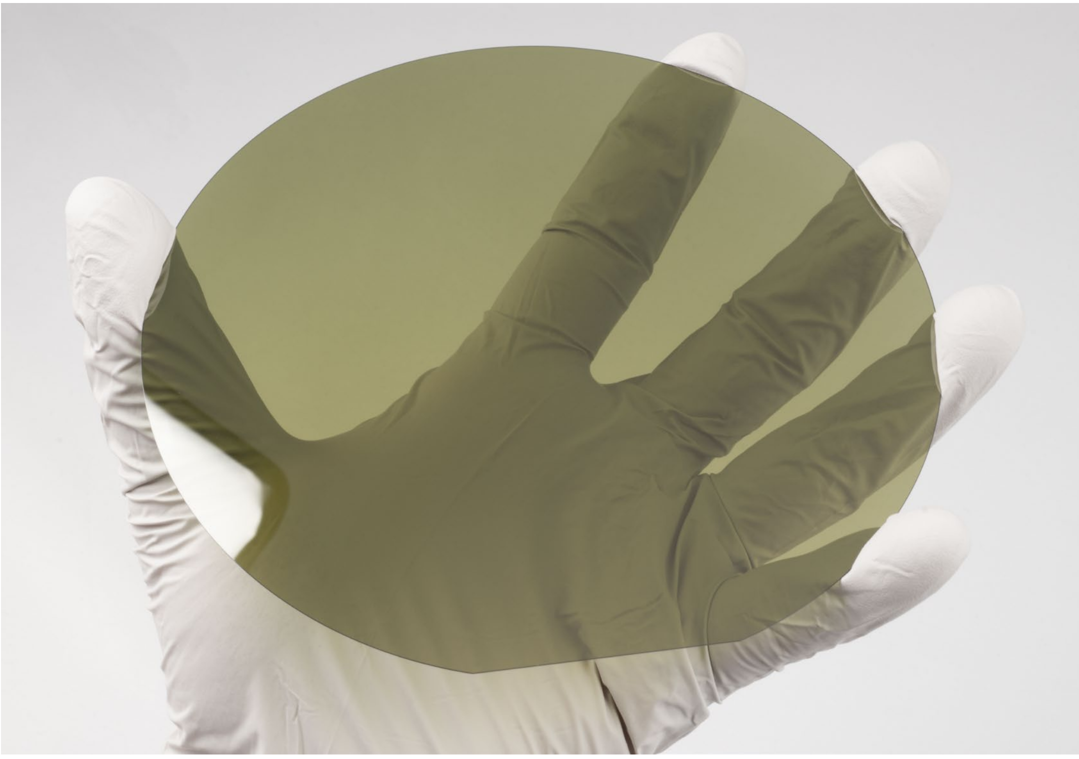

Fig. 2. Representative picture of UF6-grounded SiC wafer.

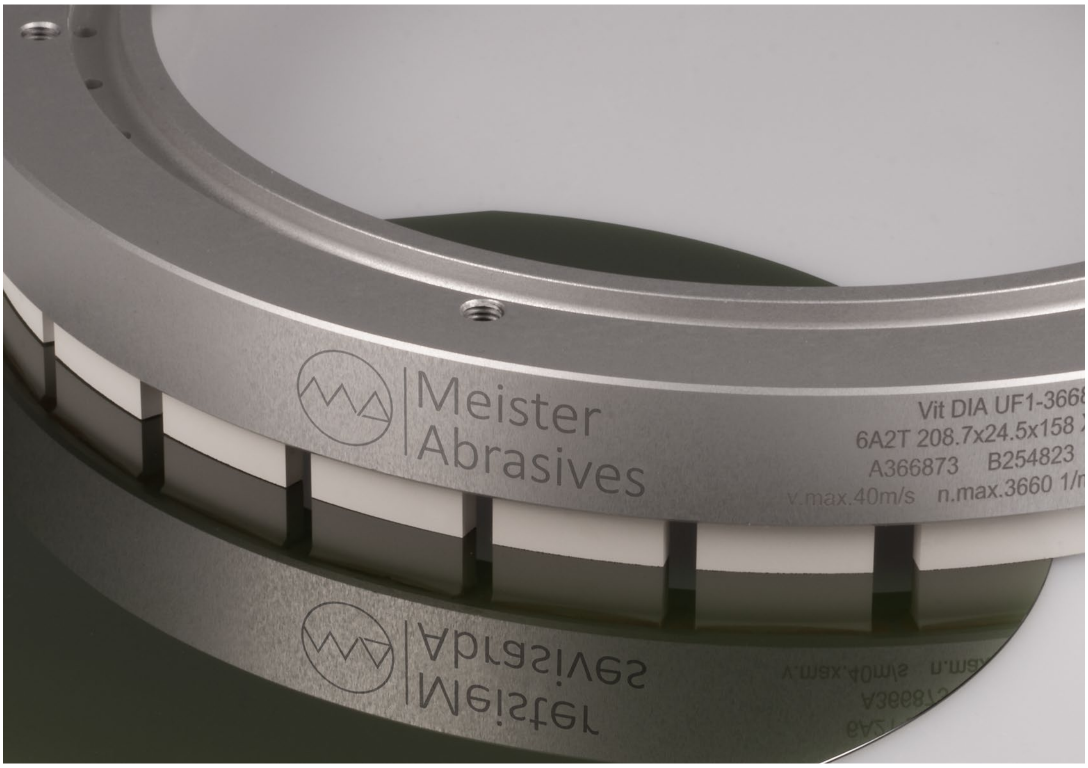

Fig. 3. Representative ultra-fine wheel with a porous structure. This novel material, exhibiting a porosity can be seen by the naked eye, maintains enough bonding to grind SiC.

Conclusions

The novel grinding wheel technology presented in this paper can help prime wafer and device manufacturers shorten wafer preparation steps to the minimum. Thanks to the ultra-smooth surface profile achieved with this method, diamond slurry costs can be therefore avoided, CMP slurry costs can be hugely reduced, and throughput can be drastically increased, and process time can be significantly reduced, as illustrated in Fig. 4. Furthermore, the pioneering nature of the bonding technology enables manufacturers to use low force grinding processes that improves wafer geometry (TTV, Bow and Warp) and decrease surface roughness even further.

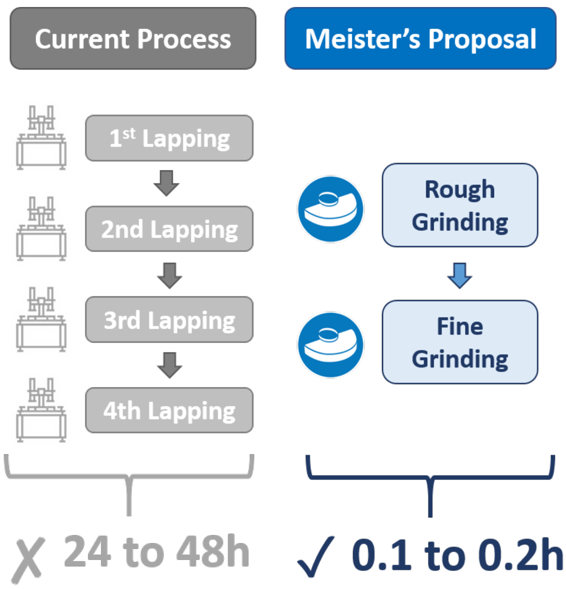

Fig. 4. Comparison of standard lapping processes vs Meister course and ultra-fine grinding technologies.

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