# Abrasive-Free Polishing of SiC Wafer Utilizing Catalyst Surface Reaction

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Although silicon (Si) power devices are currently used to regulate the frequency and impedance of electric power for its efficient usage, silicon carbide (SiC) power devices have received much attention in recent years because of their superior properties as compared with those of Si. These properties include large band gap and high breakdown electric field, which result in devices with lower power consumption. Owing to recent progress in crystal growth technologies, the quality of bulk SiC crystal is improving. In addition to bulk quality, surface quality is also important. SiC wafers are finished by chemical mechanical polishing (CMP), which can achieve atomically smooth SiC surfaces with atomic steps. However, because CMP uses a slurry consisting of a mixture of abrasives and chemical solutions, it may leave subsurface damage or subsurface scratches on polished surfaces, affecting the quality of subsequent epitaxial growth.

We have been developing a novel, abrasive-free polishing method, named catalyst-referred etching (CARE) [1-3], which does not, in principle, leave any subsurface damage or subsurface scratches on polished surfaces. If the catalyst generates reactive species that are chemically active only on the catalyst surface, the surface of the work will be chemically removed from the topmost parts in contact with the catalyst plate and planarized efficiently without any damage (Fig. 1). We considered that F and OH radicals would be effective reactive species, because such radicals are well known to be among the most reactive chemical species. We selected platinum (Pt) as the catalyst material and hydrogen fluoride (HF) aqueous solution as the solution, because Pt has catalytic properties, such as the ability to dissociate various molecules, and F and OH radicals can be expected to be generated by the catalytic dissociation of HF and $H_2O$, respectively. The CARE apparatus is quite similar to conventional CMP apparatus. The catalyst plate and the solution are used instead of the polishing pad and slurry, respectively.

From the results of CARE processing of a lapped 4H-SiC (0001) substrate (on-axis, n-type, 0.02–0.03 Ω·cm) whose surface had many scratches and microcracks, we found that CARE preferentially removed the topmost sites of the wafer surface in contact with the catalyst surface, and that the frictional force between the catalyst and wafer surface was sufficiently small to preempt introduction of mechanical scratches or cracks. Evaluation of the CARE-processed surface by atomic force microscopy (AFM) revealed the surface's step-and-terrace structure, with a step height of a single bilayer of Si and C. This showed the CARE-processed surface to be atomically flat. Such a surface structure strongly indicates that the removal mechanism is based on chemical phenomena and that a type of step-flow removal occurs on the (0001) Si surface of SiC. Thus, we can consider removal rate to be dependent on the step density of the work surface. From the results of the experiment using several SiC wafers with deference off-angle, it was shown that the removal rate was proportional to the step density of the substrate surface. Of course, the catalyst surface was not atomically flat, unlike the flattened SiC surface. However, the topmost areas on the SiC surface came in contact with the catalyst surface more frequently than the other sites through the averaging effect caused by the relative motion of the catalyst plate and SiC wafer, which allowed an atomically flat SiC surface to be obtained.

One issue of the CARE process with regard to its practical use is its relatively low removal rate. In an attempt to improve removal rate, we investigated its dependence on rotational speed and processing pressure using a 2-inch n-type 4H-SiC (0001) 8-degree off-axis substrate. From the results, we found the removal rate to be nearly proportional to both rotational velocity and processing pressure. Increasing rotational velocity (25 rpm) and processing pressure (980 hPa) to the maximum values of the apparatus, we were able to obtain a removal rate of 492 nm/h, which is comparable to that of conventional CMP processes.

Another issue is the use of HF, which is a well-known toxic chemical. We attempted to use only deionized (DI) water. The sample used was a commercially available 4H-SiC (0001) on-axis wafer. After the CARE process with a rotation speed of 10 rpm and an applied pressure of 400 hPa, a 1-bilayer-high step-and-terrace structure, which is the same structure as that processed with HF, was observed (Fig. 2). A removal rate as calculated by weight loss was 1.2 nm/h. Although this is very slow, removal rate can be increased by increasing rotational velocity, processing pressure, and step density (using an off-angle wafer).

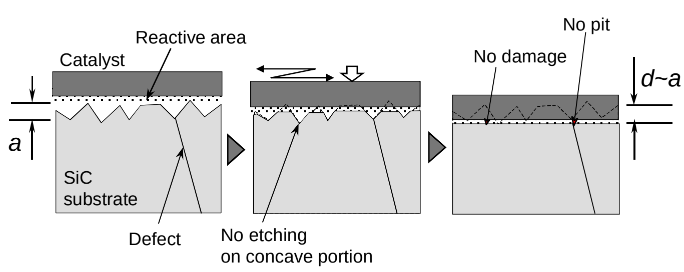


Fig. 1 Schematics of catalyst-referred etching

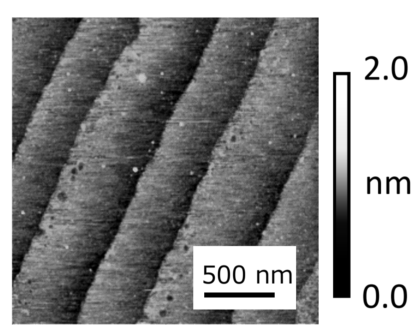


Fig. 2 AFM image of 4H-SiC (0001) on-axis surface (2 × 2 $\mu m^2$) processed by CARE with Pt catalyst and DI water.

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