SiC Lecture Series

7. Wafer processing technology for SiC crystals

Wafer processing technology for SiC crystals

The SiC monocrystal produced by the sublimation method is extracted from the crucible and undergoes several processing steps to be made into wafers, following the steps described in (a) to (e) below. The flow of this manufacturing process is shown in Figure 1.

(a) The crystal orientation of the SiC monocrystal, called a SiC boule, is confirmed, and cylindrical grinding is performed to process it into a cylindrical shape. The cylindrical crystal is sometimes referred to as a SiC puck.

(b) For n-type SiC wafers used in power devices, the top and bottom surfaces of the cylindrical crystal usually have a {0001} plane with an off-angle of 4°.

(c) An orientation flat (OF) or orientation notch is formed to indicate the crystal orientation within the wafer plane. Larger diameter SiC wafers tend to adopt notches.

(d) After (c), the cylindrical monocrystal SiC is processed into thin plates, often by slicing with a multi-wire saw. The multi-wire saw cuts by introducing abrasive grains into the gap between the wire and the SiC crystal and moving the wire while pressing it. The SiC plates immediately after cutting have thickness variations and surface irregularities, so flattening processing is necessary.

(e) In the flattening process, first, irregularities larger than the μm order are removed by lapping. At this stage, fine scratches and irregularities remain on the surface due to the abrasive grains. Next, finishing polishing removes irregularities smaller than the μm order and makes the surface mirror-like. Compared to lapping, polishing uses smaller abrasive grains and is designed to avoid surface scratches and subsurface damage.

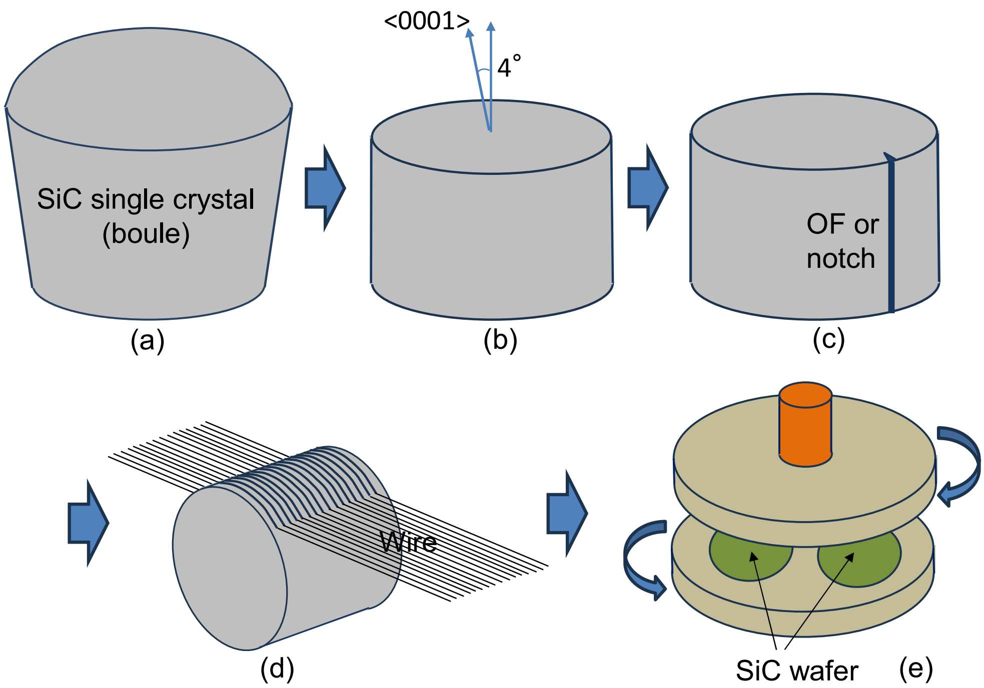

Figure 1 Overview of the SiC wafer processing steps.
(a) Extraction of SiC boule from the crucible (b) Cylindrical grinding
(c) Formation of orientation flat (OF) or notch (d) Slicing with a multi-wire saw
(e) Lapping and polishing

After polishing, the outer circumference of the wafer usually has an edge, making it very prone to cracking if it comes into contact with something. Therefore, edge grinding is performed to polish the outer circumference of the wafer and prevent sharp angles from appearing. Figure 2 shows examples of the cross-sectional shapes of the outer circumference before and after edge grinding. The edge shape is standardized by industry associations.

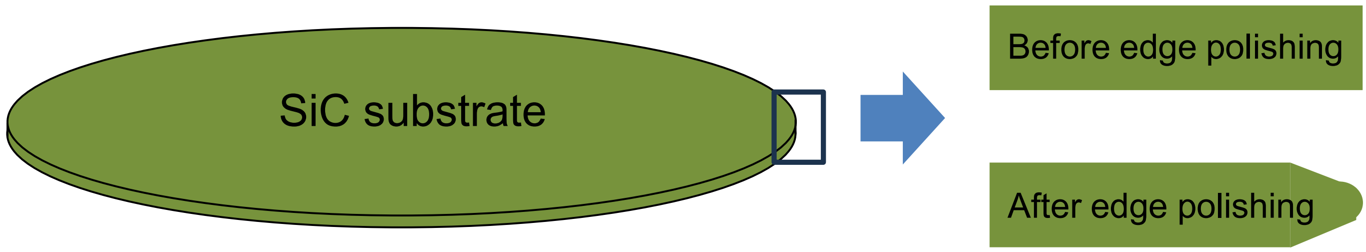

Figure 2 Examples of cross-sectional shapes of the wafer edge before and after edge grinding

Since SiC is an extremely hard material used as an abrasive grain for processing various materials, the process of converting a SiC boule into wafers is a time-consuming and challenging process, with ongoing efforts to improve it.

A new attempt in slicing processing involves using laser light. In this method, laser light is irradiated from the top surface of the cylindrical crystal, focused at the desired slicing depth within the SiC crystal to form a modified region, and then scanned across the entire surface to expand the modified region into a plane, allowing for the separation of thin plates. In the commonly used multi-wire saw slicing method, a significant amount of kerf loss occurs, and the undulations of the wire create surface irregularities, increasing the amount of lapping required and resulting in a large portion of the crystal being wasted. In contrast, the laser slicing method reduces kerf loss and shortens the processing time, making it a promising technique.

Another slicing method being explored involves applying a voltage between the wire and the SiC crystal to generate discharge and slice the crystal, thereby reducing kerf loss. This method is known as wire electrical discharge slicing.

As an alternative method to the conventional process of making wafers from SiC monocrystals, a technique has been reported where a thin film of SiC monocrystal is bonded to the surface of a different substrate (supporting substrate) to create a wafer that can undergo the process flow. Figure 3 shows an overview of the process flow during bonding and separation.

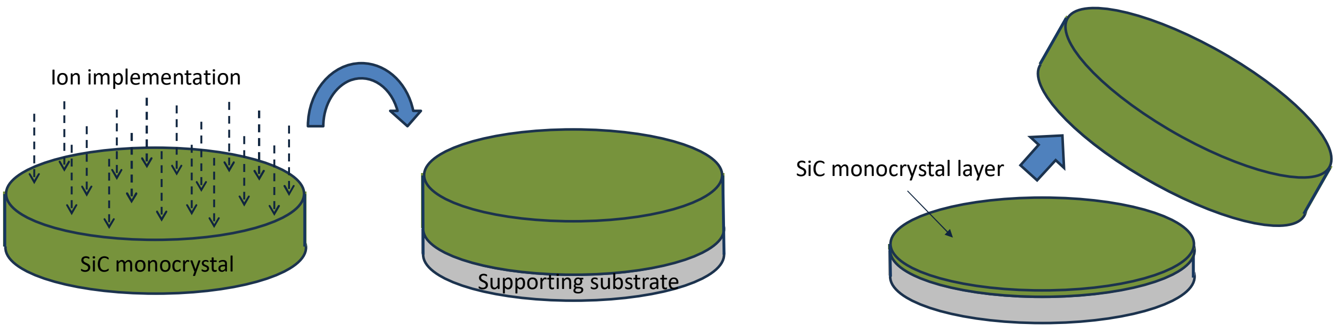

Figure 3 Process flow for fabricating SiC substrates

First, hydrogen ions or similar are implanted to a depth that allows for full-surface separation from the surface direction of the SiC monocrystal. The ion-implanted surface of the SiC monocrystal is then placed on a flattened supporting substrate (such as polycrystalline SiC), and through the application of pressure and heating, the SiC monocrystal layer is transferred to the supporting substrate and separated. After this, the SiC monocrystal is flattened again and reused in the bonding process. Since the supporting substrate is less expensive compared to the SiC monocrystal, development is ongoing with the aim of reducing wafer costs. However, many challenges remain.

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