Research on an Innovation Hybrid Machining Process for the Surface Polishing of SiC Wafer

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Abstract. An innovation hybrid machining process developed by Industrial Technology Research Institute (ITRI) Taiwan is investigated for the surface polishing of 4 inch 4H-SiC wafers to enhance material removal rate (MRR) and improve surface quality. The hybrid machining process consists of two major steps, the vibration assisted ductile-mode polishing process (VADPP) and the high-efficiency large-area plasma assisted polishing process (HELP-APP). This process device has been set up by ITRI and verified experimentally. At present, a device with a processing area of a diameter of 35 cm is set up. Here the 4 inch 4H-SiC wafers are taken as experimental sample. The experimental results show that, for the VADPP compared to the traditional rough polishing process, the MRR is increased by 96 %, and, for the HELP-APP compared to the traditional chemical-mechanical polishing process (i.e. without the plasma modification process), the MRRs of C face of 4H-SiC wafer are increased about 4.83 times. Comparing with the traditional machining process, the ITRI innovation hybrid process combined with several machining technologies has obviously some advantages, such as high material removal rate, high surface quality, and high production capacity.

Introduction

Silicon carbide (SiC) is a wide-band-gap semiconductor material with high thermal conductivity, high breakdown electric field strength, high-saturated drift velocity, and high thermal stability[1-3]. SiC has been drawing attention and is considered a replacement material for Si semiconductors in the electronics industry in certain applications [2-3]. However, the machining and polishing of SiC with 9.25-9.5 in Mohs hardness scale are more difficult than silicon. Obviously, high processing costs of SiC wafer will limit his development and application. For the SiC wafer, developing a production with high efficiency and high surface quality is the goal of many people. In recent decades, some composite processing methods have been proposed to mit the goal. Those methods are mainly based on a fine processing technology assisted by a modification function of SiC surface [4-7].

In this study, we investigate the hybrid machining process for the wafer surface of 4H-SiC by use of the high-efficiency large-area plasma assisted polishing process (HELP-APP) and the vibration assisted ductile-mode polishing process (VADPP) to enhance material removal rate (MRR) and improve surface quality. On the other hand, we also consider to promote production capacity by increasing the processing area of plasma modification. At present, a device with a processing area of a diameter of 35 cm is set up. Using the developed device, 4H-SiC wafers are taken as experimental sample to verify the effectiveness of the innovation hybrid machining process. It is shown that the hybrid machining process can enhance MRR and improve surface quality.

Experiment and Results

For the surface polishing of SiC wafer, an inovation hybrid machining process developed by Industrial Technology Research Institute (ITRI) Taiwan has been developed and the flowcharts is shown in Fig.1. One can see that there are two key machining processes in the inovation hybrid process: VADPP and HELP-APP. The first, the VADPP is used as preliminary processing and can be efficiently removing material on the SiC surface. Fig.2 shows the schematic and picture of the VADPP module. The other, the HELP-APP combining the traditional chemical-mechanical polishing (CMP) with the large area atmospheric pressure plasma modification process is proposed. The schematic of the HELP-APP module is shown in Fig3. Here, the purpose of plasma modification process is that the Si-C bond on SiC wafer surface is modified to Si-O bond. That is, the plasma modification process is used to soften the SiC wafer surface. In this module, one of the main features is the large area of plasma modification, which is currently up to 35 cm.

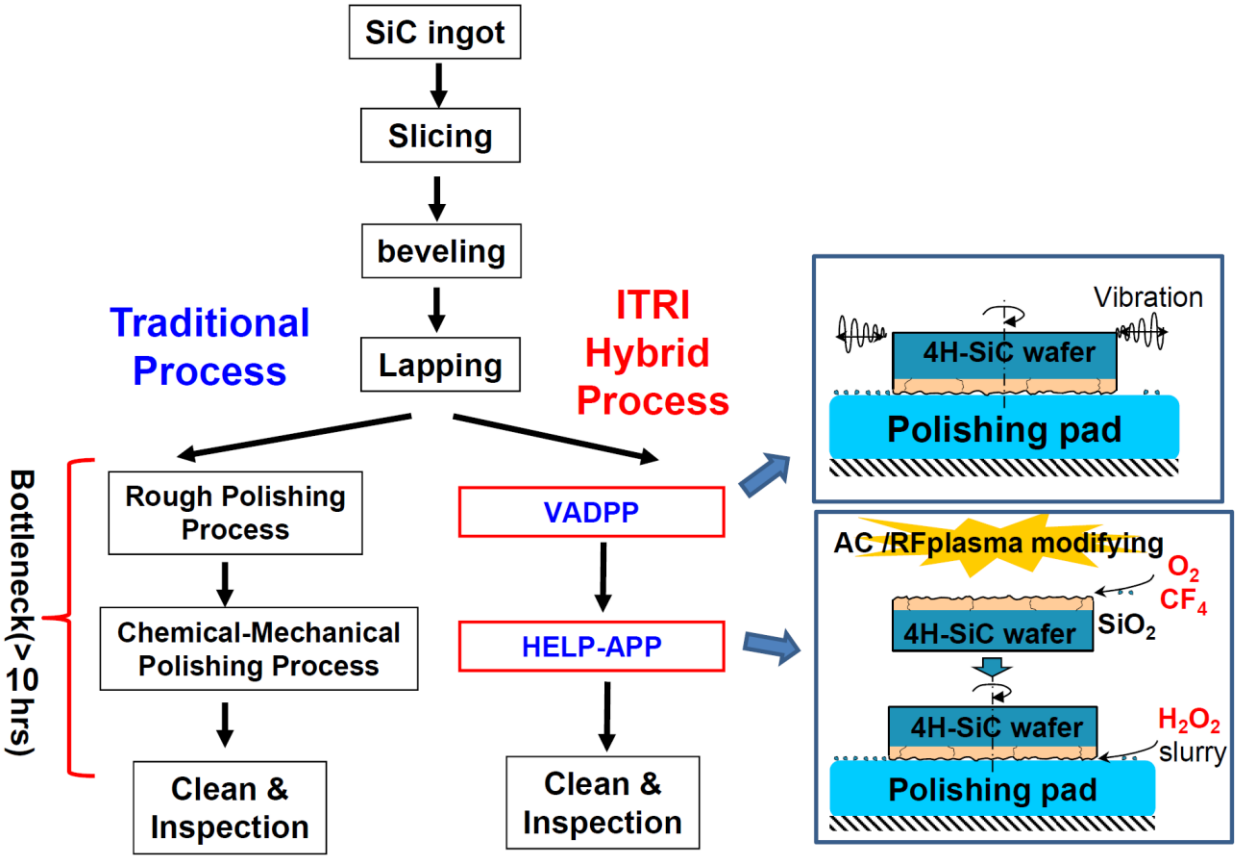
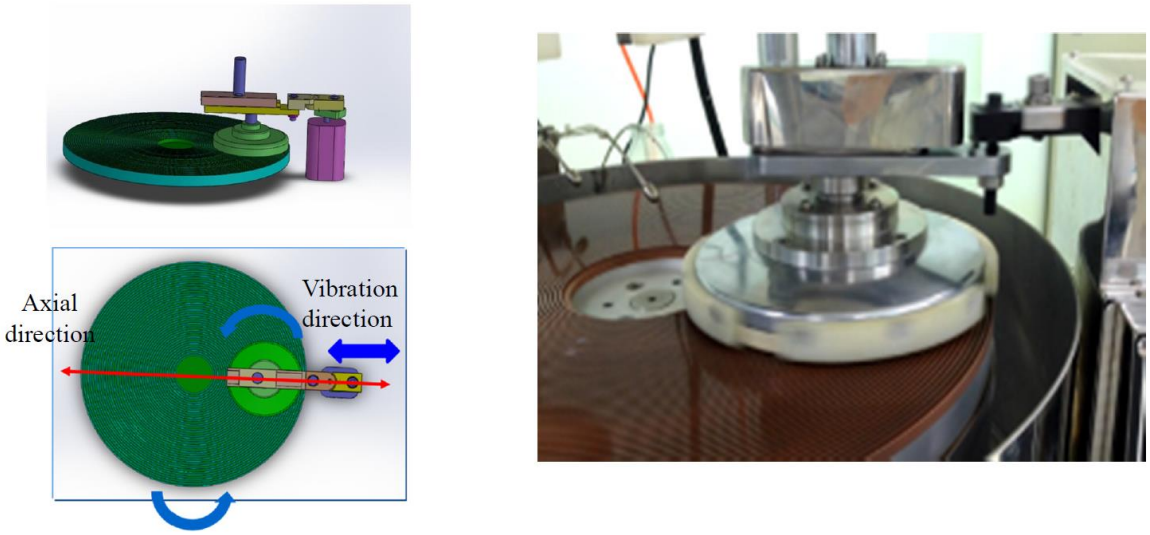


Fig. 1 Flowcharts of the ITRI innovation hybrid machining process and traditional machining process for the surface polishing of SiC wafer



(a) (b)

Fig. 2 Schematic (a) and picture (b) of the VADPP module

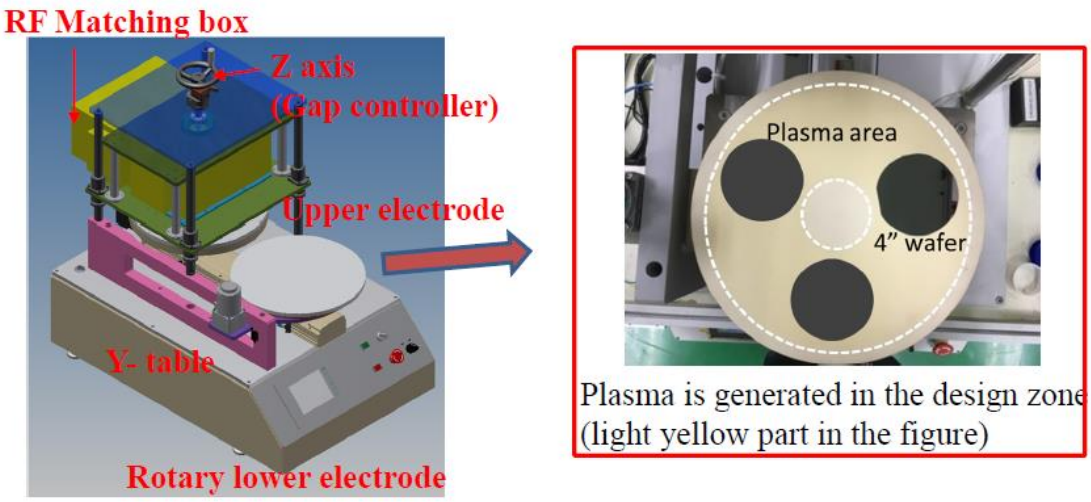


Fig. 3 Schematic of the HELP-APP module

To verify the function of ITRI hybrid machining process, the 4H-SiC wafers are taken as experimental sample. Integrating and optimizing those processes, the experimental conditions are found and listed in Table 1. Fig. 4 shows the MRRs of the traditional rough polishing process and the VADPP for the C-face of 4H-SiC. It is found that the result of the VADPP compared to the result of the traditional rough polishing is about increased by 96 %. Table 2 lists the experimental conditions of the HELP-APP. The test wafer processed by the VADPP is applied for about 5 minutes of plasma modification treatment and then polished for about 5 minutes. It is obtained and shown in Fig. 5 that, for the C-face of the SiC, the MRR of the HELP-APP is about 1.11 μm/hr. For those without plasma modification, the MRR is only 0.23 μm/hr. That is, the MRRs is enhanced about 4.83 times when the plasma modification process is considered. The roughness measurement and analysis of the finished SiC wafer surface measured by atomic force microscope (AFM), the result is shown in Fig. 6. It is seen that the

finished surface is near defect-free and the average roughness (Ra) is about 0.461 nm.

Table 1 Experimental conditions of the VADPP

Experimental conditions	✧ Pressure: 500 g/cm^2 ✧ Plate rotating speed: 40 rpm ✧ Abrasive : 3μm diamond powder ✧ Vibration : 2.5 Hz based on amplitude ±5 mm

Table 2 Experimental conditions of the HELP-APP

Experimental conditions	✧ Plasma Type: RF ✧ Main gas: He ✧ Precursors: CF_4/O_2=10 sccm/140 sccm ✧ Plasma Power: 500 W ✧ Plasma modification time: 5 minutes / per run ✧ Polishing time: 5 minutes/ per run ✧ Polishing pressure: 700-1350g/cm^2 ✧ Plate rotating speed: 40 rpm ✧ Slurry pH: 5.8-6

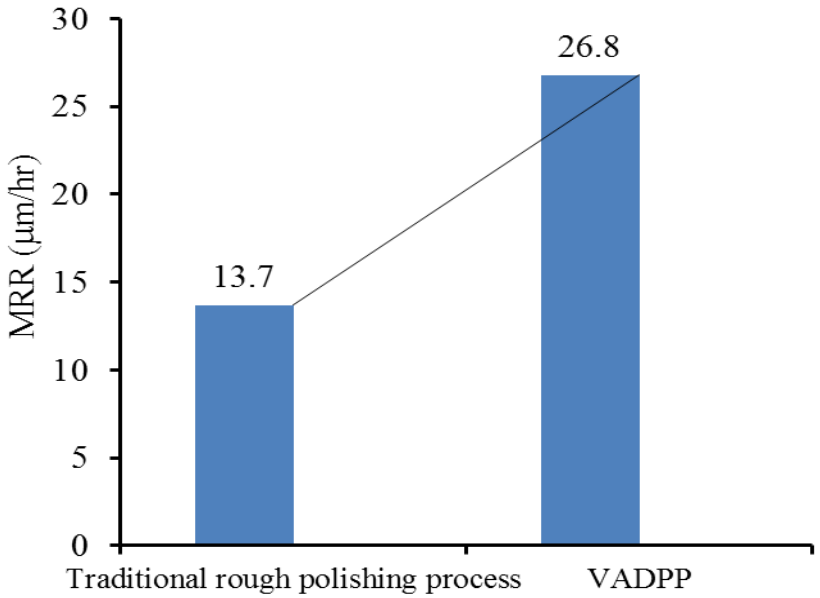


Fig. 4 MRRs of traditional rough polishing and the VADPP for the C-face of 4H-SiC wafer.

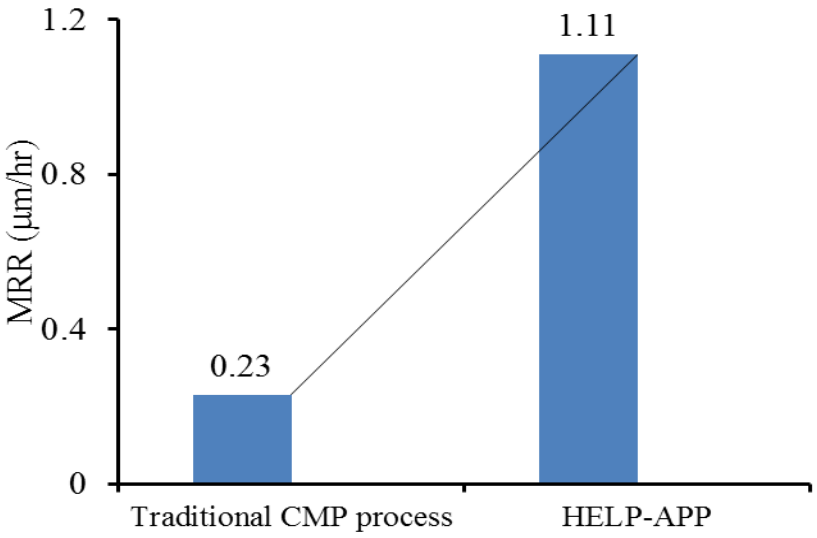


Fig. 5 MRRs of traditional CMP process and HELP-APP for the C-face of the SiC wafer

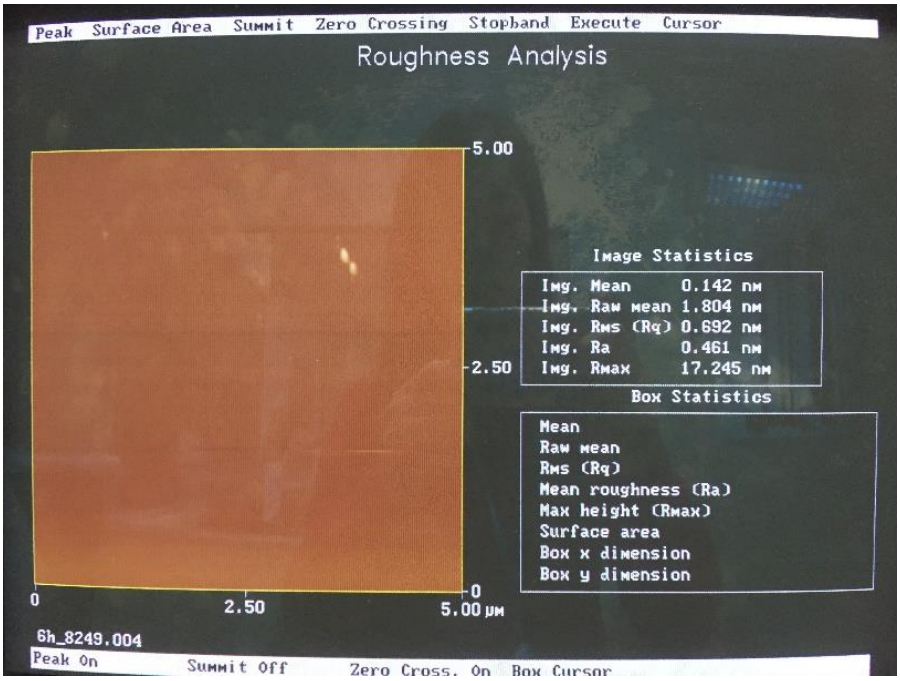


Fig. 6 Roughness analysis of the finished SiC wafer surface measured by AFM

Summary

In this study, we investigate and develop the innovation hybrid machining process developed by ITRI Taiwan for the surface polishing of 4 inch 4H-SiC wafers to enhance MRR, improve surface quality, and promote production capacity. The hybrid processing machinery has been set up by ITRI. Here the 4 inch 4H-SiC wafers are taken as experimental sample. Integrating and optimizing those processes, the experimental conditions are found and the experimental results are obtained. The experimental results show that, for the VADPP compared to the traditional rough polishing, the MRR is increased by 96 %, and, for the

HELP-APP compared to the traditional CMP process, the MRRs of the C face of 4H-SiC wafer are increased about 4.83 times. Comparing with the traditional machining process, the ITRI inovation process combined with several machining technologies has obviously some advantages, such as high material removal rate, high surface quality, and high production capacity.

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