Supporting Information

Chemical compatibility is the decisive factor, not abrasive hardness, affecting the material removal between abrasives and substrates in nanoscale polishing

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1. Experimental details

The experiments were performed to clarify the interaction mechanisms between abrasives and substrates during nanoscale polishing. A rotary-type polishing machine (UNIPOL-1200S, Kejing, China) with the semi-fixed abrasive polishing tools was used to perform the polishing experiments of the SiC and sapphire substrates. The semi-fixed abrasive polishing tool, based on the principle of sol-gel (SG), was used in this research, which would satisfy the processing demands of scratch-free and nanoscale roughness in wafer surfaces.[1-3] The schematic diagram of the polishing tool is shown in Figure S1. This polishing pad is the flexible matrix made of sodium alginate, which enables the effects of abrasives yielding and then controls the material removal evenly. Figure S2a shows the effects of abrasives yielding and the material removal mechanisms. The polishing load was set as 40 N, with the rotational velocity of the workpiece and rotational velocity of the polishing pad were 60 r/min and 120 r/min for 3 h, and distilled water was used as the coolant.

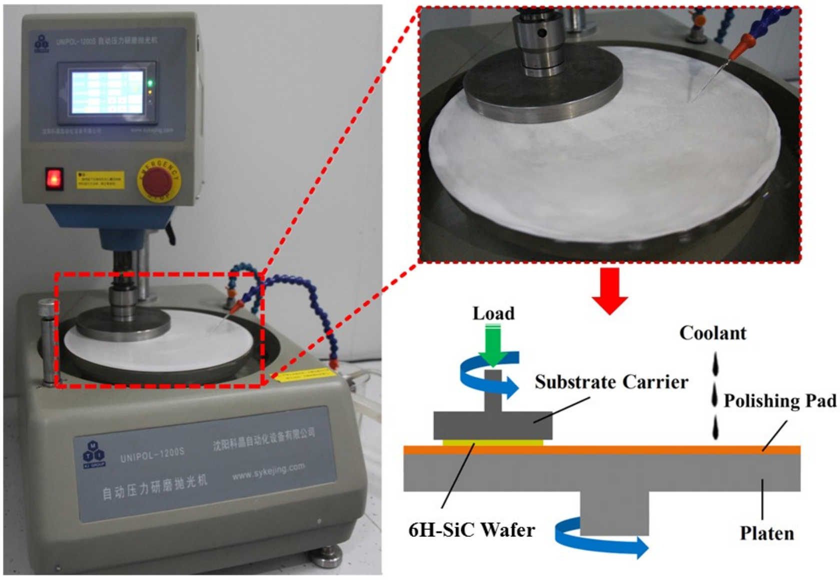


Figure S1. Schematic diagram of the polishing process.[6]

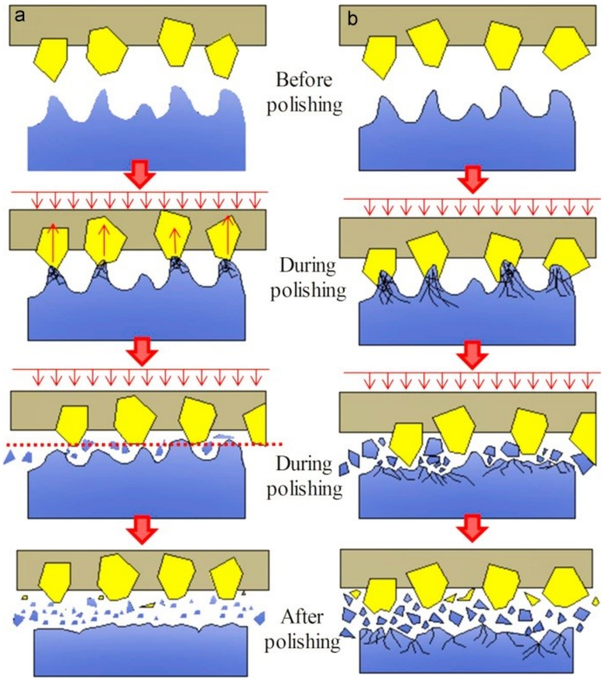
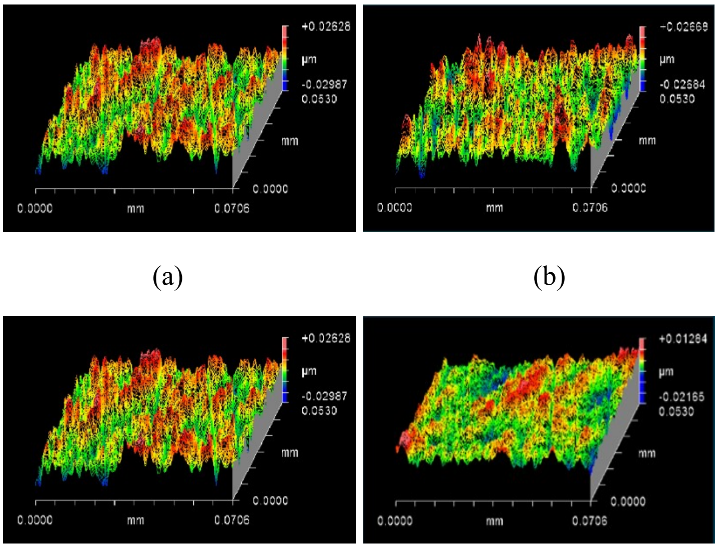


Figure S2. Material removal mechanisms of 6H-SiC using (a) semi-fixed and (b) fixed abrasive polishing film.[3]

2. Supplementary results

An interesting result found in our preliminary study, that the diamond abrasives with a diameter of 3 μm can hardly polish the pretreated sapphire substrate while that of the alumina abrasives can. The surface morphologies of sapphire substrates before and after polishing were shown in Figure S3. The surface morphology of sapphire substrate polished by diamond abrasive had almost no changed compared with the surface before polishing, while that of the sapphire surface processed by alumina changed smooth obviously.

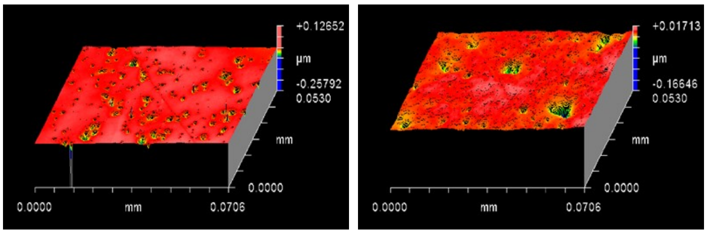


(a) (b) (c) (d)

Figure S3. Surface morphologies of sapphire substrates before (a and c) and after (b and d) polishing. (a) and (c) use diamond abrasive, (b) and (d) use alumina abrasive.

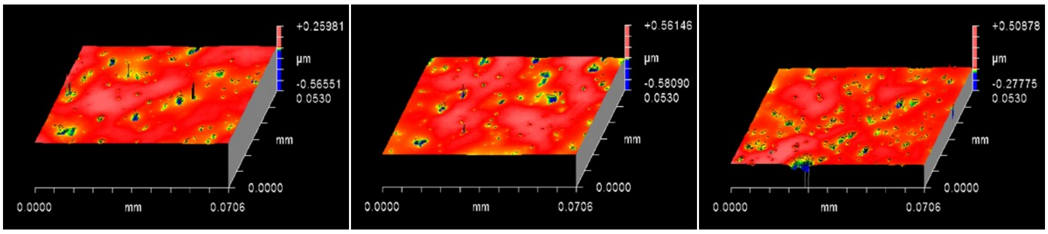
Six abrasives with a significant difference in microhardness value, consisted of oxide systems (SiO_2, ZrO_2 and Al_2O_3 abrasives) and carbide systems (SiC, B_4C and diamond abrasives), were selected to verify the interfacial interaction mechanisms between abrasives and substrates during polishing. The size of abrasives was chosen 3 μm in order to obtain an ultra-smooth substrate surface. Figure S4 shown the surface morphologies of SiC and sapphire substrates before polishing. The substrates, after mechanical polishing, had the original surface roughness Sa about 5 nm. Figure S5 and Figure S6 shown the surface morphologies of SiC and sapphire substrates after polishing with six abrasives. It can be seen that only the SiC surface using diamond abrasive had changed smooth significantly. No scratches only a few small pits with shallow depth remained on the surface. The SiC surfaces polished by the other five abrasives had no obvious change. As shown in Figure S6, there were two sapphire surfaces changed smooth polished by ZrO_2 and Al_2O_3 abrasives, and other surfaces almost had no change.

Figure S7 and Figure S8 shown surface roughness Sa of SiC and sapphire substrates before and after polishing. The ultra-smooth SiC surface with nanoscale roughness (0.67 nm) could be achieved only by using diamond abrasive. In addition, only using ZrO_2 and Al_2O_3 abrasives can significantly reduce the roughness of sapphire surface. And surface quality of sapphire substrate processed by alumina abrasive was the best, reaching the super smooth surface with a roughness of 1.51 nm.

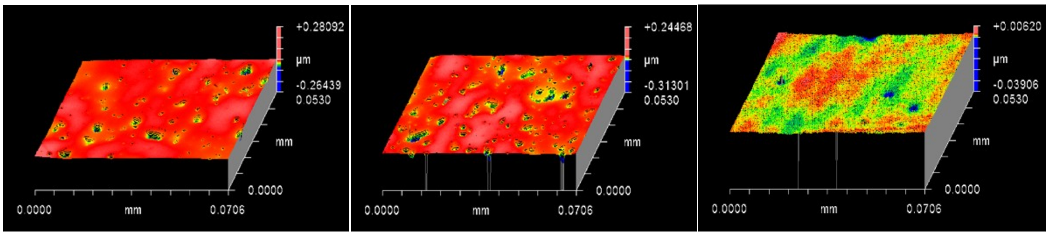


(a) (b)

Figure S4. Surface morphologies of SiC (a) and sapphire (b) substrates before polishing.

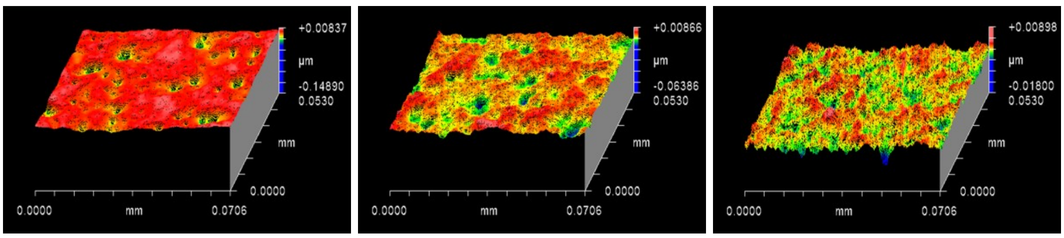


(a) (b) (c)

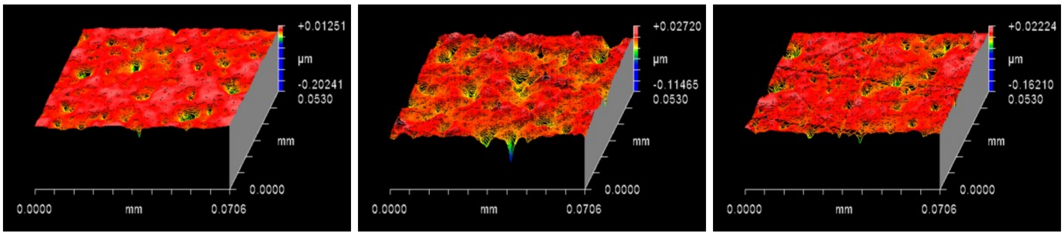


(d) (e) (f)

Figure S5. Surface morphologies of SiC substrates after polishing with six abrasives. (a) SiO_2, (b) ZrO_2, (c) Al_2O_3, (d) SiC, (e) B_4C, (f) Diamond.



(a) (b) (c)



(d) (e) (f)

Figure S6. Surface morphologies of sapphire substrates after polishing with six abrasives. (a) SiO_2, (b) ZrO_2, (c) Al_2O_3, (d) SiC, (e) B_4C, (f) Diamond.

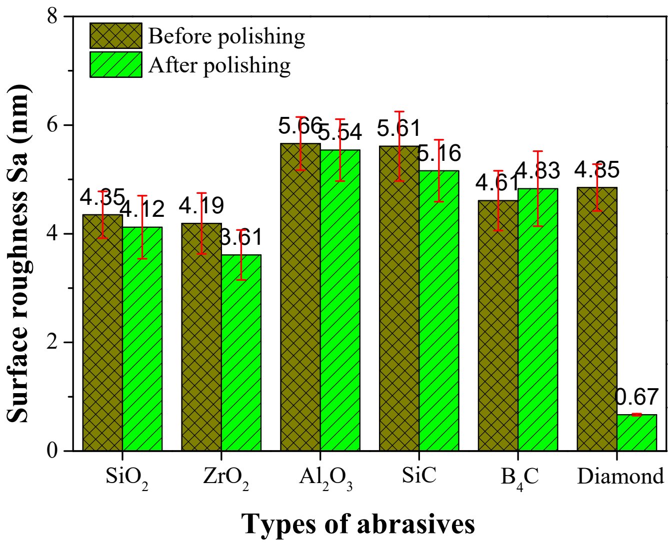


Figure S7. Surface roughness Sa of SiC substrates before and after polishing.

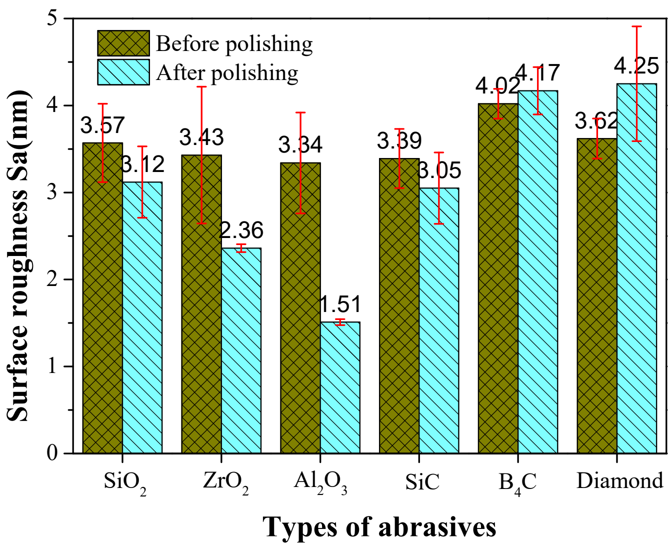


Figure S8. Surface roughness Sa of sapphire substrates before and after polishing.

References

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(2) Lu, J.; Li, Y.; Xu, X. The effects of abrasive yielding on the polishing of SiC wafers using a semi-fixed flexible pad. *Proc. IMechE. Part B: J Engineering Manufacture* **2015**, 229(SI), 170-177.

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