ON THE DEFORMATION MECHANISM OF SIC UNDER NANO-SCRATCHING: AN EXPERIMENTAL INVESTIGATION

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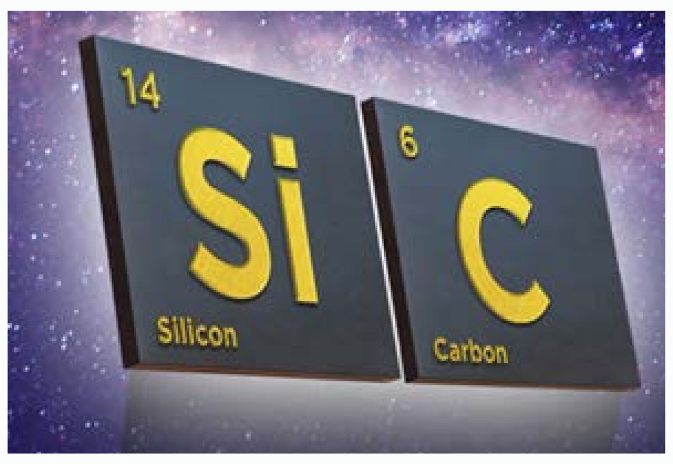
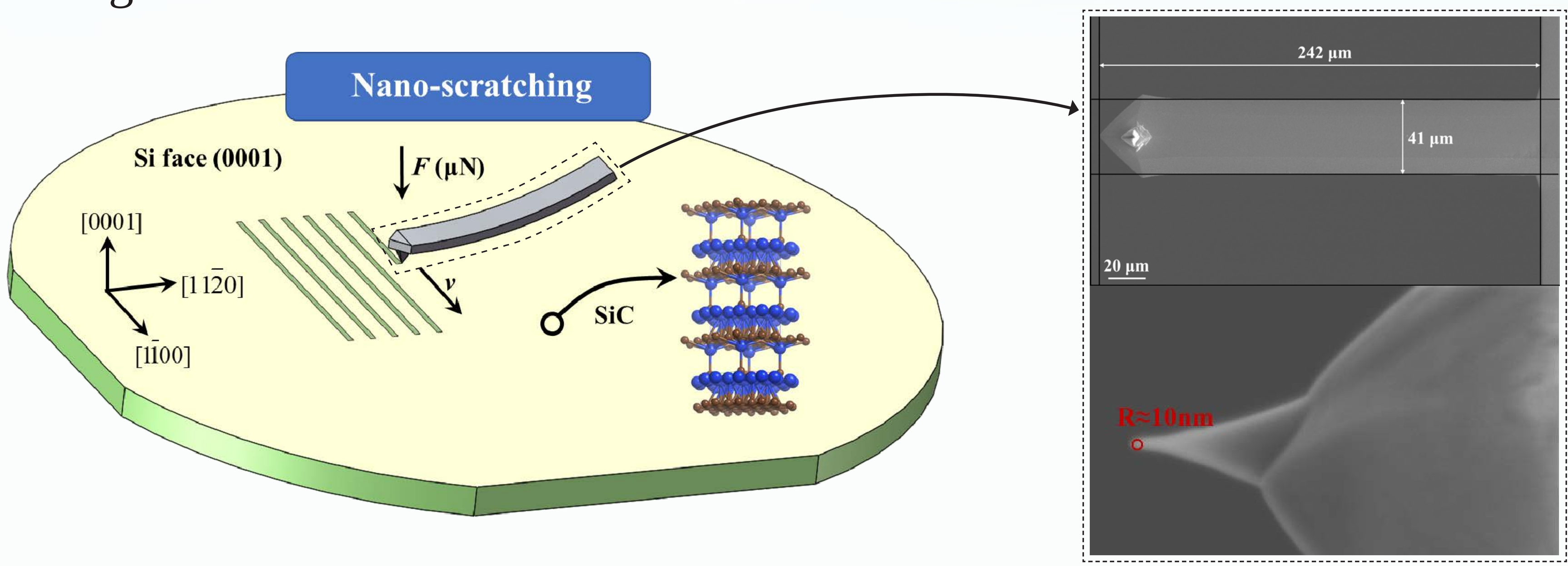
INTRODUCTION

Silicon carbide (SiC) is an important material for chips, power devices and core components in other electronics, because of its excellent performance under working conditions such as high temperature, high pressure or high frequency. However, SiC is difficult to machine due to its high hardness and low fracture toughness. The deformation mechanisms of SiC subjected to single-point cutting is so far unclear. This poster aims to clarify such mechanisms by carrying out experimental investigations at similar length and load scales to those based on molecular dynamics.



EXPERIMENTAL

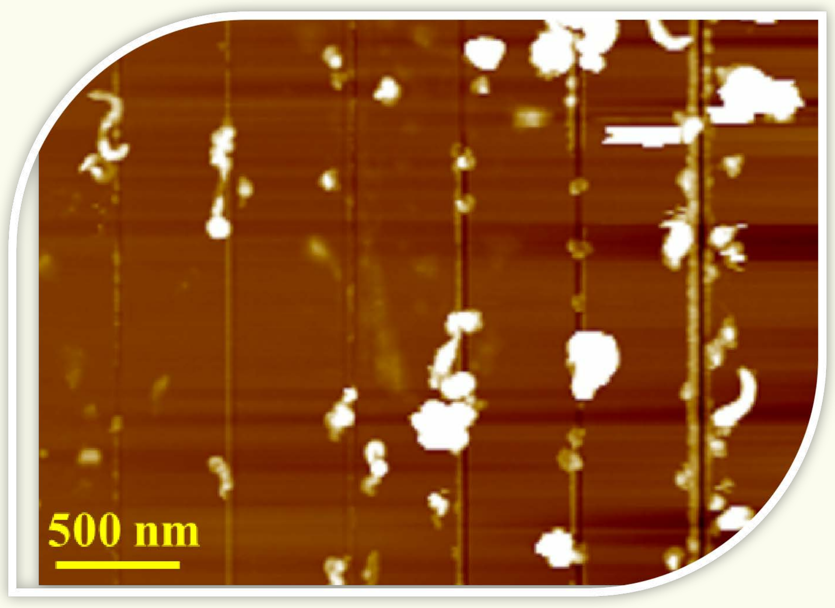
*SiC specimens ultrasonically cleaned in acetone and alcohol
*Calibration of diamond tip including the tip radius and the cantilever spring constant
*Nano-scratching with AFM diamond tip
*Sample preparation of subsurface of the scratched grooves for HRTEM by using FIB



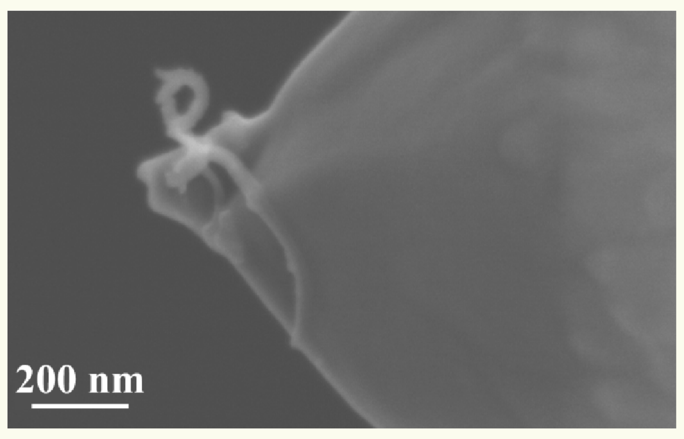
RESULTS AND DISCUSSION

A. SURFACE DEFORMATION AFTER NANO-SCRATCHING.

The diamond tip with the radius of 10 nm penetrated into the Si face of 4H-SiC under the normal loads in the range from 2 μN to 6 μN. It was clearly seen that six grooves were generated along the tip-sample contact trace, and plastic deformation without any cracks were observed from both images. The groove width was measured accurately about 15 nm, and the groove depth was about 1.1nm. Therefore, the AFM diamond tip with the radius of around 10 nm and the normal loads were several micro newtons was used to investigate the material removal mechanism of SiC, which were consistent with MD simulations in both length and load scales.

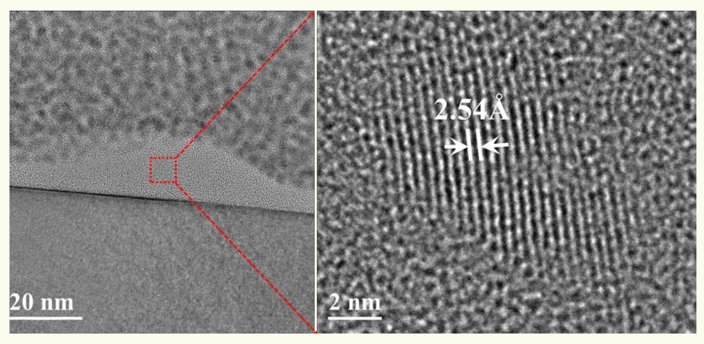


B. CHARACTERIZATION OF THE CUTTING CHIP.

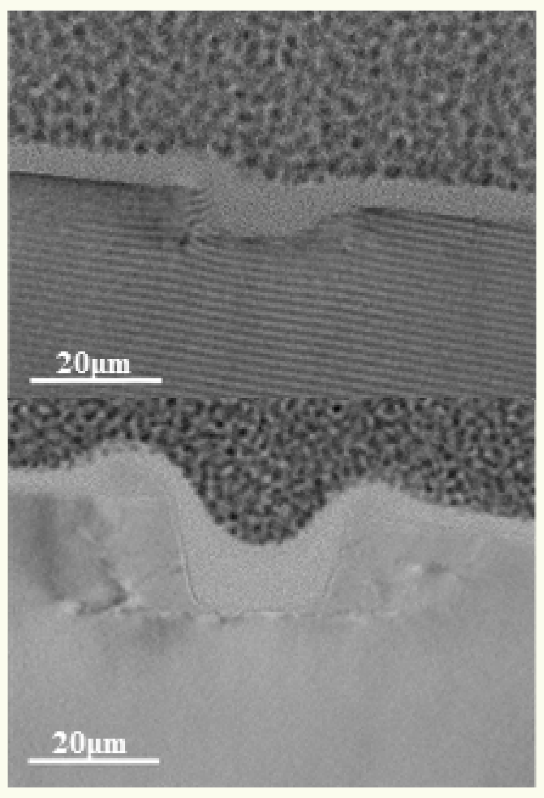


Long chips were still adhered on the apex of diamond probe. Under such a dimensional scale of cutting tool, material removal was attributed to cutting with continuous chips, i.e. that ductile-regime machining can be achieved when the depth of cut is about 1 nm.

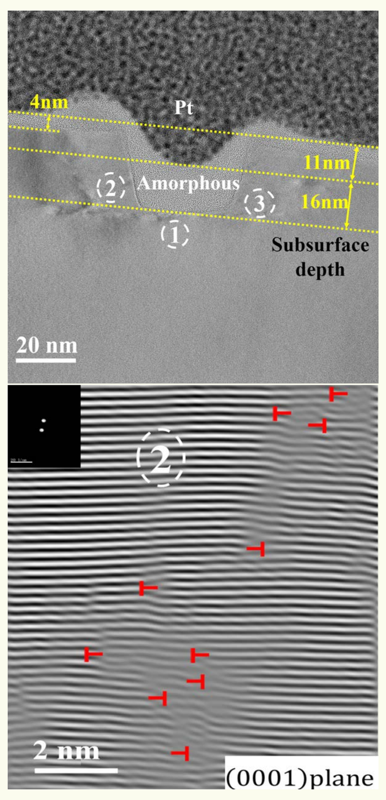
The generated chips were observed from TEM. Most atoms were fully amorphous structure. But partially incomplete deformed SiC single-crystal structure can be seen in the middle with a measured crystal plane spacing of 2.54 Å



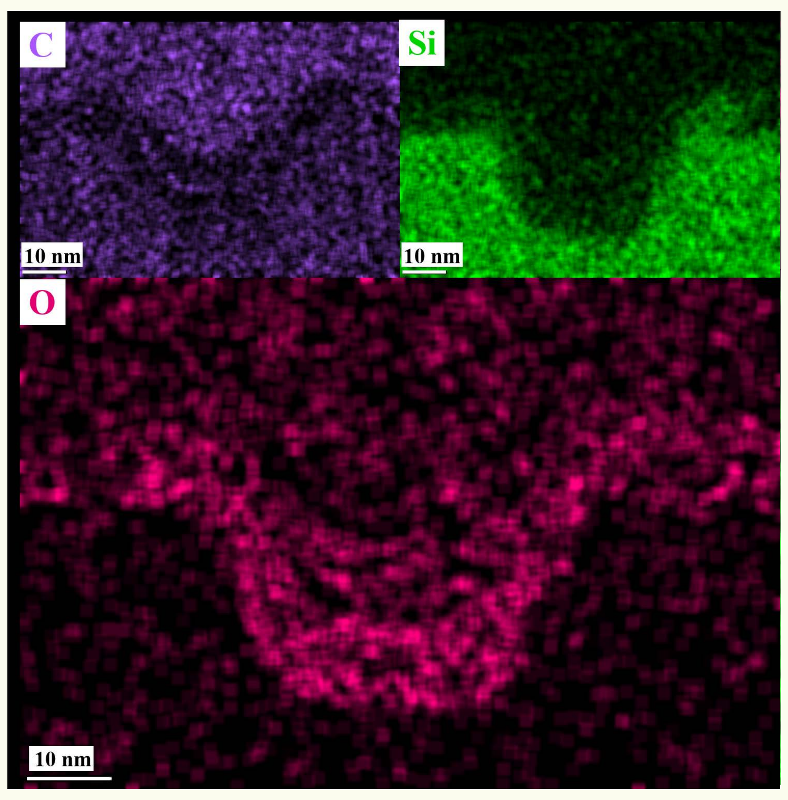
C. SUBSURFACE DEFORMATION MECHANISM.



Amorphous phase analysis:
The machined depth was less than the thickness of amorphous layer. Due to the amorphization in the monocrystalline SiC, the amorphous SiC would concentrate on the center of the indented region and extend to a deep depth.



Dislocation analysis:
No defects were seen from below the amorphous layer. But several scattered dislocations were at the corners of the groove, indicating that single-point cutting or mechanical polishing can achieve ductile and dislocation-free material processing at the atomic level.



The distributions of O and Si indicated that generated amorphous layer was mixture of amorphous SiO_2 and SiC.

CONCLUSIONS

- ✓ The material removal is in the ductile-regime when the depth of cut is about 1 nm.
- ✓ The microstructure of the chips is mostly amorphous phase.
- ✓ Plastic deformation of SiC is via amorphization with the mixture of amorphous SiO_2 and SiC in the region surrounding the diamond tip.
- ✓ Dislocation activities can rarely occur around the corner of the groove when cutting 6H-SiC, but this does happen with 4H-SiC. Thus, the material removal in both types of SiC is through the amorphization.
- ✓ The experimental results confirmed that the deformation of SiC reported by molecular dynamics analysis reflects the true mechanisms.

REFERENCES

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