Method to improve the effect of surface modification of RB-SiC mirror by SiC coating

Zhenfeng Shen (申振峰)

Key Laboratory of Optical System Advanced Manufacturing Technology, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun 130033, China

Corresponding author: zf_shen@163.com

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SiC coating for surface modification grows on reaction boned SiC (RB-SiC) substrate cannot have high quality because the material of RB-SiC has two phases. We apply a new method to improve the effect of surface modification. First the surface of RB-SiC is carbonized, and then a diamond like carbon (DLC) coating is prepared on it before the growth of SiC coating. Research and tests show that the SiC coating can grow denser and uniform because of the buffer function of the DLC coating, thus the effect of surface modification is improved. The roughness reduces from 1.397 to 0.478 nm (rms) after the surface modification using DLC buffer layer.

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The demand for high resolving power of large aperture space optical systems is becoming increasingly exigent along with the rapid development of space observation. Reaction boned SiC (RB-SiC) is a fine material for the substrate of large aperture space mirror, but the low surface optical quality restricts the application[1−6]. The effect of surface modification by SiC coating prepared of CVD method is well enough[7], but the effect by SiC coating prepared of large PVD equipment is not well. We have taken measures to improve the quality of SiC coating prepared on RB-SiC mirror based on our large PVD equipment so as to improve the effect of surface modification consequently, which can further improve the surface optical quality of RB-SiC mirror in space optical systems and satisfy the application requirements of high quality space optical systems.

There are several methods to fabricate the substrate of SiC mirror. The method of RB-SiC has the lower cost by contrast. Applying the international advanced technique of gel-casting, it can realize near net shape and much more fit for fabricating the substrate of complex lightweight structure large aperture space mirror[8,9]. So the material of RB-SiC has broad application prospects in the field of fabricating large aperture space mirrors.

A 100% dense SiC substrate can be made using RB method. But due to restrictions of preparation techniques, the material of RB-SiC generally has 10%–30% free silicon which affects the properties[10,11]. Figure 1 shows 500× photomicrograph of polished RB-SiC substrate. It can be seen that the material of RB-SiC mirror has two phases of components, the deep color parts are SiC and light color parts are Si. Figure 2 shows the surface atomic force microscope (AFM) photo of polished RB-SiC substrate. The result of surface roughness is 30.897 nm (rms). Because of the difference of polishing property, the removal rates of SiC and Si are different and it makes the defects on the surface after polishing[12]. The defects lead to a strong scattering of incident light and can greatly reduce the optical quality of the RB-SiC mirror.

We developed the surface modification by SiC coating on RB-SiC substrate based on large PVD equipment to improve the optical quality of RB-SiC substrate and make it satisfy the application requirements in space. First use ion assisted reactive evaporation (IARE) method to prepare a thick enough SiC modification coating, covering the defects on the surface, and then polish the modification coating so as to obtain a higher quality of optical surface. Figure 3 shows the surface AFM photo of RB-SiC substrate after surface modification. The result of surface roughness is 1.397 nm (rms). We can see that the surface optical quality of RB-SiC substrate is improved obviously, but we can also see big defects on the surface. The effect of surface modification is not perfect. Figure 4 shows the 500× optical microscope photo

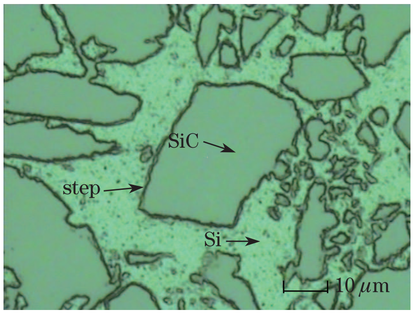

Fig. 1. 500× optical microscope photo of polished RB-SiC substrate.

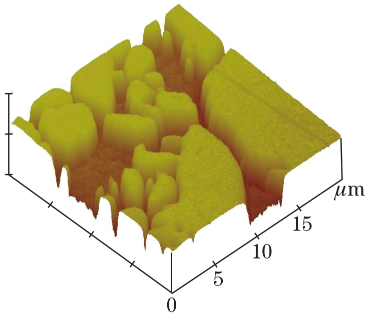

Fig. 2. Surface AFM photo of polished RB-SiC substrate.

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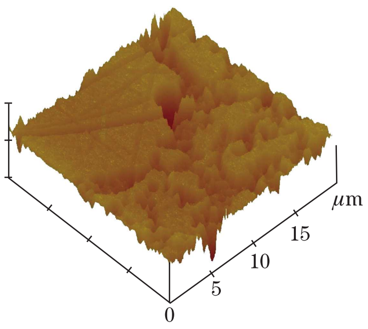

Fig. 3. Surface AFM photo of RB-SiC substrate after surface modification.

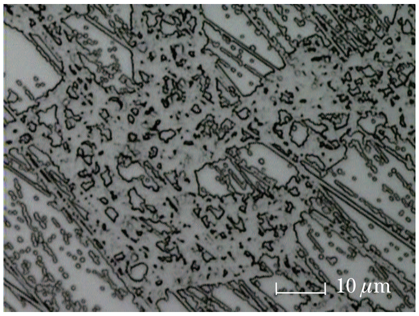

Fig. 4. 500× optical microscope photo of SiC coating on the RB-SiC substrate.

of SiC coating on the RB-SiC substrate. The coating grows neither densely nor evenly and the SiC grows on the SiC phase precede that on the Si phase. This causes the different polishing properties of different part on the surface and then leads to the defects after polishing.

Researches have shown that if we want to improve the performance of surface modification on RB-SiC, we need try to eliminate the preferred mode growth of SiC coating, thus the modification coating on the substrate can grow more densely and evenly. The property of polishing can be improved and higher quality optical surface can be obtained in this way. Considering both the material properties of RB-SiC and the preparation techniques of SiC coating, through many experimental researches, we find the method to improve the effect of RB-SiC surface modification by SiC coating.

Aim at the two-phase nature of RB-SiC substrate, we find the reasonable technique. The first is to carbonize the Si phase by ionizing CH_4 gas using high energy Kaufman ion source and make it changing into SiC component which is accordant with the SiC phase. The second is to prepare a diamond like carbon (DLC) buffer layer which can make the component of the surface identical on the two-phase material. This can help to eliminate the preferred mode growth of SiC coating. The last is to prepare the SiC coating on the DLC buffer layer using higher energy ion assisted method. This can make the SiC coating grows more densely and evenly. The structure of the coatings we prepared is shown in Fig. 5.

We prepared the DLC buffer layer on a Si (100) substrate for the purpose of making an effective property test. Figure 6 is the Raman curve of the buffer layer on Si (100) (curve 1). It can be seen that the vibration peak is not a single one. The Raman spectrum is decomposed analyzed. Actually it is superimposed by two peaks. One is at 1 332 cm^{-1} (curve 2) and the other is at 1 580 cm^{-1} (curve 3) which respectively correspond to the diamond phase characteristic peak (D peak) and the graphite phase characteristic peak (G peak). This character is just of DLC coating's. That is to say the buffer layer is a kind of DLC coating, and its component includes both Sp^3 bond and Sp^2 bond. DLC coating is a transition phase between the diamond (crystalline) phase and the graphite (amorphous) phase. This structure of DLC layer can help to relieve the imbalance of crystal lattice between RB-SiC substrate (crystalline phase) and SiC coating (amorphous phase). So it plays the role of a buffer layer.

Figure 7 shows the 500× optical microscope photo of SiC coating on the RB-SiC substrate using new technique. Compared with the SiC coating which prepared directly on the RB-SiC substrate, the coating grows more densely and evenly after the DLC buffer layer is prepared. We can hardly find preferred mode of growth. The decomposition products of CH_4 gas ionized by high energy Kaufman ion source can easily be transported to the surface of substrate. These active carbon groups can carbonize the Si component on the surface of the substrate at lower temperature and deposit to form the DLC coating under certain conditions. Because the nucleation on the surface is under low temperature, there are many grain boundaries in the DLC buffer layer and SiC coating which can help to relieve the mismatch between the

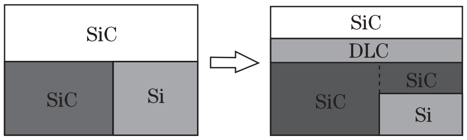

Fig. 5. Structure of the surface modification coatings.

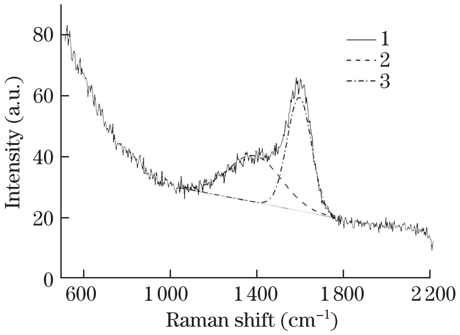

Fig. 6. Raman curves of the buffer layers on Si (100).

Fig. 7. 500× optical microscope photo of SiC coating on the RB-SiC substrate using the new method.

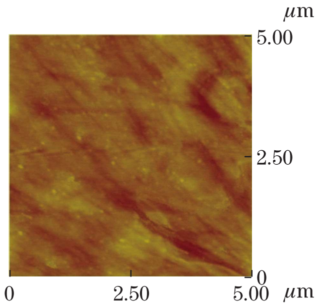

Image statistics

Img. Z range	6.840 nm
Img. Mean	−0.000001 nm
Img. Raw mean	546.11 nm
Img. Rms (Rq)	0.478 nm
Img. Ra	0.348 nm
Img. Rma×	6.840 nm
Img. Srf. area	25.002 μm^2

Fig. 8. Surface AFM photo of RB-SiC substrate after surface modification using the new method.

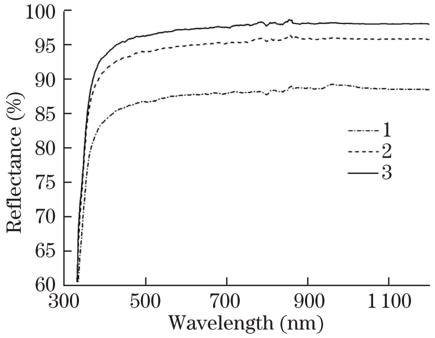

Fig. 9. Reflectance curves of the related substrates with Ag coatings.

two layers (crystalline phase and amorphous phase) and make the SiC coating for modification grow more densely and evenly.

Figure 8 shows the surface AFM photo of RB-SiC substrate after surface modification using new technique. The result of surface roughness is 0.478 nm (rms). Figure 9 shows the reflectance curves of the related substrates with Ag coatings. Curve 1 is the polished RB-SiC substrate; curve 2 is the RB-SiC substrate after surface modification without new technique; curve 3 is the RB-SiC substrate after surface modification using new technique. From the results we can learn that the surface roughness is effectively reduced and the reflectance of substrate is effectively increased after the applying of DLC buffer layer.

In conclusion, a DLC buffer layer is prepared before the deposition of SiC coating using the method of ionizing CH_4 gas by high energy Kaufman ion source in order to improve the effect of surface modification on RB-SiC substrate based on IARE method. The results of tests show that the DLC buffer layer plays the role of relieving the imbalance of crystal lattice between SiC coating and RB-SiC substrate. It makes SiC coating grow more densely and evenly and have better property of polishing. The surface roughness is effectively reduced and the reflectance of substrate is effectively increased. It is to say that using DLC buffer layer is an effective method to improve the effect of RB-SiC surface modification by SiC coating based on PVD equipment.

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