IOP Conf. Series: Materials Science and Engineering **307** (2018) 012028 doi:10.1088/1757-899X/307/1/012028

Fabrication of an ordered mesoporous nanoparticle SiO_2/Mc and their CMP of fused silica application

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Abstract. Here we developed an inorganic SiO_2 core/ mesoporous carbon shell structured (SiO_2/Mc) nano-composite particle with an average size ~50 nm as abrasives with improved dispersibility and distribution via a hydro-thermal route to obtain reserved fused silica surface and subsurface. The obtained SiO_2/Mc were characterized by scanning electronic microscope. Atomic force microscopy was used to assess the surface before and after planarization. The results indicated the as-prepared SiO_2/Mc composite abrasives gave a much lower surface roughness as well as lower topographical variations than that of traditional colloidal silica abrasives.

1. Introduction

Fused silica optic (FS) is one of the most important optical materials in the development of high-power laser systems. The laser induced damage threshold (LIDT) of FS, used in large high power laser facilities, has been an extensive research subject [1-2]. High surface/subsurface qualities are elementary required in most above mentioned applications. Thus, the final polishing step, remove surface and subsurface defects induced during grinding and lapping processes, is very critical. However, it is the very properties of FS render it as difficult-to-machine brittle materials. Currently, ceria particles are broadly adopted as abrasives to polish siliceous oxides glass for the high material remove rate (MRR), but it inevitably induces both of Ce contaminants and subsurface damages. Core/shell structured compositions, such as polystyrene (PS)/CeO_2 [3], PS/SiO_2 [4], polymethylmethacrylate (PMMA)/CeO_2 [5], and (PMMA)/SiO_2 [6], have shown an important potential as novel abrasives in efficient and damage-free polishing for their their uniform non-rigid mechanical property and spring-like effect. Nevertheless, most of the inorganic shell is not beneficial enough to improve its dispersibility and distribution which are crucial for a desired CMP performance. Thus, we developed an inorganic SiO_2 core/ mesoporous carbon structured nano-composite particle (SiO_2/Mc) as abrasives to obtain superior FS surface and subsurface.

2. Experiments.

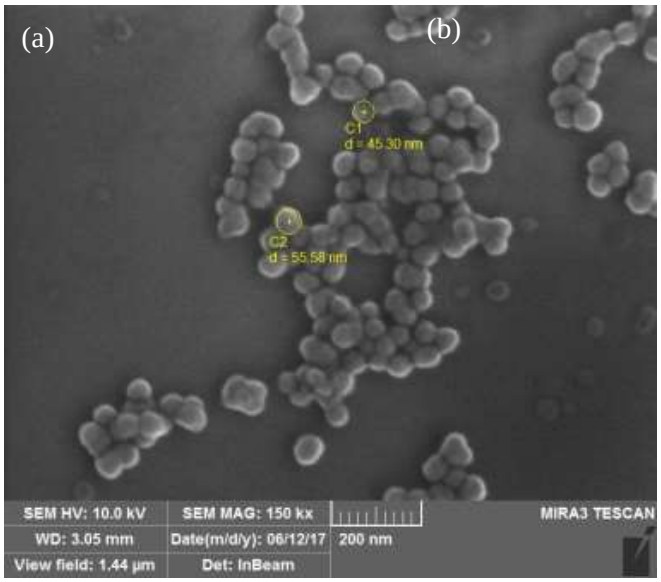
SiO_2/Mc synthetized via a hydro-thermal route. Phenolic resin and commercial triblock copolymer Pluronic F127 were used as carbon source and template, respectively. A field-emission scanning electron microscope (FE-SEM, TESCAN, Mira 3 Xmh) and High resolution transmission electron microscopy (HRTEM) measurement using a FEI TECNAI G^2 F30 at an acceleration voltage of 300 kV were performed to character the morphology and structure of the nano composited particles.

In this work, a FS wafer, with 100 mm in diameter and 5 mm in thickness, which had been preliminarily polished with ceria, was applied. The wafer was processed with different size of SiO_2 abrasives via a UNIPOL 1000S machine from *Kejing Co., Ltd* under the conditions of the pressure 64g/cm^2, slurry flow rate 20 mL/min, carrier plate rotating speed 50 rpm**.** After that, the wafer was cleaned by liquid cleaner and deionized water sequently, and then dried off by air spray. And the chemical mechanical polishing behaviors for FS were evaluated by atomic force microscopy (AFM).

3. Results and discussion

3.1 Characteristic of samples.

The morphology and structure of the obtained composites were characterized with FE-SEM and HRTEM, as shown in Fig. 1. Fig.1(a) displays a nano SiO_2/Mc composites with an average diameter of ~50 nm. The mesoporous structure can be detected by HRTEM shown in Fig.1(b).



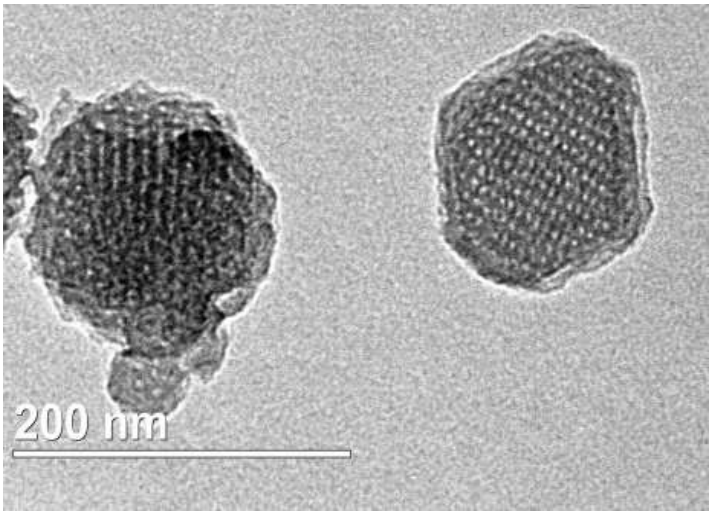
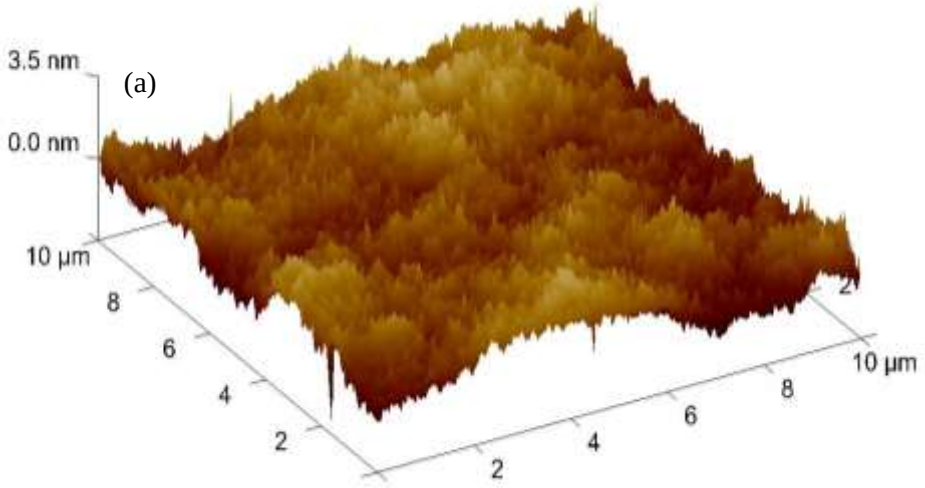


Fig.1 (a) SEM image, (b) TEM image of the SiO_2/Mc nanocomposites.

3.2 AFM measurements of polished surface

Fig.2 presented the typical 3-dimensional AFM morphologies of the FS wafer before and after polishing with SiO_2/M_c abrasive particles. As depicted in Fig.2 (a), the initial FS wafer presents a comparable rough surface with varied height hills, and the Rq roughness is 0.4 nm. While the Rq roughness is reduced to 0.08 nm after polished with SiO_2/M_c abrasive particles, as shown in Fig.2 (b). A quality of FS wafer surface polished with traditional SiO_2 abrasive as comparison, and the roughness Rq is about 0.16 nm.



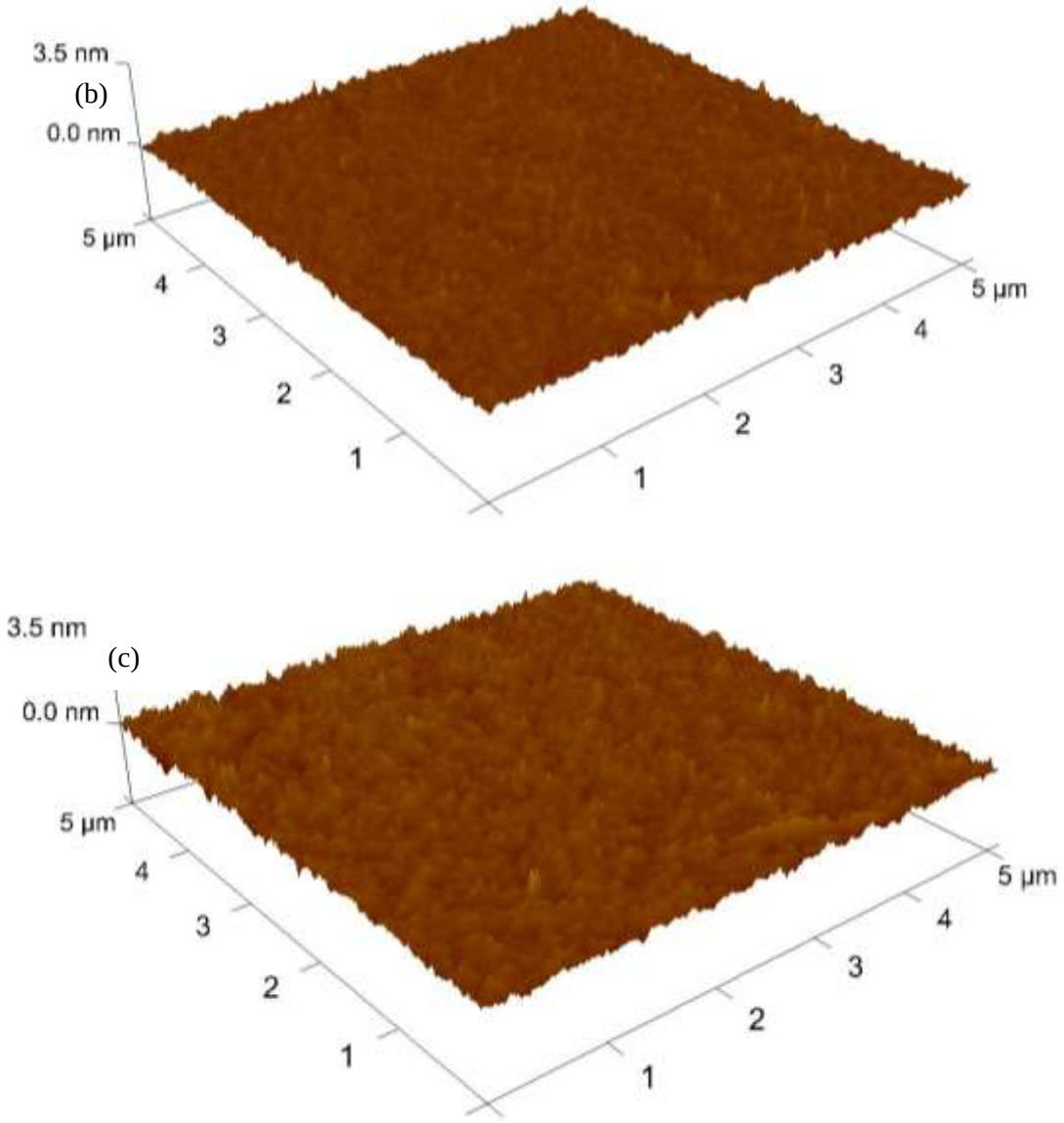


Fig.2 AFM morphologies of the FS wafer before (a) and after (b) CMP with SiO_2/M_c abrasive particles; (c) with traditional SiO_2 abrasives.

Acknowledgments

This work was supported by the Science Challenge Project (No. JCKY2016212A506-0504) and National Natural Science Foundation of China (No. 51675348).

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