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## Journal of Materials Science &amp; Technology

journal homepage: [www.jmst.org](http://www.jmst.org)

# Growth of SiC as Binder to Adhere Diamond Particle and Tribological Properties of Diamond Particles Coated SiC

Shengjie Yu<sup>1</sup>, Zhaofeng Chen<sup>1,\*</sup>, Yang Wang<sup>1</sup>, Shuwei Hu<sup>1</sup>, Ruiying Luo<sup>2</sup>, Sheng Cui<sup>3</sup><sup>1</sup> Super Insulation Composite Laboratory, College of Materials Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China<sup>2</sup> Center of Materials Physics and Chemistry, School of Physics and Nuclear Energy Engineering, Beijing University of Aeronautics and Astronautics, Beijing 100191, China<sup>3</sup> College of Materials Science and Engineer, Nanjing Tech University, Nanjing 211800, China

## ARTICLE INFO

## Article history:

Received 11 December 2014

Received in revised form

5 February 2015

Accepted 5 March 2015

Available online 14 July 2015

## Key words:

Diamond particle

LPCVD (low pressure chemical vapor deposition)

SiC

Tribological performance

The purpose of this work was to grow SiC as binder to adhere diamond particles to graphite substrate by low pressure chemical vapor deposition (LPCVD) at 1100 °C and 100 Pa using methyltrichlorosilane (MTS: CH<sub>3</sub>SiCl<sub>3</sub>) as precursor. The composite coatings on graphite substrates were analyzed by various techniques. Results show that a dense SiC coating with a cloud-cluster shape was formed both on the diamond particles and the substrate after deposition. The thermal stress (290.6 MPa) strengthened the interfacial bonding between the diamond particle and the SiC coating, which is advantageous for the purpose of adhering diamond particles to graphite substrate. The applied load of sliding wear test was found to affect not only the friction coefficient, but also the wear surface morphology. With increasing loads, the asperity penetration was high and the friction coefficient decreased.

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## 1. Introduction

Due to the incomparable performance of high hardness and excellent physical and mechanical properties, many kinds of diamond tools containing diamond particles such as wheels, core drills, saw blades, fret saws have become effective and indispensable tools in the processing of various hard materials<sup>[1]</sup>. Now, more and more diamond and diamond based composite coatings are used in different aggressive environments. One of the main factors affecting the service life and the performance of diamond tools is the adhesion between matrix materials and diamond. In the traditional manufacturing technology, diamond particles are embedded in the base matrix metal only by the mechanical clamping force resulting from the shrinkage of the matrix. Therefore, the bonding between matrix materials and diamond particles is weak to result in easy separation. In addition, for further use in industry, like cutting tools, core drills, anti-wear work pieces, etc., the tribological properties of diamond based composite coatings should be investigated.

By selecting effective methods and proper materials, we may improve the poor adhesion between diamond particle and matrix materials and increase the commercial value of the products. Ceramic hard coatings are of interest in a number of technological fields due to their physical, chemical and mechanical properties. They are capable of depositing advanced ceramic hard coatings of WC, TiN, TiAlN, TiC, CrN and SiC, which are generally recommended for providing protection against abrasion. Among these materials, SiC is a promising hard material for high bond strength to the substrate and excellent resistance to wear<sup>[2,3]</sup>. Hence, frequently, SiC, is used as a binding phase in diamond composites, which usually requires high pressure and high temperature conditions<sup>[4,5]</sup>. The use of silicon has been reported for conventional high-pressure sintering of diamonds and liquid infiltration method under high pressure and high temperature (HPHT) conditions to synthesize diamond-SiC composites<sup>[6,7]</sup>. However, the graphitization of diamond could hardly be avoided without metal additives during HPHT sintering. Up to now, the preparation of diamond composites coating was mainly focused on brazing and thermally spraying methods<sup>[8–12]</sup>. But in this paper, low pressure chemical vapor deposition (LPCVD) has been used to grow compact and reliable coating of SiC for adhering diamond particles.

\* Corresponding author. Ph.D.; Tel.: +86 18952018969; Fax: +86 02552112909.  
E-mail address: [zhaofeng\\_chen@163.com](mailto:zhaofeng_chen@163.com) (Z. Chen).

Methyltrichlorosilane (MTS:  $\text{CH}_3\text{SiCl}_3$ ) has been used as a SiC CVD precursor in the SiC CVD process<sup>[13–15]</sup>. Using MTS, SiC with the chemical composition is easily prepared because of the equal atomic amount of Si and C in its molecule. According to Naidich et al.<sup>[16]</sup>, transition elements of IV–VI groups and silicon have very strong chemical bonds with carbon, forming carbide layers with a rather permanent composition. The chemical reaction on the diamond particle surface during the depositing process can effectively improve the interface strength between diamond particle and SiC coating. The residual thermal stress at the interface can be produced due to the CTE (coefficient of thermal expansion) mismatch of diamond and SiC. This thermal stress can also strengthen the interfacial bonding between the diamond particles and SiC coating to some extent.

## 2. Experimental

### 2.1. Materials preparation

The SiC examined in this study was chemical vapor deposited at a temperature of 1100 °C. A commercial grade of monocrystalline, synthetic diamond particle (quality RVD, Henan HUAXING Diamond Industrial Co. Ltd., China) and high purity graphite were used as the deposition substrate. The substrates were hard-polished by using 500 grit SiC abrasive paper, then cleaned with ethanol at ultrasonic vibration meter and dried at 100 °C for 1 h. A single layer of diamond particles was evenly spread on the graphite substrate through a thin layer of cementing agent.

The as-prepared graphite substrates were hung in a vertical LPCVD apparatus (type: ZRGS-200). Schematic representation of the LPCVD apparatus is shown in Fig. 1. The vertical chamber is a graphite crucible with an inner diameter of 200 mm. The SiC coating was deposited on the as-prepared graphite substrates via LPCVD using MTS, argon (Ar) and  $\text{H}_2$ . The furnace was then heated to the desired temperature at a rate of 5 °C/min. After the setting temperature was reached, the deposition furnace was backfilled with Ar and  $\text{H}_2$  to stabilize the temperature for a while. Then MTS was carried to the depositing chamber by bubbling hydrogen gas. A typical hydrogen-to-MTS mole ratio used for deposition was 10. The velocity of flow was controlled with a mass flow controller and the temperature was controlled with a margin of error of  $\pm 2$  °C by programs. All the LPCVD SiC coating conditions are listed in Table 1. When the deposition process was finished, the MTS and  $\text{H}_2$  gas were shut down. Argon (Ar) gas was kept until the temperature in the chamber dropped to 400 °C. The LPCVD process resulted in the final samples consist-

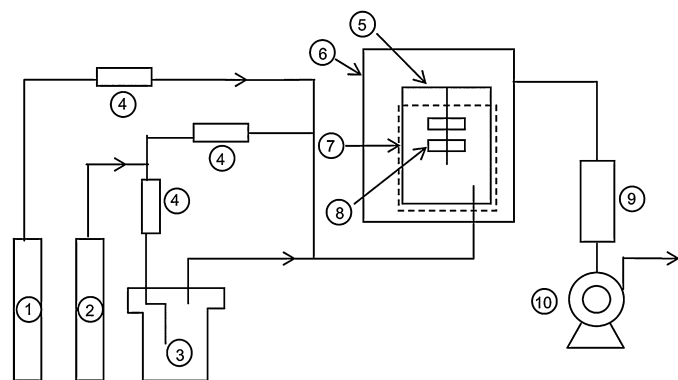


Fig. 1. Schematic representation of the LPCVD apparatus: 1—Hydrogen ( $\text{H}_2$ ) gas, 2—Argon (Ar) gas, 3—MTS, 4—Mass flow meter, 5—LPCVD chamber, 6—Stainless-steel jacket, 7—Graphite heating element, 8—Substrate, 9—Trap, 10—Vacuum pump.

Table 1  
Experimental conditions of the LPCVD SiC

Parameters	Unit	Value
Flow rate of hydrogen	mL/min	300
Flow rate of MTS	mL/min	30
Flow rate of argon	mL/min	300
Depositing temperature	°C	1100
Depositing pressure	Pa	100
Depositing time	h	10

ing of graphite substrates with a layer of SiC coating, in which the diamond particles were embedded.

After deposition, the morphologies and the wear surface features of the SiC coating with diamond particles embedded on the graphite substrates were observed by scanning electron microscopy (SEM, SU8010 Semi-In-Lens). The morphology of the pure diamond particle was also observed by scanning electron microscopy (SEM, JSM-6030LV). The thickness of the SiC coating also was directly measured by SEM. The phases of the diamond particles before and after depositing SiC were characterized by X-ray diffraction (XRD), which was carried out by using a D8 advance-X diffractometer with copper  $K\alpha$  radiation. The chemical composition of the interface between the diamond particles and the SiC coating was analyzed by energy dispersive spectroscopy (EDS, LINK-860).

### 2.2. Sliding wear test

A ball-on-disk machine (type: CFT-I) was used to determine the tribological performance of the coatings. A schematic illustration showing the test setup is given in Fig. 2. The upper specimen used as the counterface, with a diameter of 6 mm, was a standard GCr15 steel ball bearing with a hardness of 62–66 HRC and a surface roughness ( $R_a$ ) of 0.025  $\mu\text{m}$ . During the test, the ball experienced reciprocating sliding motion at an oscillating frequency of 2.0 Hz, with a stroke length of 10 mm. All the tests were conducted without lubrication at room temperature of 25 °C with different normal loads against the disk sample. The friction coefficient was evaluated using a tension–compression load cell mounted on the sliding wear rig and the friction coefficient and sliding time were both recorded automatically by programs during the test.

## 3. Results and Discussion

### 3.1. Microstructural characteristics of SiC coating

Fig. 3 shows the XRD spectra of diamond particles before and after depositing SiC. The XRD spectrum of diamond particles before depositing SiC showed a standard diamond phase. The XRD spectrum of diamond particles after depositing SiC showed only a dominating phase of  $\beta$ -SiC and a small fraction of  $\alpha$ -SiC (4H type)

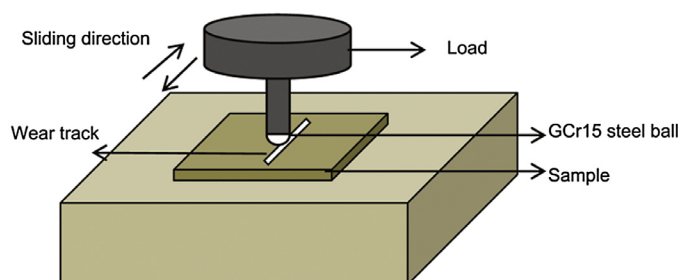


Fig. 2. Schematic illustration of the ball-on-disk test machine.

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