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Corrosion behaviour of silicon carbide–diamond composite materials in aqueous solutions

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Abstract

The corrosion behaviour of the relatively new silicon carbide bonded diamond materials (ScD) was investigated in NaOH, H_2SO_4 and hydrothermal conditions and compared with that of conventional SSiC and SiSiC-materials. The corrosion resistance increases with decreasing diamond grain size. In H_2SO_4 all investigated materials show a very high corrosion resistance, whereas in NaOH and under hydrothermal conditions above 100 °C some leaching of residual silicon takes place. Nevertheless the fine grained ScD material exhibits a residual strength of 400 MPa after 200 h corrosion in NaOH at 90 °C. Under the same conditions the strength of the SiSiC-material reduces to 50 MPa. The silicon carbide-diamond composites demonstrate corrosion resistance superior to SiSiC and wear properties analogous to that of conventional superhard materials. This material would therefore be suitable for use in demanding corrosive wear applications.

Keywords: Silicon carbide; Diamond; Corrosion; Sodium chloride; Sulphuric acid; Sodium hydroxide solution

1. Introduction

The commercial risks associated with the failure of critical wear parts dictate the use of wear resistant materials with low friction coefficients for a wide range of applications, including mechanical seal rings, bearings and nozzles. In high value applications these components are frequently manufactured from superhard diamond (PCD) or cBN (PCBN) materials. These traditional superhard materials are made using high-pressure high-temperature (HPHT) technologies and therefore geometric and cost constraints exist.[1] Hence, an intensive search for new cost-effective technologies based on powder metallurgy processes is the focus of many research groups world-wide. There are currently two approaches to producing superhard ceramic materials for demanding wear applications:

(1) covering the materials with superhard coatings[2,4,5] and
(2) the production of superhard composite materials.[3,7–9]

These superhard coatings can be nano- or polycrystalline diamond[4,5] or nanocrystalline coatings of other compounds e.g. TiN/Si_3N_4.[2] In applications where high loads are applied to the wear face and the wear is accelerated, monolithic superhard composites are preferred to coatings. Due to the metastability of both diamond and cBN, the densification of superhard composites under low pressure conditions can only be achieved if the hard phase is embedded in a ceramic matrix

An effective way to produce diamond composites with 30–60 vol% diamond content is the pressure-less reactive infiltration of diamond preforms with silicon. As a result, silicon carbide (SiC) is formed as the primary interlinking phase between the diamond particles.[3,7–9] Hardness values ranging from 27 GPa[9] to 47 GPa (HK2)[3] and a fracture toughness of 5 MPa m$^{1/2}$,[9] make these diamond composite materials suitable

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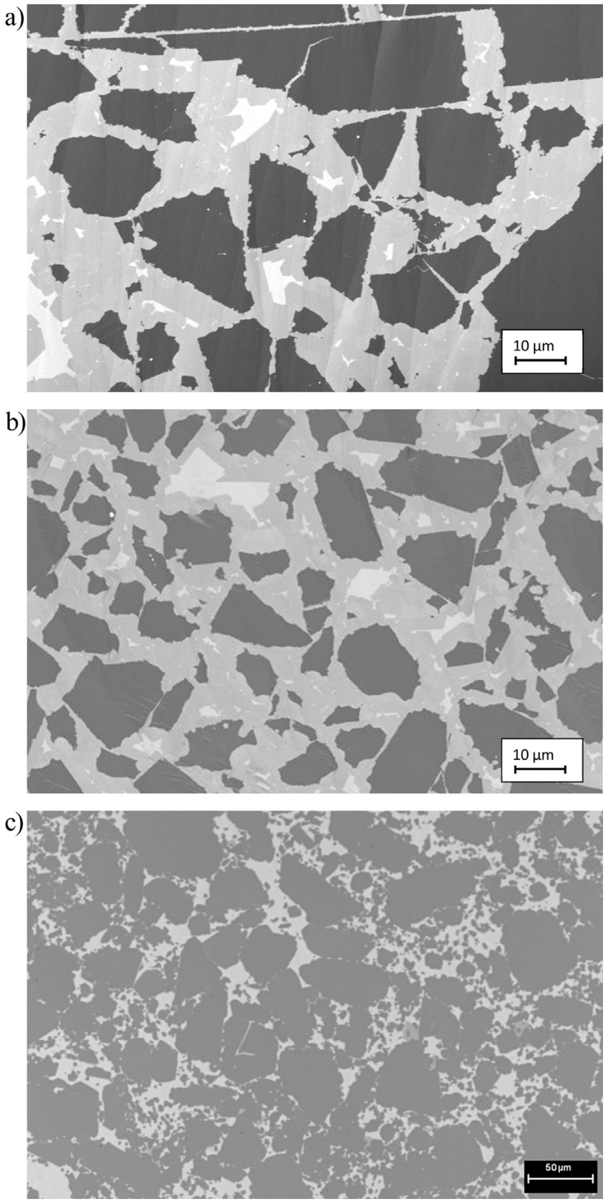

Fig. 1. FESEM micrographs of the materials (coarse grained (a), fine grained ScD (b) and SiSiC material (c); black phase - diamond; gray phase - SiC; white phase - Si).

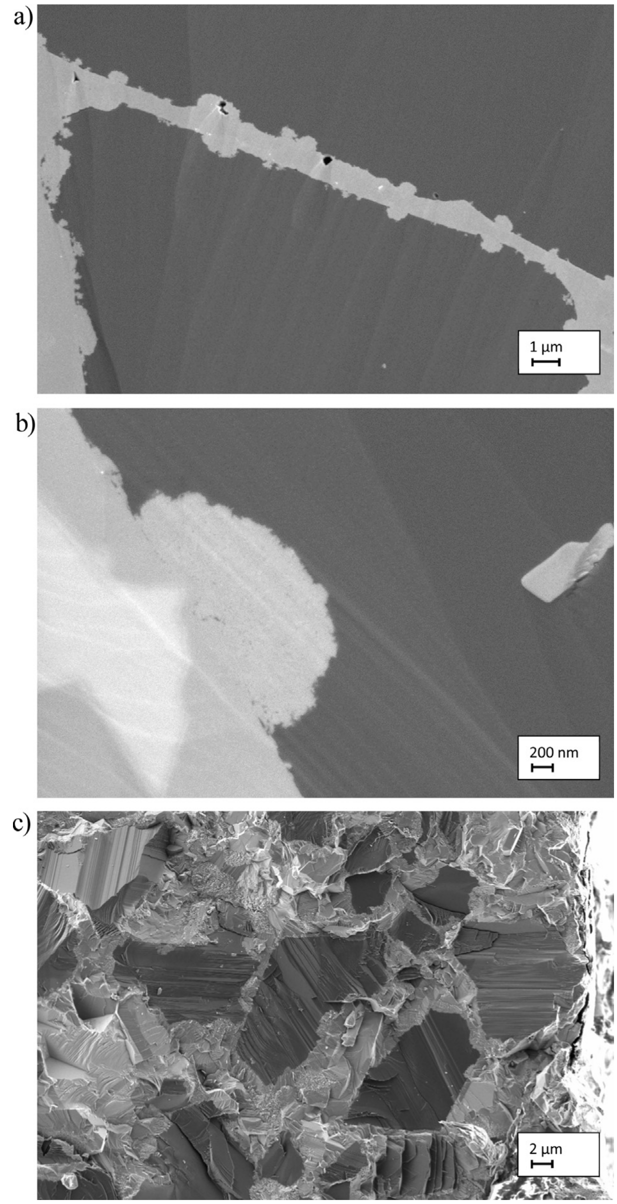

Fig. 2. Details of the ScD microstructure. (a) Infiltrated crack in the diamond (ScD-C). (b) Detail of the interface diamond-SiC (ScD-F). (c) Fracture surface of fine grained ScD (ScD-F).

for a wide range of demanding wear applications. A recent comparison of the wear performance of various materials confirmed that the wear rate of these diamond composites is significantly lower than that of conventional ceramics and that the rate of wear is controlled by the size and concentration of the diamond particles.[9,10]

In addition to the diamond and SiC phases, these materials contain small amounts of residual silicon (Fig. 1). Previous studies of SiSiC-materials have shown that the observed corrosion attack in basic solutions is attributed to leaching of the residual Si, whereas a high stability is observed in acid solutions.[11] No data exists concerning the corrosion stability of these relatively new silicon carbide-diamond composites. It is important to know whether the high hardness and wear resistance could be utilised in harsh chemical environments. Thus, the aim of this paper is to investigate the corrosion resistance of silicon carbide bonded diamond materials with varying diamond grain sizes.

2. Experimental

Three commercial SiC/Si/diamond composites – so-called silicon cemented diamond materials (ScD) from Element Six were studied. The material properties are dependent on both the diamond particle size and concentration (Table 1; Figs. 1 and 2). For comparison a commercial sintered silicon carbide (SSiC) material and a silicon infiltrated silicon carbide (SiSiC) material were used. The properties of these materials are given in Table 1. The ScD-materials exhibit superior hardness when compared to the SiC-ceramics, whilst the strength and fracture toughness of all the SiC based materials are similar (Table 1).