Materials Letters 219 (2018) 41–44

Contents lists available at ScienceDirect

Materials Letters

journal homepage: www.elsevier.com/locate/mlblue

Effect of V_8C_7-Cr_3C_2 nanocomposite on microstructure and properties of vitrified bond cBN grinding tools prepared by microwave heating method

Feixiao Chen, Hongjuan Zheng, Zhiwei Zhao *, Xiaomiao Zhao, Qiuling Chen, Shufang Mao

College of Materials Science and Engineering, Henan University of Technology, Zhengzhou 450001, China

A R T I C L E I N F O

Article history:
Received 30 November 2017
Received in revised form 9 February 2018
Accepted 13 February 2018
Available online 14 February 2018

Keywords:
Nanocomposites
Microstructure
Sintering
Microwave heating
Grinding tools

A B S T R A C T

V_8C_7-Cr_3C_2 nanocomposite was synthesized by an in-situ microwave heating method using nanometer oxides and nanometer carbon black as raw materials. The effect of V_8C_7-Cr_3C_2 nanocomposite on microstructure and properties of vitrified bond cBN grinding tools prepared by microwave heating method was investigated. The vitrified bond cBN grinding tool doped with 4.0 wt% nanocomposite presented an improved microstructure and possessed excellent properties. The fluidity and refractoriness of vitrified bond were increased and reduced by about 45% and 50 °C, respectively. Additionally, the bending strength and Rockwell hardness of vitrified bond cBN grinding tools were increased by about 4.6% and 9.3%, respectively.

1. Introduction

Superhard material cubic boron nitride (cBN) has attracted much attention due to its higher chemical stability and more excellent abrasion resistance than diamond at high temperature [1]. Moreover, thanks to its unique characters of low temperature vitrified bond such as controllable porosity, high elastic modulus, high level of resistance to wear, and easy dressing etc [2,3], vitrified bond cBN grinding tools become an increasing factor in grinding manufacturing industry. In comparison with metallic bond grinding tools, vitrified bond cBN grinding tools exhibit good self-dressing capability, controlled porosity, etc. Furthermore, they also have higher bond strength and thermal stability compared with resinoid bond grinding tools [4].

Even though cBN grain owns outstanding properties, its grinding performance, i.e. the removal rate of workpiece materials and the endurance of grinding tools, is still a great challenge to the high speed and high precision grinding manufacturing technology [5,6]. Extensive studies have been done on the improvement of vitrified bond by adding some oxides and metals [7,8].

However, the study on effect of nanocomposite on microstructure and properties of vitrified bond CBN grinding tools is important and still open. Vanadium and chromium carbides (V_8C_7-Cr_3C_2) nanocomposite exhibits a high specific surface area and activity, it can reduce the refractoriness of vitrified bond and the sintering temperature of vitrified bond cBN grinding tools. Furthermore, the nanocomposite possesses the excellent properties of nano vanadium carbide (V_8C_7) and nano chromium carbide (Cr_3C_2), such as high hardness and wear resistance, good toughness and oxidation resistance [9,10]. Therefore, their nanocomposite can enhance the strength and wear resistance of vitrified bond cBN grinding tools.

Microwave heating is a novel and effective heating technology with an instantaneously stable and excited electromagnetic wave energy transfer style [11,12]. Such heating method is uniform, rapid with high reaction rates and selectivity, it can dramatically reduce the reaction time, and gives a high product-yields [13,14]. In this study, effect of V_8C_7-Cr_3C_2 nanocomposite on microstructure and properties of vitrified bond cBN grinding tools prepared by microwave heating method was investigated.

2. Experimental

The basic vitrified bond is composed of talc, kaolin, sodium borate, fluorite and quartz, with the contents of 40 wt%, 10 wt%, 20 wt%, 8 wt% and 22 wt%, respectively. V_8C_7-Cr_3C_2 nanocomposite was firstly synthesized by an in-situ microwave heating method using nanometer vanadium pentoxide (V_2O_5), nanometer chromic oxide (Cr_2O_3) and nanometer carbon black as raw materials.

* Corresponding author.
E-mail address: zhiwei_zhao@haut.edu.cn (Z. Zhao).

https://doi.org/10.1016/j.matlet.2018.02.063
0167-577X/

Specific synthetic processes and characteristics of nanocomposite were addressed in our previous studies [15]. Vitrified bonds with different contents of V_8C_7-Cr_3C_2 nanocomposite (0 wt%, 2.0 wt%, 4.0 wt%, 6.0 wt%) were pressed into rectangular bars (32 mm × 6 mm × 6 mm) and cylindrical strips (Φ 10 mm × 10 mm) with temporary binder (polyvinyl alcohol). Then, the composites of vitrified bond cBN grinding tools were prepared by the homogeneous mixing of cBN grains, vitrified bond and temporary binder. Finally, the composites were cold pressed into rectangular strips (32 mm × 6 mm × 6 mm) and cylindrical bars (Φ20 mm × 10 mm). After being dried, the compacts were sintered in a multimode 2.45 GHz RWS microwave furnace (Zhongsheng Thermal Technology Co., Ltd., China) at different temperatures.

The structures of the nanocomposite and vitrified bond were analyzed by X-ray diffraction (XRD) using a Bruker D8 Advance diffractometer. Seger-cone and plane flowing methods were used to measure the refractoriness and fluidity of vitrified bond, respectively. WCP-2 microcomputer differential thermal expansion instrument (Beijing Optical Instrument Factory, China) was used to measure the average linear coefficient of thermal expansion (CTE) of vitrified bond. The mean bending strength of samples was tested on a universal tester (WDW-10, Ji'nan Chuanbai Instrument Equipment Co. Ltd., China). The Rockwell hardness (HRB) of cBN grinding tools samples was characterized by HR-150 Rockwell apparatus (Wu Zhong Material Testing Machine Factory, China). Scanning electron microscope (SEM, INSPECT F50, FEI Co., Ltd., USA) was used for observing the microstructure of vitrified bond cBN grinding tools.

3. Results and discussion

Fig. 1 shows the XRD patterns of vitrified bonds with different V_8C_7-Cr_3C_2 nanocomposite contents. As shown in Fig. 1(b)–(d), the peaks are identified as SiC (JCPDS 22-1301), $NaCa_2Mg_5AlSi_7O_{32}$ (JCPDS 41-1430), Ca_2SiO_4 (JCPDS 24-0034), α-quartz (JCPDS 65-0466), V_8C_7 (JCPDS 35-0786) and Cr_3C_2 (JCPDS 35-0804). The diffraction peak intensity of V_8C_7 and Cr_3C_2 basically increases with the addition amounts. The peak intensity of α-quartz increases firstly and then decreases with the nanocomposite content increment, and it reaches the maximum value for 4.0 wt%. The phenomenon is mainly caused by the network formation in the presence of V_8C_7-Cr_3C_2 nanocomposite, similar phenomenon has been reported [16].

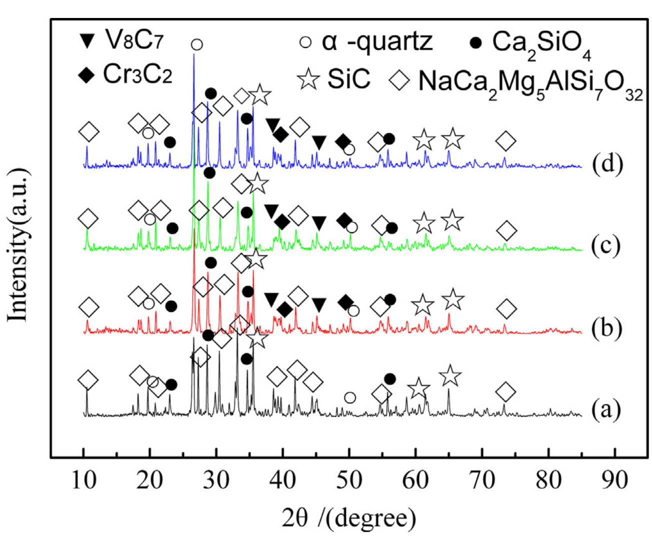

Fig. 1. XRD patterns of vitrified bonds with different V_8C_7-Cr_3C_2 nanocomposite contents: (a) 0.0 wt%; (b) 2.0 wt%; (c) 4.0 wt%; (d) 6.0 wt%.

Refractoriness is an important parameter in determining the softening temperature of vitrified bond, which plays a key role in the overall performance of grinding tools [17]. The fluidity is used for judging the flowing ability of vitrified bond, which is inversely proportional to viscosity. The mean refractoriness and fluidity of vitrified bonds with different amounts of V_8C_7-Cr_3C_2 nanocomposite are shown in Fig. 2. From Fig. 2, it can be seen that the refractoriness of vitrified bond with V_8C_7-Cr_3C_2 nanocomposite is lower than that of basic vitrified bond, and the refractoriness of vitrified bond decreases with the addition amounts. The refractoriness of vitrified bond reaches the minimum value of 700 °C for 4.0 wt%, showing a 50 °C lower than that of basic vitrified bond. Also from Fig. 2, addition of V_8C_7-Cr_3C_2 nanocomposite improved the fluidity of vitrified bond until the content exceeds 4.0 wt%. The best fluidity (158.8%) was achieved at this content, with 45% higher than that of basic vitrified bond (108.8%). This shows that a proper amount of nanocomposite can reduce the melting temperature and melt viscosity of vitrified bond, thus reducing the refractoriness and increasing the fluidity. Generally speaking, the lower the refractoriness, the higher the fluidity of vitrified bond will be [1,17]. Good fluidity is conducive to realizing an uniform distribution of vitrified bond around cBN grains and improving the holding force of the joint connection of vitrified bond to cBN grains [16,18].

Fig. 3 shows SEM images of vitrified bond cBN grinding tools samples with different amounts of nanocomposite (0 wt%, 2.0 wt %, 4.0 wt%, 6.0 wt%). Compared with the basic vitrified bond CBN grinding tool (Fig. 3(a)), the grinding tools with 2.0 wt%, 4.0 wt% and 6.0 wt% nanocomposite (Fig. 3(b)–(d)) show relatively compact structure with a homogeneously distributed cBN abrasive grains, due to the high fluidity of the composites. That is, the microstructure was changed by the nanocomposite as shown in Fig. 3(a–d). In Fig. 3(c) and (e), the sample with 4.0 wt% nanocomposite shows a homogeneous microstructure and cBN abrasives are uniformly coated by vitrified bond, suggesting that a proper amount of nanocomposite can reduce the refractoriness and improve the fluidity of vitrified bond.

Fig. 4 displays the bending strength and Rockwell hardness (HRB) of vitrified bond cBN grinding tools sintered at 850 °C for 40 min. As shown in Fig. 4, the bending strength of samples shows a similar behaviour like refractoriness, and it reaches the maximum value of 72.75 MPa for 4.0 wt%. The Rockwell hardness (HRB) of samples has a similar tendency to their bending strength. The maximum Rockwell hardness (HRB) of the sample is obtained (82.5HRB) at 4.0 wt%, which is 7.0HRB (increasing by 9.3%) higher than that of sample without nanocomposite (75.5HRB). The best

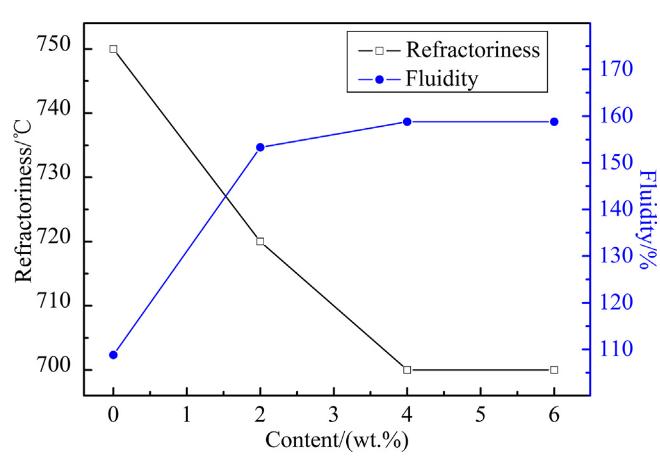

Fig. 2. Effect of V_8C_7-Cr_3C_2 nanocomposite on the refractoriness and fluidity of vitrified bonds.