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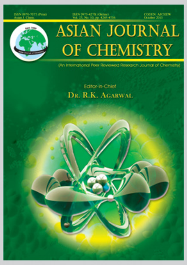

Metal Powder Applies to Vitrified Bond Diamond Abrasive

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Vitrified bond diamond abrasive was prepared by sintering diamond grains (3.5 μm) with low temperature vitrified bonds in air. In this work, Cu and Co were chosen as the additives to yield more gratifying abrasive. The fluidity and the wetting angle were investigated to characterize the flowing ability and wettability, mechanical property of samples were analyzed by means of single particle compressive strength and the interfacial bonding states between diamond grains and vitrified bonds were observed by scanning electron microscope (SEM). The results indicated that the properties of vitrified bond were meliorated by adding appropriate amount metal powder by which the mechanical property of diamond abrasive was promoted.

Key Words: Metal powder, Vitrified bond, Diamond, Abrasive.

INTRODUCTION

Diamond abrasive and grinding technology not only affect the traditional industries[1-3], such as machinery, automobiles, metallurgy *etc.*, but also affect the development of other high technology and industry, taking the new materials, aerospace and information technology, *etc*. The previous studies have proved that abrasive is still an important factor affecting the quality of grinding among various factors[4-6].

Because of the limited resource of natural diamond, diamond applied to abrasive is basically in the formation of synthetic diamond. Nowadays, synthetic diamond is synthesized by graphite[7]. However, this approach has its limitations, taking account of its disadvantages[8,9] (the preparation is fussy and the price is expensive). Besides, each diamond abrasive particle made by this way contains only a small number of diamond crystal grains (sometimes just contains one crystal grain). Therefore such diamond abrasive is difficult to meet the requirements of grinding performance. In order to improve the grinding performance of abrasive, it is urgent and necessary to find alternative method to prepare diamond abrasive. Under such conditions, a new type microcrystalline abrasive-vitrified bond diamond abrasive is put forward. Vitrified bond diamond abrasive is a kind of composite material, composed of micro-level abrasive and vitrified bond. Each particle of ceramic abrasive consist many small grains. Compared with the tradition diamond abrasive, vitrified bond diamond abrasive is superior in many ways[10], such as high grinding efficiency, good self-sharpening, low fracture toughness, good cutting capacity, cost-effective *etc*. During grinding process, the new abrasive located in the inner layer is exposed to continue grinding after small blunt particles broke off from the big particle. So vitrified bond diamond abrasive not only ensures the grinding efficiency, but also improves the grinding accuracy and surface quality of workpieces. At the same time, the service life of grinding tools is greatly enhanced, which is beneficial to reduce the cost of grinding. What's more, sintering at low temperature can save fuel costs, reduce the sintering cycle, improve the abrasive quality, reduce waste and prevent heat damage to the properties of abrasive. Therefore, vitrified bond diamond abrasive made by low temperature vitrified bond is becoming the focus nowadays.

In this work, basic Na_2O-B_2O_3-Al_2O_3-SiO_2 system vitrified bond, characterized with high strength and low melting, with different metal powder was prepared. The effects of types and amounts of metal powder on properties of low temperature vitrified bond and diamond abrasive are investigated.

EXPERIMENTAL

Preparation of vitrified bonds and diamond abrasive: Basic vitrified bond of Na_2O-B_2O_3-Al_2O_3-SiO_2 glass system was used to prepare vitrified bond diamond abrasive. The specific procedures are as follows. Ball milling the raw materials in order to obtain finely pulverized and completely blended powder. Then fired the mixed powder at 1300 ºC for 4 h and quenched the molten glass in cold water. Finally, after being dried, crushed and seized, basic vitrified bond was obtained. A part of basic vitrified bond was mixed with various different proportions of metal powder for comparison. The mass fraction of metal powder (in the formation of copper and cobalt) introduced into the basic vitrified bond are 2 wt. %, 4 wt. %, 6 wt. %, 8 wt. % respectively.

Green samples were prepared by mixing with diamond grains (the size of diamond grains is 3.5 μm) and vitrified bond. Then the powder was pre-pressed, crushed and seized to select abrasive grains with size between 60 mesh and 40 mesh. Then the samples were heated to the sintering temperature (800 ºC) in air, at the rate of 5 ºC/min, holding for 2 h at the sintering temperature and then naturally cooled to the room temperature.

Characterization of the vitrified bonds and their interfaces with diamond grains: The vitrified bond with and without the metal additives were uniaxially pressed into cylinders, which were sintered in an electric furnace used for measuring fluidity. Measurement of the wetting angle was obtained using high-temperature microscope (EM201) by applying the sessile drop method in air. The linear thermal expansion coefficient of the vitrified bond was determined with a high-temperature dilatometer (Netzsch DIL 402 C, Germany) in air at a heating rate of 5 ºC/min.

The strength of specimens was measured by single particle compressive according to ZMC-II type diamond static strength tester. The abrasive internal morphology, grain shapes and size distribution of the sintered specimens and the bond between diamond grains and vitrified bond were observed by scanning electron microscope (Phillips XL30E).

RESULTS AND DISCUSSION

Vitrified bonds' fluidity: The metal powder in the formation of copper and cobalt was imported into the basic vitrified bond with different content. As a general rule, the performance of vitrified bond abrasive was governed largely by the fluidity of the vitrified bond. Vitrified bond with appropriate fluidity was helpful to the achievement of the high intensity abrasive for the application concerned[11]. If the fluidity of vitrified bond was too small, the vitrified bond would not distribute between abrasive grains uniformly, which was harmful to produce a homogeneous structure of vitrified bond abrasive. Fig. 1 showed the fluidity of different vitrified bonds. It was obvious that both copper and cobalt were beneficial to improve the fluidity of vitrified bond, however, they affected the fluidity in different levers. From Fig. 1, it is clear that no matter whether copper or cobalt was introduced, the fluidity increased with the increase content of additive. In addition, it was obvious that the effect of copper on the fluidity of vitrified bond was larger than that of cobalt. When the addition of copper reached 8 wt. %, the fluidity increased by 39 %, while with the same addition of cobalt, the increase value of fluidity was 29.9 %. Consequently, the addition of metal powder could improve the fluidity of vitrified bond in different degree.

Vitrified bonds' wettability: The previous research has proved that vitrified bond with satisfying wettability can make sure that vitrified bond coated each abrasive grain entirely. As a result, wettability of vitrified bond was critical to the admirable vitrified bond diamond abrasive[12,13]. In this work, wettability was measured by wetting angle. The lower wetting angle vitrified bond, the better the wettability vitrified bond possessed. From Fig. 2, the wettability of basic vitrified bond was obviously affected by the different metal additives. It could be seen that the curves changed in the similar tendency, the wettability of vitrified bond increased with the increasing introduction of metal additive. According to the curves, it was shown that the wetting ability of vitrified bond containing copper and cobalt were better than basic vitrified bond.

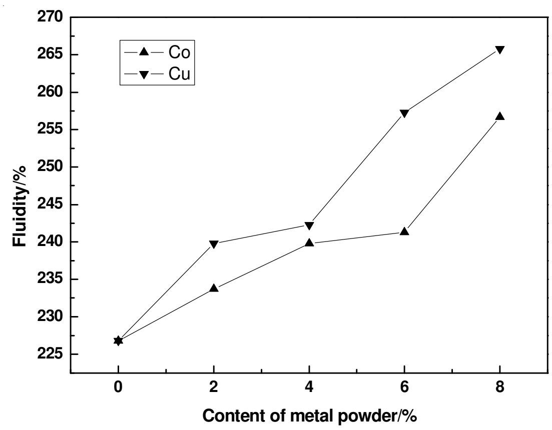


Fig. 1. Effect of kinds and amounts of the additive metal powder on the fluidity of vitrified bond

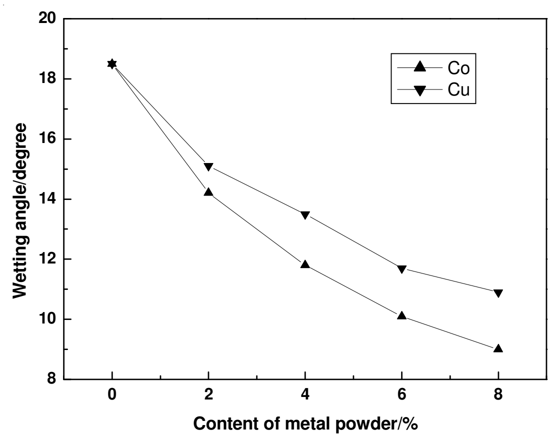


Fig. 2. Effect of kinds and amounts of the additive metal powder on the wettability of vitrified bond

Mechanical property: In this study, the single particle compressive strength of the samples with vitrified bond in diverse additives and mutative contents sintering at 800 ºC, holding for 2 h were shown in Fig. 3. The mechanical property of vitrified bond abrasive was distinctly influenced by the metal powder. As shown in Fig. 3 it could be seen that the kinds and amounts of metal powder had great influence on the single particle compressive strength of vitrified diamond abrasive. It was obvious that the optimal amount of metal powder no matter Cu or Co was 6 wt. %. That stated the only proper fluidity could had positive effect on the mechanical property of diamond abrasive. If the fluidity was too high, it had negative effect on abrasive. The abrasive got to the maximum value 2.5 N when 6 wt. % copper was mixed, while with the same addition of cobalt, the value achieved 2.2 N.

Microstructure analysis: Some diamond abrasive was observed using scanning electron microscope. Fig. 4A acquainted us with the central element of vitrified bond diamond abrasive (diamond grains, vitrified bond and pores).

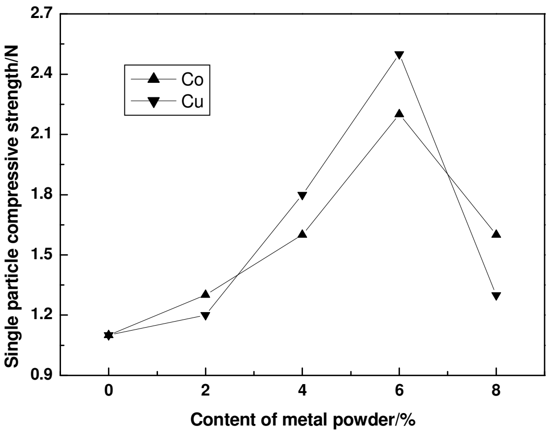
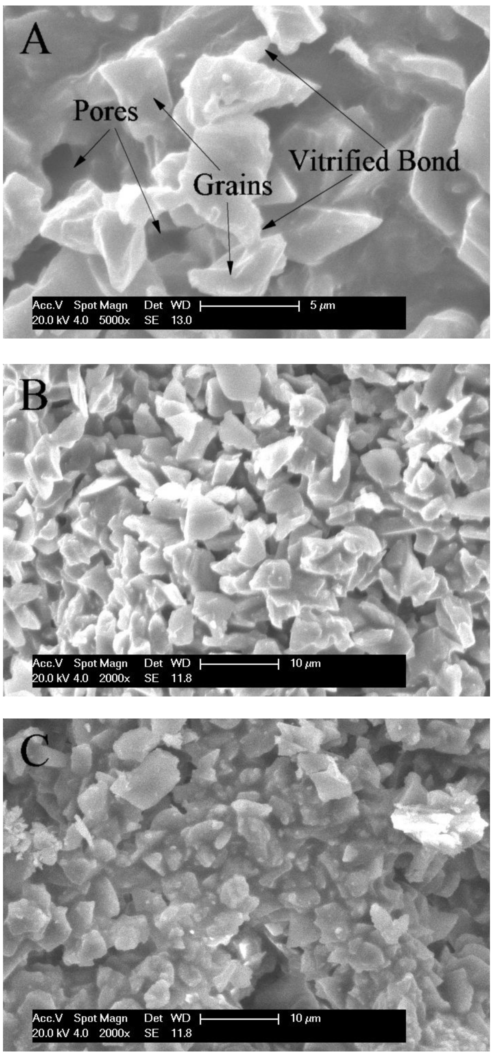


Fig. 3. Effect of kinds and amounts of the additive metal powder on single particle compressive strength of diamond abrasive

Fig. 4B-D displayed the scanning electron microscope (SEM) images of diamond abrasive sintered at 800 ºC for 2 h prepared by different vitrified bonds. As shown in image B, the unitary structure of abrasive was very loose and lacunose. The bond between the glass matrix and diamond grains was very weak and the glass did not cover the diamond grains fully. However, with the introduction of metal powder, the more identified structure of abrasive had been achieved. Compared C, D with B, it was obvious that the pores left after sintering



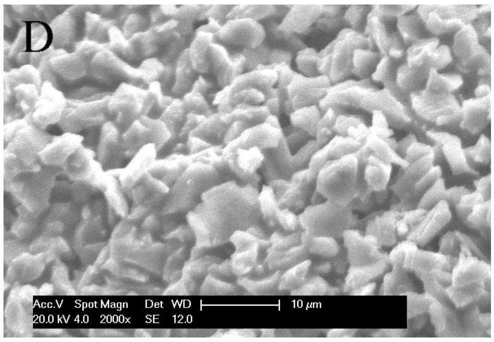


Fig. 4. Scanning electron microscope (SEM) images of diamond abrasive with different vitrified bonds B basic vitrified bond C vitrified bond with 6wt.% Cu D vitrified bond with 6 wt. % Co

were smaller and less. Besides, the diamond grains were more intimately covered by vitrified bond and the bond between the glass matrix and diamond grains was strengthened. All of these, exteriorly explained the reason why the mechanical property of abrasive was improved. In addition, it was also noted that there were some differences between C and D. As a whole, vitrified bond with copper powder covered the diamond grains more completely than that with cobalt.

Conclusion

In this paper, effects of kinds and amounts of the additive metal powder on the properties of vitrified bond and diamond abrasive were discussed. The experiment results were as follows: (1) The introduction of metal powder by means of copper or cobalt into low temperature vitrified bond for diamond abrasive, the more admirable vitrified bond with higher fluidity and the more adaptive wettability was obtained. Compared with the basic vitrified bond, the fluidity increased from 226.8 % to 265.8 % and the wetting angle decreased from 18.5º to 9º when the addition of copper was 8 wt. %; while the increasing value of fluidity was 29.9 % and the decreasing value of wetting angle was 7.6º when the amount of cobalt was 8 wt. %. (2) With the addition of metal powder in basic vitrified bond, the single particle compressive strength of diamond abrasive was enhanced in the same sintering process. The maximum value of abrasive mechanical property was 1.4 by adding 6 wt. % copper. Meanwhile, the single particle compressive of diamond abrasive got to 2.2 from 1.1 when the amount of cobalt was 6 wt. %.

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