Preparation and Coefficient of Friction of YBa2Cu3O7-δ/Graphene Oxide Composites

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ABSTRACT

YBa2Cu3O7-δ/graphene oxide (YBCO/GO) composite materials were fabricated by using powder metallurgy process combined with cold isostatic pressing (CIP) technique. The coefficient of friction (COF) of YBCO matrix composites with addition of 0, 0.5, 1.0 and 2.0 wt% GO were reported for the first time. The friction behavior was observed by means of the ball-on-disk technique with a steel ball used as the counterpart in ambient atmospheric and dry sliding condition. The measured properties were then assessed with respect to sliding speed and the mass fraction of the GO additives. GO is able to reduce COF and brittleness for YBCO ceramic. The excellent performance offers materials with 0.5 wt% GO, which has the lowest COF and lightest wear track.

KEYWORDS

Coefficient of Friction, Cold Isostatic Pressing, Composites, Graphene Oxide, YBa2Cu3O7-δ

INTRODUCTION

Compounds Ceramic materials have outstanding properties, such as low density, lower coefficient of friction (COF), low thermal expansion, high corrosion resistance and high hardness over a wide range of temperature. Because of these advantages of ceramic materials, their usages are increasing in wide applications. Thus they are promising candidates for wear-resistant components, especially under severe conditions. Many applications using the superconductor ceramic materials have been realized: magnetic applications such as levitation (flywheel) and transport applications (current transport and fault current limiter) (Ding, 2008). The superconducting transition temperature of pure metal is very low (in liquid helium), therefore, there is no utility value. The superconducting transition temperature of high temperature superconducting compounds YBa2Cu3O7-δ (YBCO) is above 90 K, which can be realized at liquid nitrogen temperature. Therefore, it has strong theory and utility value to study the tribological property of high temperature superconducting ceramics (Yue, 1993). The solid lubricating materials should work long term effectively in a wide temperature range. YBCO belongs to oxide ceramics and has good tribological property at high temperatures above 600°C, but its ceramic brittleness and tribological property need to improve at room temperature (Grossin, 2005).

One of the merging self-lubrication materials is graphene, which has received significant attention due to its combination of remarkable mechanical, thermal, chemical, electrical, and recently, graphene has also shown great promise in tribological applications (Penkov, 2014; Berman, 2013). Weak van der Waal force between the 2D layers results into easy inter-layer sliding in multilayer graphene, leading to reduction in coefficient of friction (COF). This unique feature has motivated researchers to evaluate the potential of graphene in tribological applications. Also, the lubrication behavior of graphene is retained in harsh environment exposed to space irradiation, making it suitable for applications in out
space (Harshal, 2014; Shah, 2015; Yi, 2013; Peng, 2013). Graphene nanoplatelets (GNPs) are excellent nanofiller for enhancing the tribological performance of ceramics. Under high contact pressures, GNP is able to reduce friction and increase the wear resistance (Belmonte, 2013; Fan, 2010; Jan, 2014; Harshit 2014; Seiner, 2013; Hvizdo, 2013). As derivatives of graphene and possessing the same lamellar structure as graphene, Graphene oxide (GO) has also been investigated with respect to their tribological properties (Kim, 2015; Hang, 2015; Geetha, 2014). Wang et al. (Wang, 2012) have investigated the atomic-scale friction in GO using density functional theory calculation including dispersion corrections and revealed a strong dependence of friction on the interfacial interactions between GO layers, which can be tuned by structural and chemical modifications. Graphene-based materials with controllable friction could potentially find wide applications in nanolubrication in micro- and nanoelectromechanical systems (Yang, 2015).

Unfortunately, only a few attempts have been done to investigate or improve the tribological properties of YBCO compounds. Yue et al. (1993) have investigated the coefficient of friction of YBCO-YBCO and YBCO-Ag ball-on-flat couples and found the stable coefficient of friction of YBCO in the steady state varies from 0.9 to 0.26 and from 0.8 to 0.26 depending on temperature for a constant load of 2.2 N and speed of 0.020 or 0.013m/s corresponding to YBCO and Ag couples, respectively. Ding et al. (2001) have investigated the tribological properties of YBCO film in ambient environment and the results showed that the friction coefficient of YBCO films was lower and more stable than that of polysilicon films when sliding against a sapphire ball or a steel ball. Ding et al. (2008) have studied the mechanical and tribological properties of YBCO/Ag composites and found Ag particle in matrix improved the mechanical and tribological properties of YBCO.

In addition, cold isostatic pressing (CIP) is a key stage in many synthesis processes, not only to manufacture products such as ceramics, intermetallics, metals, but also pharmaceutical products, and most of the densification of these materials occurs during this stage, as opposed to sintering. (Aakasmas, 2011; Galusek, 1999) Moreover, CIP was used as a physical method to optimize material properties (Peng, 2013). Zhang et al. (2011) improved the micro-structure and dielectric properties of Ba0.6Sr0.4TiO3 film by CIP treatment. Mahesh et al. (2014) enhanced dielectric and ferroelectric properties of lead-free Ba(ZrTi)O ceramics compacted by CIP.

In fact, to the best of our knowledge, the tribological performance of YBCO/GO composites has not been reported hitherto. The YBCO/GO composite bulks were prepared by powder metallurgy combined with CIP technique. The addition of GO was expected to improve the brittleness and tribological properties of YBCO ceramics. Therefore, this work analyzes for the first time the COF of YBCO/GO composites. Unlubricated rotating ball-on-disk configuration is used in order to explore their tribological properties in ambient atmospheric condition.

**EXPERIMENTAL**

The YBCO powders were prepared using conventional solid state reaction technique, with Y2O3 (A.R.), BaCO3 (A.R.) and CuO (A.R.) powder. GO was prepared from pristine graphite via the modified Hummers’ method (Hummers, 1958). The synthesized YBCO powders and GO were accurately weighed in the appropriate amounts to give nominal composition of 100 wt% YBCO and x wt% GO (x = 0, 0.5, 1.0, 2.0). The corresponding final products were labeled as YBCO-xGO. The powders containing YBCO and GO were thoroughly mixed in an agate mortar 0.5h by bad grinding and then were perforemed into disks in high carbon steel mould at 60 MPa without any extra binder. After being respectively sealed with plastic film and bags, the above disks were further compacted by adopting CIP technique at a pressure of 250 MPa for 2 min at room temperature (isostatic press machine, KJYs 150-300, SHXI GOLDEN KAIYUAN CO., LTD) and subsequent calcined at 800 °C for 1 h under nitrogen atmosphere. Heating rates was chosen as 10 °C /min and naturally cooled to room temperature. The sintered disk specimens were polished on abrasive paper (W5 (06)) and YBCO/GO composites bulk specimens (diameter of about 25 mm, thickness of about 4 mm) were prepared successfully.
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