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Short communication

Surface coating copper powder with carbon nanotubes using traditional and stirred ball mills under various experimental conditions

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ABSTRACT

We investigated the effect of the raw powder properties of carbon nanotube surface coatings on metal powder, with the goal of obtaining high-quality nanocomposites. The mechanical dry coating technique was used to fabricate CNT coatings (guest particles) on the surface of copper (Cu, host) particles using a traditional ball mill and a stirred ball mill. The coatings were produced under various experimental conditions (varying rotation speed and grinding duration, with a ball diameter of 5 mm), and the effect of these conditions on the surface of the powder was determined. The coated surfaces were characterized using scanning electron microscopy and field emission scanning electron microscopy. We compared prolonged milling (48 h) at a low rotation speed (50 rpm), with a short milling period (12 h) at high rotation speed. We found that for the TBM, successful CNT coating was achieved at 50 rpm over 48 h. In contrast, for the SBM, CNT coatings were obtained after a short milling period (12 h) at low rotation speed (50 rpm).

Introduction

In the past few decades, the surface properties of metal matrix nanocomposites produced by coating particles have been extensively investigated (Kim, Park, & Lee, 2013; Kim, Satoh, & Iwasaki, 2003; Chen et al., 2003; Roman'kov, Sagdoldina, Kaloshkin, & Kaevitser, 2008). The dry particle coating process allows tailored modifications of host particle properties in the production of these nanocomposites. Coating fine guest particles onto the surface of host particles is achieved through mechanical forces, such as shear and impact forces generated during the milling process (Serris et al., 2013; Sato et al., 2013). Recently, the dry particle coating process has received increased attention, owing to its lower negative environmental impact and potential cost effectiveness, compared with other coating processes. In addition, dry particle coating processes have been mechanized in the interest of reducing the cost, energy consumption, and time involved. Dry coating is an essential process in many industries, including powder metallurgy, metal injection molding, and solder paste design (Kim et al., 2003; Serris et al., 2013; Sato et al., 2013).

New applications of ball milling, for example, mechanical coating, have recently been reported. The metal or alloy powders are able to adhere to the surfaces of ceramic or metal grinding media, owing to the repeated collision, friction, and abrasion that occurs during the mechanical coating process (Hao, Lu, Sato, Asanuma, & Guo, 2013; Hao, Lu, Sato, & Asanuma, 2012; Pouriamanesh, Vahdati-Khaki, & Mohammadi, 2009). Hao et al. (2012) investigated the Zn coating of Al_2O_3 balls. In that work, the coatings and their evolution during the process were characterized. The authors found that the evolution of the coatings was significantly enhanced at high rotation speeds, owing to the increased collision strength or collision power associated. The fabrication of Zn coatings using a ball mill indicates that mechanical coating is a promising technique for modifying the surface conditions and improving various surface properties of materials (Hao et al., 2012).

Several metal/carbon nanotube (CNT) nanocomposites have been fabricated using the ball milling process (Liu et al., 2012;

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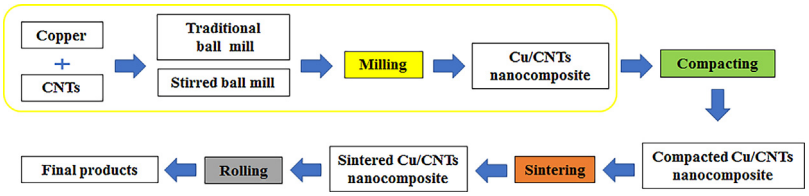

Fig. 1. Experimental scheme used in this study.

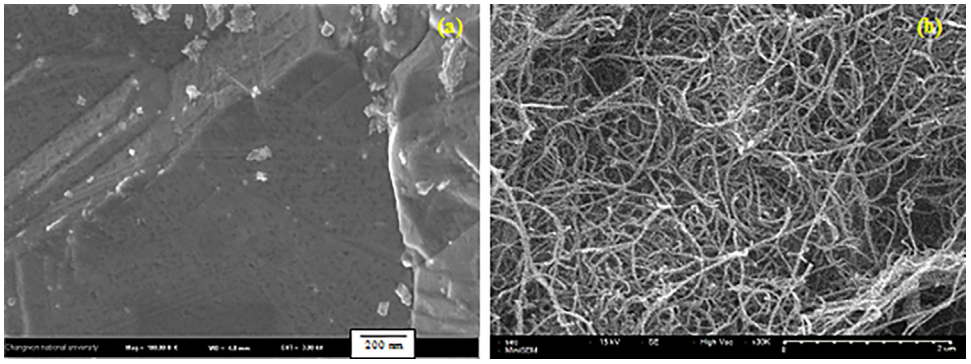

Fig. 2. FESEM micrographs of the (a) pure Cu and (b) MWCNT starting materials used.

Yoo, Han, & Kim, 2013; Choi, Wang, Cheon, & Lee, 2013; Uddin et al., 2010; Carvalho, Miranda, Soares, & Silva, 2013). However, CNT coating of individual particles for the development of high-quality products remains unexplored. Since the pioneering work of Iijima on the synthesis of CNTs in the early 1990s (Iijima, 1991), CNTs have generated considerable interest, owing to their small size, high aspect ratio, low mass, and excellent mechanical, electrical, and thermal properties (Puchy et al., 2013; Wang et al., 2003). New CNT-containing coatings offer enhanced strength and corrosion resistance. Fig. 1 shows a schematic of the Cu/CNT nanocomposite fabrication process (highlighted) based on the powder metallurgy method.

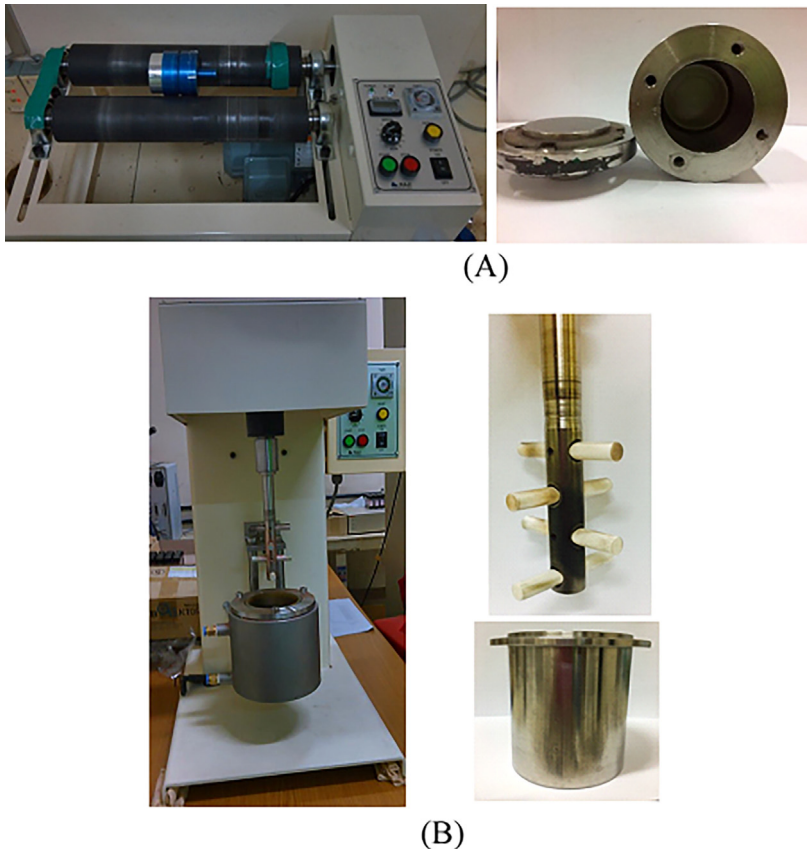

Fig. 3. Photographs of the (A) traditional ball mill and (B) stirred ball mill (HAJI Engineering, Korea) used.

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