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Short Communication

Fabrication of hollow nickel micro-spheres with high degree of hollowness by silicon powder-mixed spark erosion

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ABSTRACT

For the purpose of developing a simple, fast and low cost method to fabricate the hollow nickel micro-spheres, the hollow nickel micro-spheres with high degree of hollowness were fabricated by silicon powder-mixed spark erosion (SPMSE) in the present paper. Morphologies and loose packed densities of hollow nickel micro-spheres fabricated by the SPMSE and conventional spark erosion (CSE) respectively were studied. The results showed that the hollow nickel micro-spheres fabricated by the SPMSE are bigger and exhibit higher degree of hollowness as compared to the CSE. It is expected that the powder-mixed spark erosion can fabricate hollow nickel micro-spheres with satisfactory particle size and hollowness through adjusting the particle size of silicon powders and machining parameters, even selecting other kinds of semi-conductive or conductive powders. In addition, the powder-mixed spark erosion can also fabricate other kinds of hollow metallic micro-spheres.

1. Introduction

In recent years, there has been growing interest in fabricating hollow nickel micro-spheres because their unique properties are different from solid nickel micro-spheres, i.e. large specific surface area, low density and interesting optical properties [1–9]. The hollow nickel micro-spheres were mainly fabricated by the method of template precursors so far [5–9]. However, this method is not only complicated, but it is also difficult to remove the template precursors. Recently, Berkowitz et al. [10–11] succeeded in manufacturing hollow nickel micro-spheres using the adopted spark erosion equipment in liquid nitrogen. Unfortunately, the adopted equipment is rather complicated and the cost of production is high. Note that their research developed a new idea to fabricate the hollow nickel micro-spheres. For the purpose of overcoming the limitations of the above technologies, a simple, fast and low cost method silicon powder-mixed spark erosion (SPMSE) was developed to fabricate the hollow nickel micro-spheres with high degree of hollowness in this paper.

2. Principle of fabricating hollow nickel micro-spheres by silicon powder-mixed spark erosion

Spark erosion is the foundation of electric discharge machining (EDM), by which the desired shape can be machined. During the EDM process, the ejected metals solidify into micro-spheres in the dielectric fluid. In the case of conventional spark erosion (CSE), the dielectric fluid is a single and insulating medium, and thus the energy of every spark is high and concentrated. As a result, most of the ejected metals become large molten droplets while a very limited amount of the ejected metal is gasified [12]. When the ejected molten droplets contact with the dielectric fluid, their surfaces solidify first and their centers solidify subsequently. As a result, shrinkage cavity or porosity forms in the center of the solidified spheres [13], as seen in Fig. 1. Accordingly, the shrinkage cavities or porosities, resulting from the solidification of molten droplets, present in the center of spheres fabricated by the CSE. Note that these spheres exhibit low degree of hollowness because the size of shrinkage cavities or porosities is rather small.

Powder-mixed dielectric electric discharge machining (PMD-EDM) is one of the recent innovations to improve the surface finish of the work-piece [14–17]. For the PMD-EDM, semi-conductive or conductive powders are added into the dielectric fluid to increase the number of discharge point. As a result, the energy of every spark decreases and the mass of metal eroded by each spark decreases. Hence, the size of the molten droplets remarkably decreases [14–17]. These ejected small molten droplets would be easily adsorbed on the surface of the small bubbles, which are formed due to the high temperature of the discharge channel in the dielectric fluid. These small molten droplets solidify and form hollow spheres as seen in Fig. 1(b). If the amount of small droplets is not enough to cover the bubble completely, some holes would present on the surface of the spheres. Such forming mechanism is

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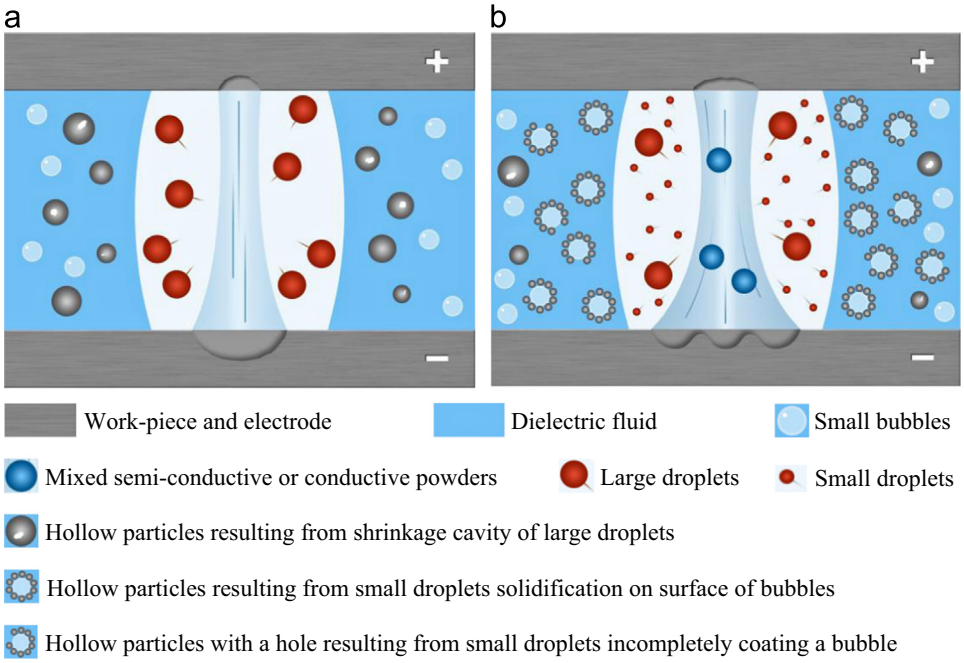

Fig. 1. Physical models of discharge and solidification process of molten metal in the convention spark erosion (a) and the powder-mixed spark erosion (b).

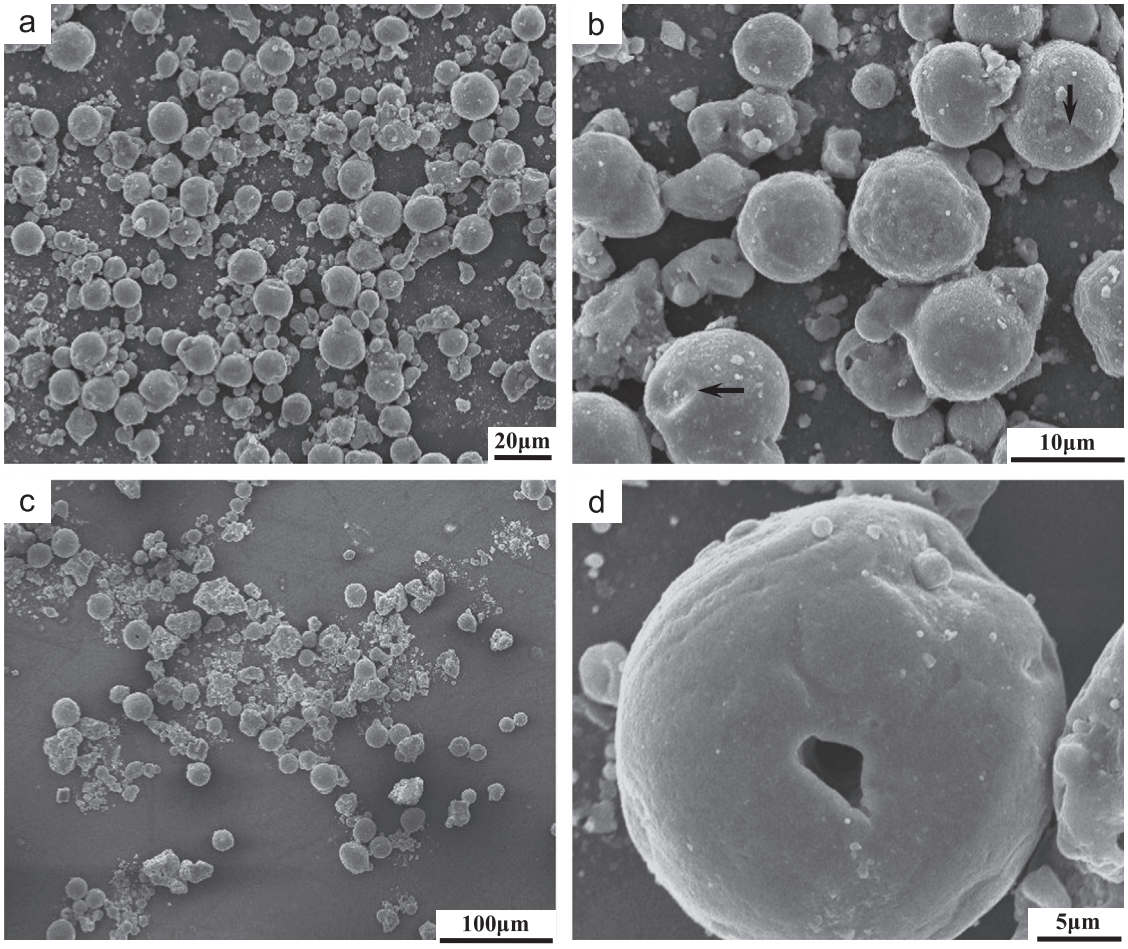

Fig. 2. SEM micrographs of nickel particles fabricated by the CSE (a) and (b) as well as by the SPMSE (c) and (d).

difficult or even impossible by conventional EDM because their molten droplets are too large to be adsorbed on the surface of small bubbles. Based on the above analysis, this paper proposes a new method for the fabrication of hollow nickel micro-spheres with high degree of hollowness by silicon powder-mixed spark erosion.