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Assembly of magnetic microcomposites from low pH precursors using a novel micro-fluidic-jet-spray-dryer

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ABSTRACT

Spray drying is a convenient method to produce particles in high yields within a short period of time. The benefits of this technique include efficient uses of energy and solvent, and being a virtually waste-free process that allows for scale-up. A major drawback in conventional spray drying is the polydispersity of the produced particles. Herein, a specially designed spray dryer called micro-fluidic-jet-spray-drier (MFJSD) coupled with a micro-fluidic-aerosol-nozzle (MFAN) could generate droplets in a single trajectory pattern, to produce monodisperse particles. The drying temperature could vary from <90 °C to 300 °C to accommodate heat sensitive materials if necessary. For the first time we investigated the use of MFJSD to generate uniform magnetic microcomposites, specifically focusing on the effects of precursor composition, droplet size, and secondary heat treatment on the final properties of the particles. The presence of silica nanoparticles in the precursor was demonstrated to directly affect the morphology of the particles. Precursor containing silica nanoparticles generated particles with bowl-like shapes due to slower redistribution of solutes to support the particle skeleton during drying. In the absence of silica nanoparticles, the particles were almost perfectly spherical albeit with dimpled surfaces. After being subjected to calcination after drying, iron oxide crystals were found on the particle surfaces accounting for the overall magnetic property of the microcomposites, with lower magnetisation observed for particles containing higher amount of silica.

Keywords: Magnetic microcomposites; Microfluidic drying; Silica nanoparticles; Morphology; Iron oxide

1. Introduction

Magnetic-based particles have been used extensively in diverse sectors, such as biomedical, magnetic separation, and as supports for catalysts. In bio-related applications, magnetic-based particles are often coated with biocompatible and/or polymeric materials. Consequently, low temperature wet-chemistry processes such as sol–gels and co-precipitations are generally the preferred routes to give better control over the particle size distribution. However, these methods require extensive uses of solvent during production, and involve a number of steps post-production for recovery, including washing and drying, during which some of the particles could be lost, resulting in a relatively low yield.

Previously, methods such as flame spray pyrolysis have been used to produce magnetic-based materials (Li et al., 2006). Dry synthesis methods such as spray pyrolysis or spray drying can produce high yields within a short production time and is easy to scale-up. The main step is to evaporate the solvent from the atomized droplets to form particles, or in the case of spray pyrolysis, also inducing nucleation and growth of crystals due to the high temperature (>1000 °C) involved in the process.

We investigated for the first time the use of a novel spray dryer, called a micro-fluidic-jet spray dryer (MFJSD) (Wu et al., 2007, 2009, 2011a) to produce uniform magnetic microcomposites. The specially designed micro-fluidic-aerosol-nozzle (MFAN) of the dryer could generate monodisperse droplets in a single trajectory pattern, allowing better contacts between droplets and the drying air for a more efficient formation of solid particles with uniform size and morphology. This efficient drying process provides the possibility to operate the dryer at a relatively low temperature range (<90–300 °C), as an alternative technique for the assembly of magnetic or thermal sensitive composites with relatively lower energy consumption and virtually no solvent waste. Previously we have

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