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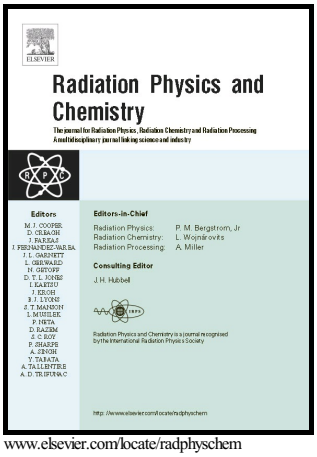

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Highly Magnetic Co Nanoparticles fabricated by X-ray Radiolysis

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Abstract

Advanced routes for the synthesis of nanomaterials, such as ferromagnetic nanoparticles, are being explored that are easy to perform using cost-effective and non-toxic precursors. Radiolytic syntheses based on the use of X-rays as ionizing radiation are promising towards this effort. X-rays were used to produce highly magnetic cobalt nanoparticles (NPs), stable in air up to 200°C, from the radiolysis of water. Crystal structure analysis by XRD indicates a mixture of Co_{fcc}, 63%, and Co_{hcp}, 37%, phases. Magnetic analysis by VSM gave a saturation magnetization (M_s) ~136 emu/g at 1T and coercivity (H_c) = 325 Oe when the reaction solution was purged with N_2 while an air-purged treatment resulted in Co NPs having ~102 emu/g with a coercivity (H_c) ~270 Oe. Overall, the reduction of Co^{2+} occurred in an aqueous reaction environment without addition of chemical reductants resulting in Co NPs with size distribution from 20-140 nm. This clean approach at ambient temperature produced highly magnetic Co NPs that may be used for switching devices (i.e. reed switches) or as magnetic nanocomposite additives for alloys that require high Curie points.

Keywords: cobalt, X-ray radiolysis, ferromagnetism, nanoparticles

1. Introduction

Exploring alternative fabrication methods that offer clear improvement for the synthesis of known metallic nanomaterials such as magnetic nanoparticles (NPs) is relevant to nanomaterials research (Clifford 2014; Jyothi et al., 2015; Nugroho and Kim, 2014). This is accomplished when the alternative fabrication method uses either cost effective precursors and/or green chemicals to generate a material that has competitive properties with those made by traditional synthesis routes, namely wet-chemical, sonochemical or thermal decomposition (Ansari et al., 2017; Shao et al., 2006). X-ray radiolysis has gained attention as a promising alternative for nanomaterial synthesis since it involves low cost and non-toxic solvents (Amardeep et al., 2016; Clifford et al., 2017; Feldman et al., 2013; Liu et al., 2009; Ohkubo et al., 2014; Ozkaraoglu et al., 2007; Remita et al., 2007; Zezin et al., 2009). It is a simple process as it is performed using ambient conditions which enable minimal to no reaction monitoring. Furthermore, X-ray photons can be obtained using commercially available irradiators, as opposed to more elaborate synchrotron sources. X-ray irradiators offer adjustment of the photon energy used for synthesis and the possibility to turn it off when not in use. Therefore, performing radiolysis thru X-rays is advantageous over the γ-based routes (^{60}Co, ^{137}Cs) since less regulation is required (Lee et al., 2012; Misra et al., 2012; Procházková et al., 2016). Notably, a synthesis based on radiolysis differs from one based on photolysis by the energy of the photons. Radiolysis occurs with ionizing radiation, e.g. X-rays or γ-rays, while photolysis takes place when using photons with energy <10 eV. This allows for radiolysis to be non-selective toward the solute making it a solvent-based synthesis process (Alrehaily et al., 2012).

Radiolytic synthesis has been performed using either a small amount of a radical scavenger (IPA:H_2O, 1:100 v/v), or no scavenger to yield magnetic oxides of Co and Fe rather than metallic Co and Fe (Alrehaily et al., 2012; Gupta et al., 2014; Jurkin et al., 2016). Traditional aqueous-based reductions have