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Fabrication and characterization of dendrimer-encapsulated monometallic Co nanoparticles

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ABSTRACT

A series of cobalt (Co) nanoparticles were synthesized by employing PAMAM dendrimers with different generations (G 0.0–3.0) as templates and sodium borohydride as a reducing agent. Extensive characterizations of the products were done using TEM, FT-IR, VSM, TGA, and XPS. The magnetization curves have superparamagnetic non hysteric characteristic at lower fields and with nonsaturation characteristic at high fields. All XRD patterns indicate that amorphous structure of all products. The shake-up satellites are observed at higher energies of the XPS peaks.

1. Introduction

Magnetic nanoparticles (MP) exhibit enhanced magnetic, optical, and electrical properties when compared with their bulk counterparts rendering nanoparticles of interest for a variety of applications information storage [1,2], color imaging [3], magnetic refrigeration [4], ferro-fluids [5], cell sorting [6], medical diagnosis [7], and controlled drug delivery [8]. Most of these applications require chemically stable, well-dispersed and uniform size particles. For this reason, new technologies in synthesis and methods of analysis have been developed.

Dendrimers are very exiting cascade type three-dimensional polymers that have well-defined molecular weight/size, uniform dense terminal functional groups, and porosity. Generally, dendrimers of low generation tend to exist in relatively open forms, at higher generations ($G \geq 4.0$) take intrinsically well-defined globular structure. Dendrimers might provide reaction sites including their interior or periphery. Accordingly, it is expected that the use of dendrimers as templates/stabilizers for the synthesis of nanoparticles are affected by the generation of dendrimers and show different behavior from those prepared using conventional linear polymers [9]. A poly-amidoamine (PAMAM) dendrimer is highly branched macromolecule that contains interior tertiary amine groups which can effectively make coordination with metal ions. Such metal ions may then be reduced to form encapsulated metal particles that can be highly stable in solution. Since the same number of chelating sites is present in all dendrimer molecules, this process can yield mono-disperse metal particles [10–12].

Dendrimer-stabilized nanoparticles (DSN) may provide one avenue toward controlled synthesis of supported metal catalysts. Dendrimers are a special class of hyper branched polymers with a specific molecular structure and controllable size. At higher generation, they possess a very dense exterior, while containing hollow pockets that can be ideal for use as nano-scale containers [12]. This property finds widespread application in catalysis and biomedical research. Dendrimers containing metal nanoparticles also find applications in catalysis [13,14]. It is possible to produce dendrimer–metal nanocomposites by the following routes: (1) forming of complexes by binding of metal ions to a template of dendrimer molecules and (2) nanoclusture forming by immobilization of the metal ions onto dendrimer templates. Composition, size and structure of the system also strongly affect the properties of dendrimer–metal nanocomposites [15–18].

In this study, the synthesis of Co nanoparticles via the template of PAMAM dendrimers with different generation was presented. Extensive characterizations of the fabricated nanocomposites have been performed by using a variety of microscopy and spectroscopic techniques.

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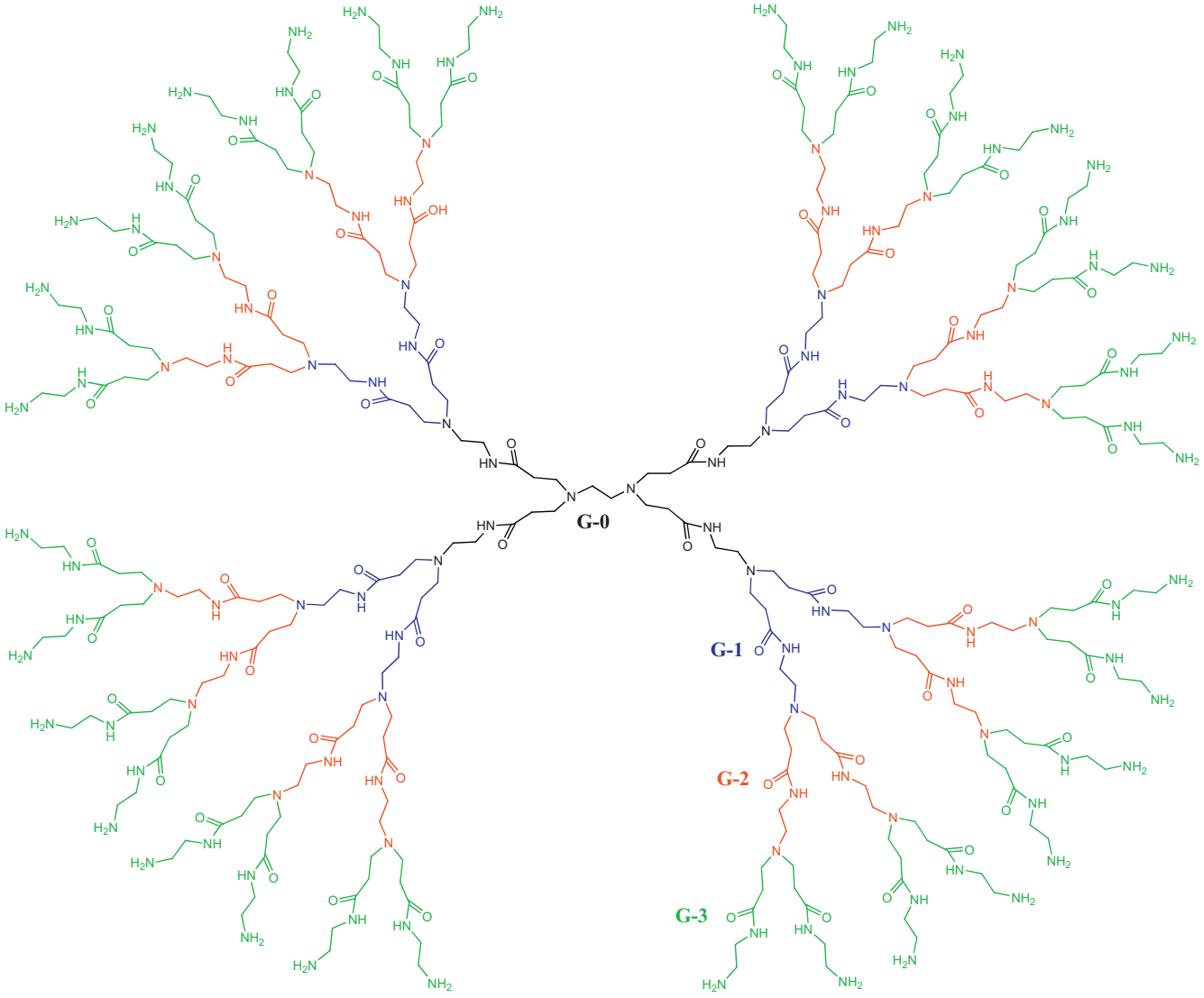

Fig. 1. The structure of G0.0–G3.0 dendrimers.

2. Experimental

2.1. Materials

Cobalt chloride ($CoCl_2 \cdot 6H_2O$), sodium borohydride ($NaBH_4$), were purchased from Merck and used as received without further purification. All the chemicals are of analytical grade.

2.2. Characterization

X-ray powder diffraction (XRD) analysis was conducted on a Rigaku Smart Lab Diffractometer operated at 40 kV and 35 mA using Cu Kα radiation (λ = 1.54178 Å).

Fourier transform infrared (FT-IR) spectra were recorded in transmission mode with a Perkin Elmer BX FT-IR infrared spectrometer. The powder samples were ground with KBr and compressed into a pellet (in the range 4000–400 cm^{-1}).

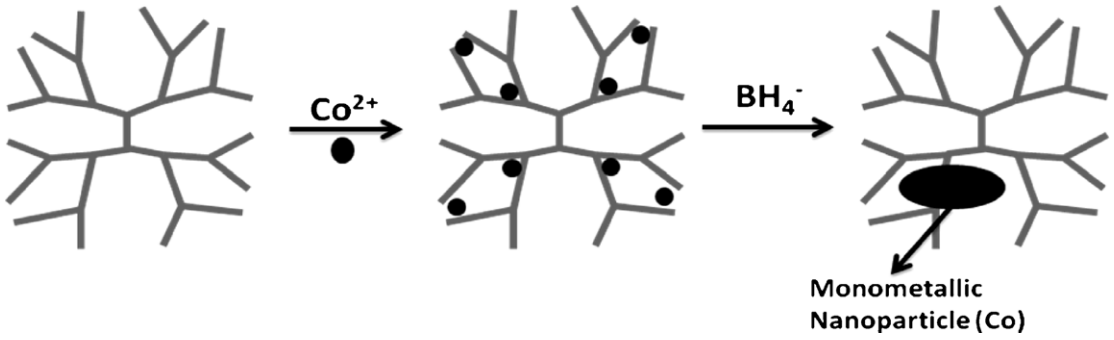

Fig. 2. Schematic representation of the synthesis of dendrimer encapsulated Co nanoparticles.