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Effect of reaction time on structural and magnetic properties of green-synthesized magnetic nanoparticles

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ABSTRACT

Fe_3O_4 magnetic nanoparticles (MNPs) were prepared using the modified green synthesis method and the effects of reaction time on the structural and magnetic properties of MNPs were evaluated. For the synthesis of MNPs, green tea extract and ethylene glycol were used as a reducing agent and solvent, respectively. The MNPs were characterized by X-ray diffraction (XRD), field emission scanning electron microscope (FESEM), thermogravimetric analysis and vibrating sample magnetometer. It was observed that the reaction time strongly influenced the magnetic and structural properties. With increasing reaction time, the crystallite size was found to be increased from 7.5 to 12 nm along with improvement in saturation magnetization (M_S). The magnetic measurement study revealed that MNPs were superparamagnetic at room temperature, while at 60 K they have ferromagnetic as well as superparamagnetic contributions. The effect of an increase in particle size with reaction time was also reflected with an increase in blocking temperature, which is consistent with the Stoner–Wohlfarth theory.

1. Introduction

Magnetic nanoparticles (MNPs) offer interesting physicochemical properties such as superparamagnetism, large surface area, high surface-to-volume ratio and low toxicity based on their size and shape [1]. Owing to these properties, MNPs have widespread applications in the field of magnetic resonance imaging (MRI) [2], magnetic separation [3], catalysis [4], environmental remediation [5], targeted drug delivery [6], etc. A number of physical synthesis methods of MNPs such as gas-phase deposition, mechanical techniques and chemical synthesis methods which include sol-gel, coprecipitation, hydrothermal, solvothermal and thermal decomposition have been developed [7]. These physical and chemical methods have several disadvantages as they require high reaction temperature, high pressure and use of toxic chemicals, which create biocompatibility issues if MNPs have to be used for bioapplications. Hence, the development of simplistic, cost-effective and reliable green chemistry methods for the synthesis of MNPs is gaining importance. Considering these facts, several green synthesis methods such as leaf extracts, peels extracts and seed extract mediated reduction routes with the combination of solution hydrogen reduction were developed to reduce the environmental hazards [8]. These green synthesis methods are a good alternative to other methods as they are environment-friendly and have high yield, good reproducibility and good scalability at low cost [9]. There are several reports on the green synthesis of iron oxide nanoparticles (NPs) using plant extracts of *Camellia sinensis*, *Azadirachta indica*, *Tridax procumbens*, green tea, *Punica granatum*, ridge gourd peels and *Aloe vera*, etc. [10]. Green tea extract is one of the most important reducing agents used for the production of diverse metal and metal oxide NPs. Green tea is highly rich in nutrients and contains important antioxidants known as polyphenols. It contains catechin polyphenols, specifically (−)epigallocatechin-3-gallate (EGCG) [11]. These polyphenolic compounds from green tea extracts are mainly water-soluble, biodegradable and nontoxic. Polyphenols form metal chelating complexes with dissociated metal ions from the precursor and reduce them into zero-valent metallic states. In addition, different alcoholic functional groups present in tea extract also

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