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Mössbauer analysis and induction heating evaluation of grapes like FZ@MWCNT towards cancer treatment

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A B S T R A C T

We have successfully modified the synthesis of γ-Fe_2O_3 and ZnO in a variety of potential matrices, like as multiwall carbon nanotubes (MWCNT) and graphene oxide (GO), referred to as FZ@MWCNT and FZ@MWCNT-GO. X-ray diffraction (XRD) and scanning electron microscopy (SEM) were performed for phase formation and morphological analysis. Phase purity and superparamagnetic environment of maghemite and FZ@MWCNT were investigated by ^{57}Fe Mössbauer spectrometry at 77 and 300 K, confirming the reduction of dipolar interaction. Induction heating of γ-Fe_2O_3, FZ@MWCNT and FZ@MWCNT-GO was analysed at various concentrations of nanoparticles to investigate the suitability of this nanocomposite for hyperthermia application. Ironically, the inductive heating rate of FZ@MWCNT at 3 mg/ml concentration is reflecting its high potential for hyperthermia therapy in cancer treatment.

1. Introduction

Cancer is considered to be one of the leading causes of human mortality as a consequence of the unregulated growth of malignant cells, which have the ability to spread across the body parts. According to reports from World Health Organization, cancer causes millions of deaths annually (9.6 million) and 18.1 million people worldwide were living with cancer in 2018 [1]. Conventional methods of cancer treatment include surgery, radiotherapy, chemotherapy and sometimes combination of them. The key drawback of current approach of chemotherapy is the toxic side effects to healthy cells [2]. Magnetic hyperthermia therapy (MHT) is an emerging and effective cancer treatment technique [3–5]. Hyperthermia temperature can damage and destroy cancer cells, typically with minimal side effects to normal tissue, which triggers natural cell self-destruction mechanisms called apoptosis. In the presence of sinusoidal magnetic field, magnetic nanoparticles produce a significant amount of heat (42–45 °C). The heat produced by the magnetic nanoparticles causes direct cancer cell necrosis through temperature elevation or damaging the protein structure within the cell and may shrink the tumour [6]. The heating capability of magnetic nanoparticles is defined by two parameters, the specific absorption rate (SAR) and the intrinsic loss parameter (ILP). The SAR value is influenced by the magnetic anisotropy, average particle size and their particle distribution, and also by the external parameters such as amplitude and frequency of the applied field. But forecasting and regulating the concentration of particles in tissues to achieve effective heat generation is a challenge for therapeutic purposes [7].

Due to the biocompatibility and simple synthesis process, ferrites are the most studied compound in the field for hyperthermia [8]. However, non-toxic ZnO nanoparticles have been widely investigated as targeted anticancer agents and bio-imaging probes because of its semiconducting properties, photoluminescence activities, biocompatibility and eco-friendliness [9]. It is possible to minimize the dipolar interactions between the nanoparticles by regulating the mean separation distance between them through the incorporation of non-magnetic ZnO nanoparticles. As a result, the linear response theory correctly predicts the

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