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Multifunctional fluorescent SPIONs display exceptional optical/magnetic contrast and enhanced photoconductivity in interdigitated electrode based photoresponsive devices†

Ashish Tiwari, *[ab] Ayan Debnath,[c] Mohamad G. Moinuddin,[d] Aamir Mushtaq,[e] Anup Singh,[c] Satinder K. Sharma[d] and Jaspreet K. Randhawa *[a]

SPION based multifunctional nanostructures have gained significant attention in multiscale imaging and therapeutic applications. Multistep synthesis and post-synthesis modifications/doping have been extensively used to synthesize such nanostructures; however, single step synthesis and *in situ* surface coating/doping are still challenging and require the development of a robust method. Using a direct synthesis approach, we address this research dilemma by synthesizing nitrogen doped carbon coated core–shell SPIONs along with nitrogen doped carbon dots as a biproduct. This method allows for the creation of two products from a single synthesis as well as *in situ* doping in both products. The synthesized core–shell SPIONs demonstrated unique two-photon absorption, multicolor emission behavior and optical nonlinearity, which are essential for optical and fluorescence imaging applications. Moreover, by customizing the core shape and shell surface coating, core–shell SPIONs demonstrated high saturation magnetization, increased magnetic contrast, and high T2 relaxivity ($R = 156$ mM^{-1} s^{-1}). Additionally, in order to assess the efficacy of photoinduced conduction, we constructed an interdigitated electrode device utilizing these SPIONs. The generation of photocurrent was evaluated across various illumination conditions. The device demonstrated exceptional photoconductivity, as evidenced by the observed photo-to-dark current ratio (ION-IDark/IDark) of 7.53 and 6.64 under green and red laser illumination, respectively. The photocurrent study measured the rise and fall times of device response to be 93/281 milliseconds under green laser illumination determining the strong applicability of SPIONs in device applications. The enhanced photoelectronic capabilities may be attributed to the utilization of carbon shells as active light harvesting sites and nitrogen doping as charge donors within the core–shell architecture. The current study elucidates a synthesis technique for the production of multifunctional fluorescent SPIONs and reveals their immense potential for applications in photoresponsive devices and multiscale imaging.

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1 Introduction

Biomedical researchers are intrigued by the multifunctionality of superparamagnetic iron oxide nanoparticles (SPIONs). These nanostructures have proven useful in a variety of applications, including magnetic resonance imaging, drug delivery and flexible bioelectronic devices.[1–3] Several studies have reported the synthesis of these nanoarchitectures using a multistep fabrication process and hybrid approaches to achieve optical[4–6] and magnetic properties.[7,8] As an illustration, the synthesis of core–shell supernanoparticles with a fluorescent coating of silica was carried out by a multistep method using SPIONs and quantum dots.[7] Similarly, magneto-fluorescent nanohybrid quantum dots/quantum rods (QDQRs) were fabricated in multistep synthesis.[9] Fluorescent-tagged multifunctional core–shell nanoparticles in post-synthesis modification were reported.[10]

[a]*School of Mechanical and Materials Engineering, Indian Institute of Technology Mandi, Himachal Pradesh, 175005, India. E-mail: ashishtiwari111@outlook.com; ashish.larpm@gmail.com; ashisht@campus.technion.ac.il; jaspreet@iitmandi.ac.in*

[b]*Faculty of Biomedical Engineering, Technion-Israel Institute of Technology, Haifa, 3200003, Israel*

[c]*Center for BioMedical Engineering, Indian Institute of Technology Delhi, New Delhi, 110016, India. E-mail: Anup.Singh@cbme.iitd.ac.in; ayan.newton@gmail.com*

[d]*School Computing and Electrical Engineering, Indian Institute of Technology Mandi, Himachal Pradesh, 175005, India. E-mail: moin.ahmad111@gmail.com; satinder@iitmandi.ac.in*

[e]*Department of Materials Science and Engineering, Ohio State University, Ohio 43210, USA. E-mail: mushtaq.11@osu.edu*

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