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Superparamagnetic magnesium ferrite nanoparticles: a magnetically reusable and clean heterogeneous catalyst

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Dedicated to memory of Hassan Tehrani Moghadam.

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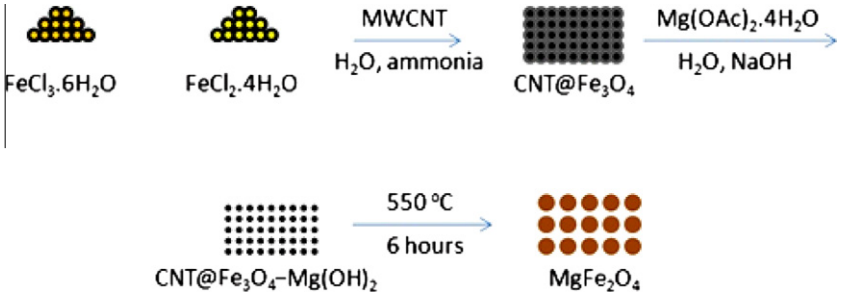
ABSTRACT

A highly efficient magnetically recoverable nano-catalyst was fabricated. The material synthesized has been fully characterized by vibrating sample magnetometry (VSM), X-ray powder diffraction, scanning and transmission electron microscopy, FT-IR, and the Brunauer-Emmett–Teller (BET) isotherm method. An investigation of its catalytic activity showed it to be a unique heterogeneous Lewis acid catalyst for the synthesis of α-hydroxy and α-aminophosphonates, giving a total turnover number ⩾450 for five consecutive runs. The catalyst is superparamagnetic having a 'magnetization (left behind after an external magnetic field is removed)' to 'magnetic saturation' ratio of about 0.0008, and thus could be easily separated by the use of an external magnetic field and was not agglomerated by exposure to magnetic fields.

Magnetic nanoparticles have gained considerable interest in various disciplines such as ferrofluids, magnetic drug delivery, separations, magnetic high-density information storage, magnetic resonance imaging (MRI), and cancer hyperthermia treatment.[1–3] Magnetic nanoparticles are attractive catalysts since they can be separated from the reaction medium after magnetization by an external magnet. Magnetic separation is an intriguing alternative to filtration or centrifugation as it prevents the loss of catalyst and enhances reusability, rendering the catalyst cost-effective and is promising for industrial applications.[4–8] Clearly, the development of magnetic nanoparticles with tunable catalytic activity is of great significance for both academia and industry. The cubic spinel ferrites represent an important class of magnetic transition metal oxide materials. Among ferrites, nano magnesium ferrite is very important for its potential use in high-density recording media, adsorption, sensors and magnetic technologies,[9] and has good photoelectrical properties, low saturation magnetization, high resistivity and uniform and reproducible characteristics.[10] A literature survey revealed that few attempts have been made to prepare nano magnesium ferrite and to study its potential application in organic synthesis.



Scheme 1. Synthesis of magnesium ferrite nanospheres.

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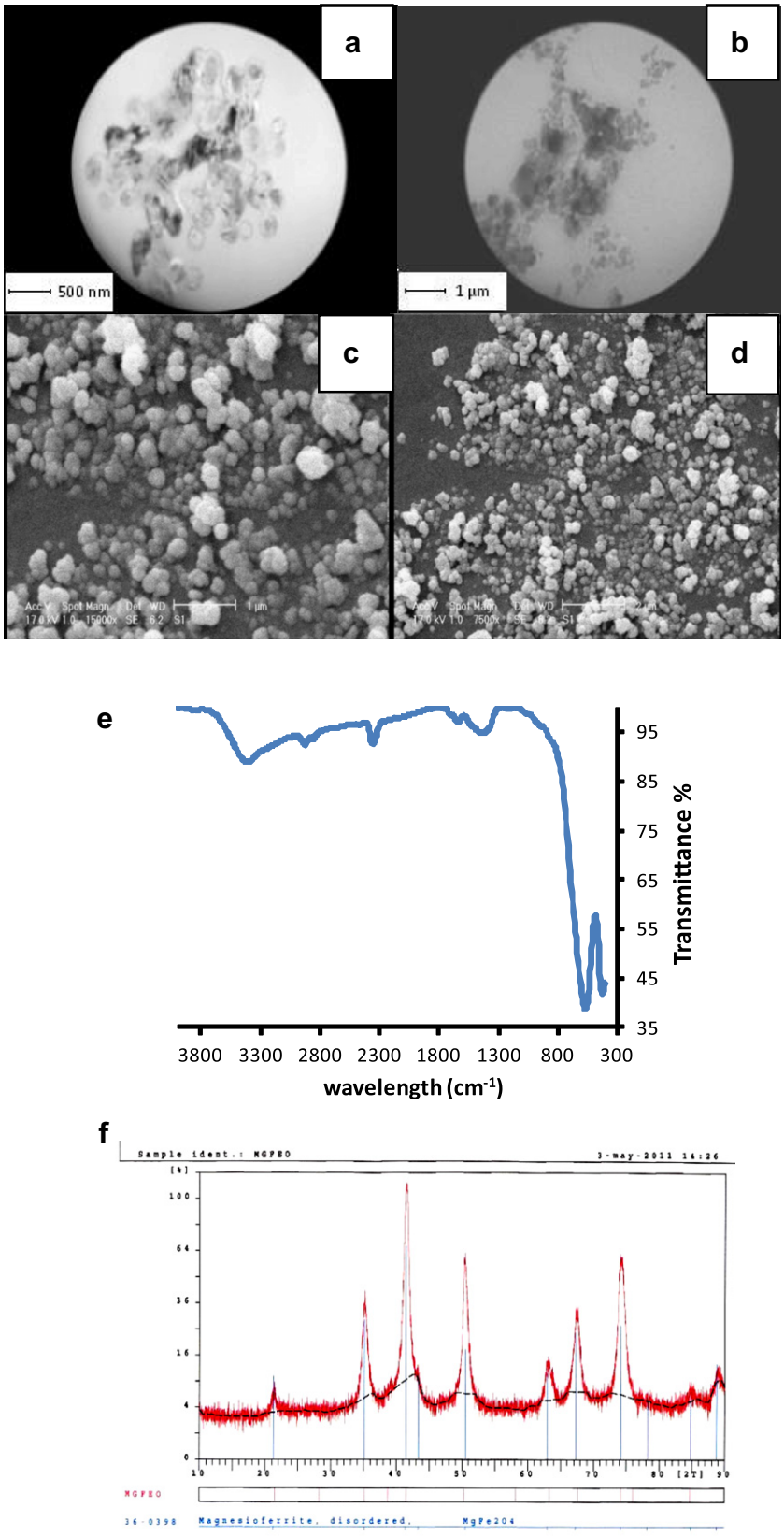

Figure 1. (a) and (b) TEM micrographs, (c) and (d) SEM images, (e) FTIR spectrum and (f) XRD spectrum of the $MgFe_2O_4$ nanospheres.

In the past few years, highly efficient couplings catalyzed by various nano magnetic catalysts have been described.[11–14] Hu reported that such a coupling can also be catalyzed by Fe_3O_4.[15] Unfortunately, Fe_3O_4 nanoparticles are usually unstable and the