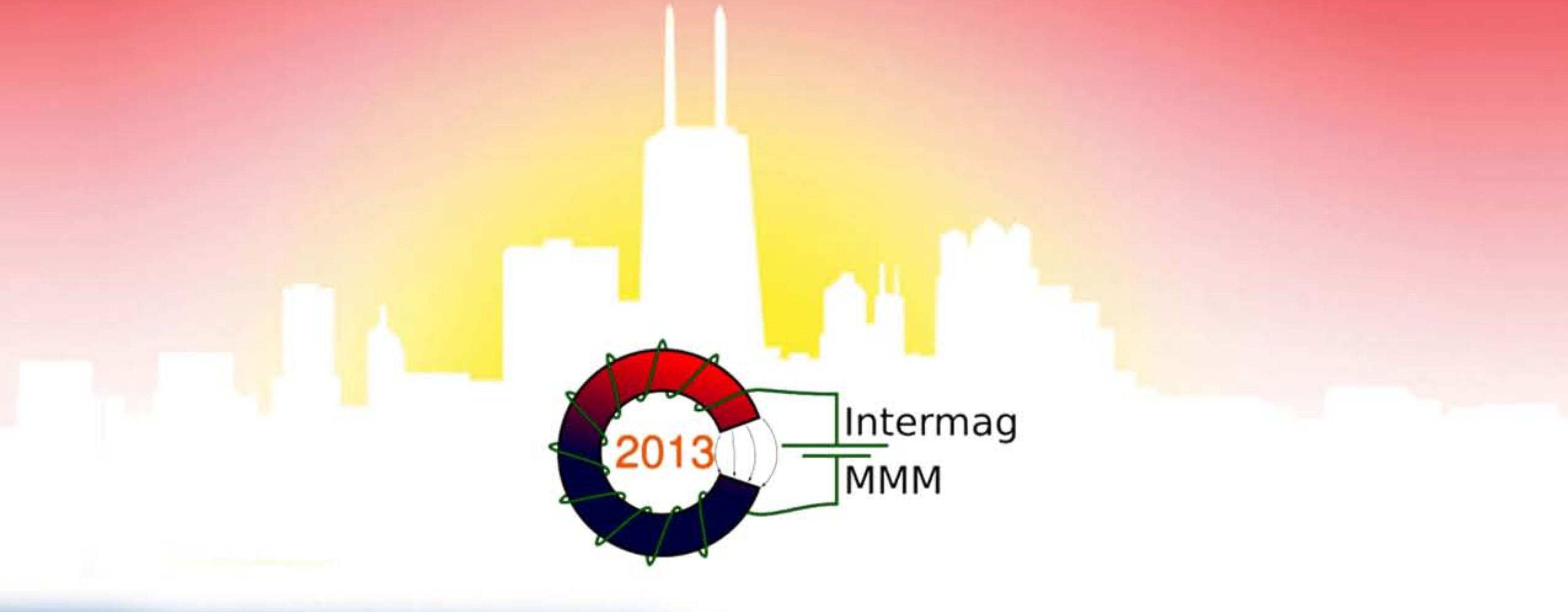
12TH JOINT MMM–INTERMAG CONFERENCE

January 14–18, 2013
Chicago, Illinois, USA



ABSTRACTS

IEEE MAGNETICS

AIP American Institute of Physics

THURSDAY MORNING, 17 JANUARY 2013 RIVERSIDE CENTER, 9:00 TO 12:00

Session EU
MAGNETIC FLUIDS AND APPLICATIONS I (POSTER SESSION)
Zoe Boekelheide, Chair

CONTRIBUTED PAPERS

EU-01. Mesoporous Fe-MCM-22 additive effect on magnetorheological response of magnetic carbonyl iron suspension. Y. Liu[1], X. Quan[1], W. Ahn[2] and *H. Choi*[1] *1. Department of Polymer Science and Engineering, Inha Univ, Incheon, Republic of Korea; 2. Department of Chemical Engineering, Inha Univ, Incheon, Republic of Korea*

Magnetorheological (MR) fluids are concentrated suspensions of magnetic particles, of which their rheological performances of shear viscosity, dynamic modulus, and yield stress are able to be significantly enhanced by the application of a magnetic field [1], thus possessing extensive engineering applications. Magnetic particles of iron, iron oxide and iron alloys are the most applied materials in MR fluids. However, all these candidates encounter serious sedimentation problem due to the large density mismatch between the particles and the carrier liquid. Non-magnetic particles in nano- or submicro-scale, such as fume silica, organoclay and graphene oxide, were used as additives in the MR fluid system to prevent fast settling of the magnetic particles [2-4]. There are also other problems accompanying with the introducing of the additives, e.g., higher off-state viscosity and lower yield stress than the MR fluid without the additive. In this study, we applied a mesoporous molecular sieve Fe-MCM-22 [5] with magnetic iron contained in the pores, in the carbonyl iron (CI)-based MR fluid. The Fe-MCM-22 was synthesized by a hydrothermal method reported before. Three MR fluids were prepared containing the same volume fraction of CI but different contents of Fe-MCM-22 (1, 3, 5 wt% according to the carrier fluid). MR performances of the MR fluids were measured by a commercial rotational rheometer including shear stress and shear viscosity in a steady shear flow and elastic modulus in an oscillatory measurement. The application of magnetic additive enhanced the MR effect (yield stress) of the MR fluid which was proportional to the component of the Fe-MCM-22, as shown in Fig. 1. Sedimentation rate was found to also reduced by the additives comparing to the MR fluid without Fe-MCM-22.

[1] B. J. Park, F. F. Fang, and H. J. Choi, Soft Matter 6, 5246 (2010). [2] S. T. Lim, M. S. Cho, I. B. Jang, and H. J. Choi, J. Magn. Magn. Mater. 282, 170 (2004). [3] H. B. Cheng, L. Zuo, J. H. Song, Q. J. Zhang, and N. M. Wereley, J. Appl. Phys. 107, 09B507 (2010). [4] W. L. Zhang and H. J. Choi, J. Appl. Phys. 111, 07E724 (2012). [5] S. T. Yang, J. Y. Kim, J. Kim, and W. S. Ahn, Fuel 97, 435 (2012).

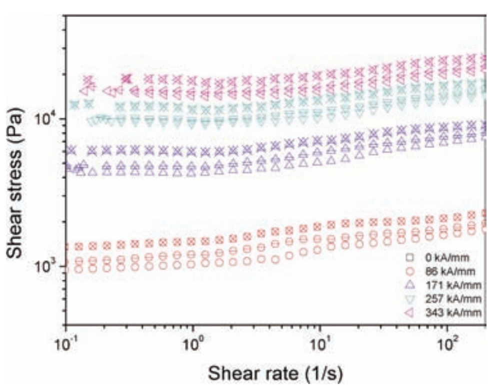


Figure 1. Flow curves of the CI MR fluids with Fe-MCM-22 of 1% (center open), 3% (center bar) and 5% (center cross) at various magnetic filed strengths.

EU-02. Sub-micron sized magnetic particles of Mn0.25Fe2.75O4 and their magnetorheological characteristics. Y. Liu[1], Y. Li[2], C. Kim[2] and *H. Choi*[1] *1. Department of Polymer Science and Engineering, Inha Univ, Incheon, Republic of Korea; 2. Department of Physics, Kookmin University, Seoul, Republic of Korea*

Ferrite magnetic particles (MxFe3-xO4, where M= Mn, Fe, Co, Ni, Cu, Zn), either in nano- or micron-scale, have attracted special attention due to their electromagnetic properties including high saturation magnetization, stability and low loss energy, and their wide technological applications [1]. Among these materials, MnFe2O4 has the inversed spinel structure to Fe3O4, and thus, a doping degree by Mn2+ to Fe3O4 can change the spin structure of the particles. However, in this study, we pay attention to the magnetic response of this kind of particles when dispersed in a viscous base-oil. The suspension is called a magnetorheological (MR) fluid, which is a smart material of magnetic particles in nonmagnetic liquid, possessing the ability of being changed from a liquid-like to a solid-like state upon the application of a magnetic field [2]. Monodispersed Mn0.25Fe2.75O4 sub-micron spheres [3] (200~400 nm) were synthesized by a solvothermal reaction method, possessing single crystal strucutes and excellent ferromagnetic property. The as-synthesized magnetic particles were then applied in an MR fluid with the particle fraction of 20 vol%. The MR fluid, measured by a rotational rheometer, showed good field-responsive property both in flow curves (Fig. 1) and dynamic oscillatin test: stepwise increase in shear stress and storage modulus. In addition, the Mn0.25Fe2.75O4 particles with smaller size than the commonly applied carboyl iron microparticles [4, 5] in MR fluid, are expected to ehxibit better setlling stablility, therefore introducing a new application field to the particles.

[1] J. H. Lee, J. Jang, J. Choi, S. H. Moon, S. Noh, J. Kim, J. G. Kim, I. S. Kim, K. I. Park, and J. Cheon, Nat. Nanotech. 6, 418 (2011). [2] B. J. Park, F. F. Fang, and H. J. Choi, Soft Matter 6, 5246 (2010). [3] Y. H. Li, T. Kouh, I. B. Shim, and C. S. Kim, J. Appl. Phys. 111, 07B544 (2012). [4] H. B. Cheng, L. Zuo, J. H. Song, Q. J. Zhang, and N. M. Wereley, J. Appl. Phys. 107, 09B507 (2010). [5] Y. D. Liu and H. J. Choi, J. Appl. Phys. 111, 07B502 (2012).

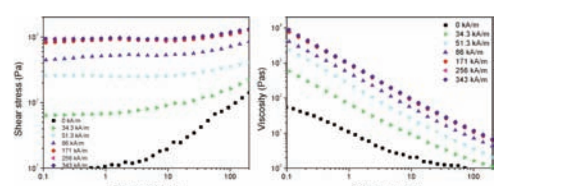
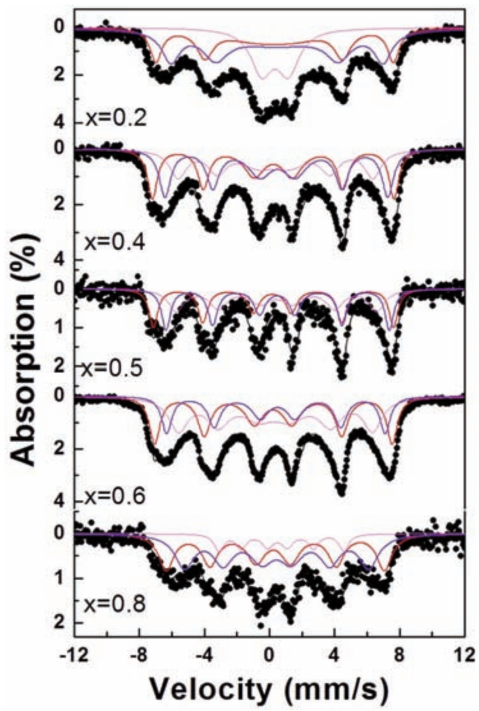


Figure 1. Shear stress and viscosity of hte Mn0.25Fe2.75O4 MR fluid as a function of shear rate measured at different magnetic field strengths.

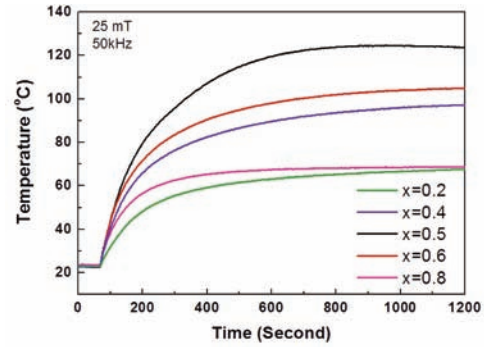
EU-03. Thermal variation of MgZn-nanoferrites for magnetic hyperthermia. *S. Hyun*[1], H. Kim[2], M. Kim[1], K. Yoo[2] and C. Kim[1] *1. Physics, Kookmin University, SEOUL, Republic of Korea; 2. Nanomedical Graduate Program, Yonsei University, SEOUL, Republic of Korea*

A study on bio-applications for hyperthermia, drug delivery, magnetic resonance imaging and bio-sensors has been reported with the properties of a few nanometer size-materials, especially, ferrite materials [1-3]. In this research, the crystallographic and magnetic properties for $Mg_{1-x}Zn_xFe_2O_4$ (x=0.2, 0.4, 0.5, 0.6, 0.8) nanoparticles (NPs) were characterized by using a x-ray diffraction (XRD), field emission scanning electron microscope (FE-SEM), vibrating sample magnetometer (VSM) and Mö ssbauer spectroscopy. These were also measured with hyperthermic properties by magneTherm devices (nanoTherics) and treated hyperthermia therapy using nude mice. The Rietveld refinement for XRD was used to confirm that Zn ion occupied on B-site over 0.5 doping. The lattice constants (a_0) were increased from 8.3969 to 8.4100 ± 0.0001 Å with increasing Zn concentration. Measuring FE-SEM and Using Scherrer equation, the average particle-sizes were determined to be 11 ± 1 nm. The magnetization (M_s) was increased from 66.2 to 82.0 ± 0.1 emu/g with maximum applied field of 1.5 T at room temperature (RT). Mö ssbauer spectra of all NPs samples were taken at RT, which show Fe^{3+} and Fe^{2+} valence states as shown in Fig. 1. The thermal properties of all NPs samples were measured with 50 kHz and 25 mT. The heating temperature was increased up to 124 ^oC until 0.5 doping of Zn ions, however it was decreased down to 69 ^oC over 0.5 doping of Zn ions as shown in Fig. 2. These results consist with Rietveld refinement and can be explained that Ms was increased by Fe^{2+} ion, however, the heating temperature was decreased due to occupation of Zn ions on B-site over 0.5 doping. Furthermore, breast cancer cells (SKBR3) were xenografted to the abdomen of nude mice for hyperthermia therapy. In case of untreated mouse, the size of tumour was increased, however, hyperthermia-treated mouse showed sustenance of tumour-size.

[1] Y. Piao et al., Nature Mater. 7, 242-247 (2008). [2] Q. Song, Y. Ding, Z. L. Wang and Z. J. Zhang, Chem. Mater. 19, 4633-4638 (2007). [3] J.-H. Lee et al., Nature Nanotechnol. 6, 418 (2011).



Mössbauer spectra at room temperature for $Mg_{1-x}Zn_xFe_2O_4$ (x=0.2, 0.4, 0.5, 0.6, 0.8).



The heating temperature of $Mg_{1-x}Zn_xFe_2O_4$ (x=0.2, 0.4, 0.5, 0.6, 0.8) for hyperthermia.

EU-04. Selective Isolation of Superparamagnetic Beads by a Magnetic Microfluidic Chip. *C. Gooneratne*[1], O. Yassine[1], I. Giouroudi[2] and J. Kosel[1] *1. King Abdullah University of Science and Technology, Thuwal, Saudi Arabia; 2. Vienna University of Technology, Vienna, Austria*

In this research a magnetic microfluidic chip (MMC) is presented, to first trap and then selectively isolate superparamagnetic beads (SPBs). The application of this research is to separate and investigate rare cells by tagging them with SPBs [1,2]. Experiments were performed to demonstrate the effectiveness of using magnetic dots to trap and separate SPBs in a heterogenous solution (Fig.1). 2.85 μm COMPEL™ magnetic beads (dragon green), were mixed with non-magnetic 1 μm Fluoresbrite® YG Carboxylate Microspheres and flown through a channel with a row of four NiFe dots with a thickness of 50 nm and diameter 3 μm. It can be seen from Fig. 1 that the SPBs can be separated from the non-magnetic particles with high efficiency. The proposed MMC consists of a main channel with two side channels leading to two chambers as shown in Fig. 2. A permanent magnet is used to magnetize the NiFe dots in order to trap very low concentration SPBs, so ensuring a high throughput and recovery of SPBs. Triangular current lines are utilized to selectively transport the trapped SPBs inside the two chambers, isolating them on the NiFe dots there, thus increasing the purity of the sample. These current lines are designed in a manner in which the SPBs will move from a low magnetic field gradient region to a high field gradient region; the current density is highest at the narrowest region of the line and lowest at the widest. Once transported to the chamber, detection, specific treatment and/or culturing can be performed in the case of rare, tagged cells. A magnetic sensor can be utilized to detect the presence of SPBs, paving the way for a fully automated microfluidic chip. Furthermore, the MMC can easily be re-used by removing the permanent magnet, flushing out the existing sample of SPBs and replacing with a new sample.

[1] U. Dharmasiri, M.A. Witek, A.A. Adams, and S.A. Soper, "Microsystems for the Capture of Low-Abundance Cells," Annual Review of Analytical Chemistry, 3, pp. 409-431, 2010. [2] M.M.A. Gijs, F. Lacharme, and U. Lehmann, "Microfluidic Applications of Magnetic Particles for Biological Analysis and Catalysis," Chemical Reviews, 110, pp. 1518-1563, 2010.