

# High Density bulk Nanocomposite Magnets Prepared by Warm Compaction

Chuanbing Rong, Vikas Nandwana, Naranyan Poudyal, Yang Li and J. Ping Liu

Department of Physics, The University of Texas at Arlington, Arlington, TX 76019

Mikhail E Kozlov, Anvar Zakhidov and Ray Baughman

NanoTech Institute, University of Texas at Dallas, Richardson, TX 75083

## ABSTRACT

4 nm FePt nanoparticles are mixed with 8 nm Fe<sub>3</sub>O<sub>4</sub> nanoparticles and are compacted under pressure of 2.5GPa at different temperatures. The density reaches 90% of the theoretical density while the grain size is still very small (under 16 nm) when the compacting temperature is 600°C. It is also interesting to observe that a high pressure can decrease the fcc-fct phase transition temperature. Due to the well controlled nanostructure, effective inter-phase exchange coupling in the bulk nanocomposite magnets is obtained and thus, high energy product of 13.2 MGOe has been achieved in the as-compact isotropic bulk samples.

## INTRODUCTION

Monodisperse hard magnetic FePt nanoparticles have been successfully synthesized with well controlled particle size and shape[1, 2]. These particles can be used as building blocks for exchange-coupled FePt/Fe<sub>3</sub>O<sub>4</sub> nanocomposite magnets with high energy products [3]. However, fabrication of bulk exchange-coupled nanocomposite magnets remains a great challenge. Among the limited available techniques for processing nanostructured bulk materials, warm compaction is an attractive method because the yield strength drops and an effective lubrication mechanism can occur in heated powder mixes[4]. In this presentation, we report our recent results on the warm compaction of FePt/Fe<sub>3</sub>O<sub>4</sub> nanoparticle powders.

## EXPERIMENTAL

A typical wet chemical route is used to synthesize 4nm FePt and 8nm Fe<sub>3</sub>O<sub>4</sub> nanoparticles [1-3]. After the synthesis, the two kind of nanoparticles are mixed to get the self-assembly and then removed the surfactant by low-temperature annealing. The QUICKpress Piston-Cylinder Apparatus is used to compact the powders under 2.5Gpa at different temperature (shown in Fig.1). To improve the magnetic properties, the bulk samples are annealed under forming gas (Ar+7%H<sub>2</sub>). Their assemblies are characterized by transmission electron microscopy (TEM), X-ray diffraction (XRD), and superconducting quantum interference device (SQUID) magnetometer.

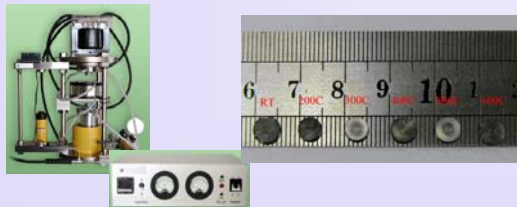


Fig. 1 Schematic illustration of warm compaction

## RESULTS and DISCUSSIONS

### I. Density and grain size

Fig. 1 shows the shape of as-compact samples. The diameter is about 5.5-6mm and thickness is about 1.0~1.5mm. Fig. 2 gives the density of the bulk samples as a function of compacted temperature. Here we determine the density by Archimedes method. It is found that the density increases almost linearly with compacted temperature. 90% theoretical density can be obtained for the 600°C compaction. Fig. 3 gives the dependence of grain size of the bulk samples on compaction and annealing temperature. Here the grain size are calculated by Scherrer method from the XRD patterns. The grain size does not increase with increasing the compaction temperature until 400°C. More importantly, the microstructure of the compacted samples is kept very fine even the compacted and annealing temperature are as high as 600°C. Hence, we can get high density bulk nanocomposite with fine microstructure.

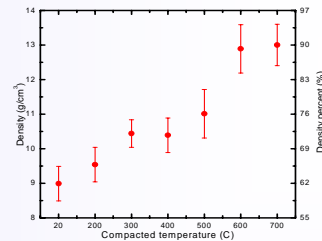


Fig 2 The density as a function of compacted temperature

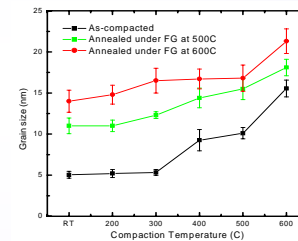


Fig 3 The grain size as a function of compacted and annealing temperature.

### II. Phase transition

Fig 4 shows the XRD patterns of the as-compact bulk samples and powders. The heat treatment of the powders is same as the compacted samples except the pressure. It shows clearly that compaction at 400°C can lead to a phase transition from FCC to FCT. However, there is no phase transition for the powders until the annealing temperature is 500°C. It means that high pressure can stimulate the phase transition and decrease the transitional temperature. Fig. 5 gives the dependence of coercivity on the compacted temperature of bulk samples or annealing temperature on powders. It also proves the high pressure can reduce the phase transitional temperature.

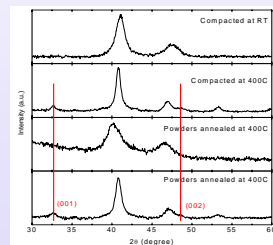


Fig. 4 XRD patterns of the compacted samples and powders.

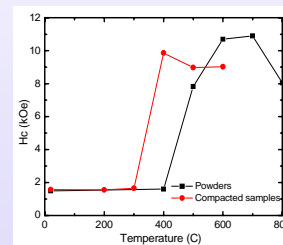


Fig. 5 The dependence of Hc on the compacted temperature of bulk samples or annealing temperature on powders

### IV. Magnetic properties

Fig. 6 shows the dependence of energy product (BH)<sub>max</sub> of theoretical density on the compacted and annealing temperature. As can be seen, (BH)<sub>max</sub> increases fast when annealing temperature is higher than 400-450°C. High energy production about 19-20MGOe can be obtained by low temperature annealing. 13.2MGOe, which exceeds the theoretical limit of 13MGOe for nonexchange-coupled isotropic FePt, is produced even we use the real density (as shown in Fig. 2) to calculate the energy production.

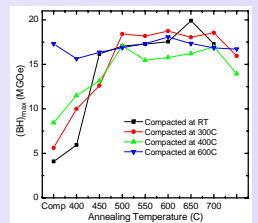


Fig. 6 The dependence of (BH)<sub>max</sub> on compacted and annealing temperature

Fig. 7 shows the δm and demagnetization curves of the powders and compacted samples. The δm curves prove the effective enhancement of exchange coupling in nanoparticles by warm compaction. This leads to the improvement of demagnetization curves and then magnetic properties.

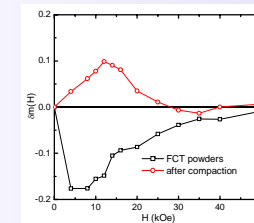


Fig. 7 δm and demagnetization curves of the powders and compacted samples.

## CONCLUSIONS

Bulk nanocomposite FePt/Fe<sub>3</sub>O<sub>4</sub> are obtained by self-assembly method and warm compaction. The density about 90% of theoretical value are obtained while the microstructure is kept fine. More interestingly, it is found that high pressure can decrease the phase transitional temperature of FePt. High energy product 20MGOe is obtained by warm compaction and subsequent annealing under forming gas.

## REFERENCES

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