Prospect of MnBi permanent magnets for traction motors and generators

M.Gjoka[1,*], C. Sarafidis[1], D. Niarchos[1]
[1]INN, NCSR Demokritos, Athens 15310, Greece

MnBi has recently attracted large attention due to its potential for permanent magnetic applications. Although it does not present high saturation magnetization, it has large coercivity, above 1 T, which results in a theoretical BH_{max} value above 17 MGOe. It is also very interesting that the coercivity increases with temperature, up to 2.6 T at 523 K, while for higher temperatures the structure is unstable [1-2]. `

MnBi ingot was prepared by arc-melting the constituent elements (purity better than 99.9%) in argon atmosphere. The ingot was annealed at 573K for 24 h in vacuum to obtain the low-temperature phase (LTP) MnBi. The annealed alloy ingots were manually crushed and ground down to less than 150μm. Low-energy ball milling (LEBM) of 5 g crushed ingot powder was carried out for different milling times up to 4 h in a hardened stainless steel vial using rotary mill with rotation speed of 400 rpm. The milling was performed in hexane with hardened-steel balls 2–4 mm in diameter. The ball-to-powder weight ratio was about 10 : 1. The milled powders were compacted at room temperature in the presence of a 1.0 T magnetic field. The structural characterization of the as-milled powders and hot compacted samples were carried out using x-ray diffraction (XRD) with a Cu-$K\alpha$ radiation. Microstructural characterization of the powders as well as the hot compacted magnet was carried out using scanning electron microscopy (SEM) equipped with energy dispersive *x*-ray spectroscopy (EDX). Magnetic properties of the field aligned powders samples were measured using a vibrating sample magnetometer (VSM) and SQUID.

The magnetic properties depend heavily on the quality of the basic material. Microstructure plays also a dominant role, the best magnetic properties were obtained after ball milling for three hours, which resulted in a narrow grain size distribution from 0.7 to 4 µm. We have managed to achieve coercivity near 1.5 T at RT in epoxy oriented powder samples while saturation magnetization was 61 Am^2/kg. The production of high-density bulk pieces from MnBi and exchange spring improved magnets could be an alternative for some technological applications, which will be shown.

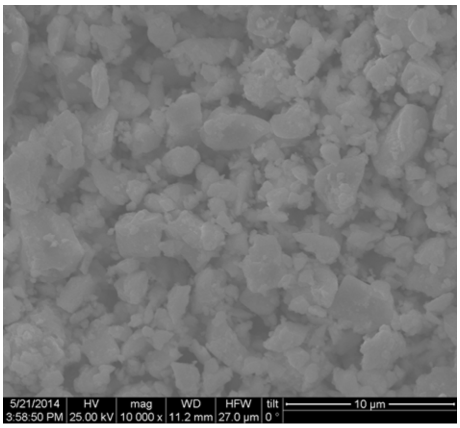

Fig. 1 SEM image of LEBM MnBi powder, milling time 3 h.

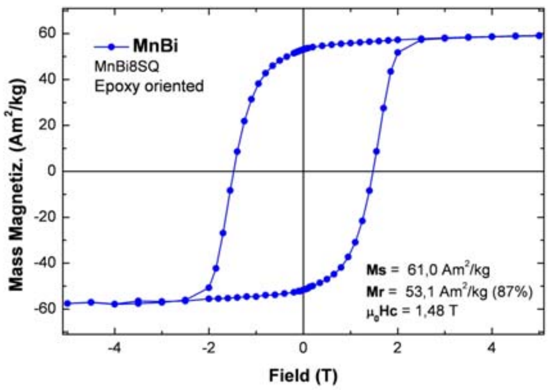

Fig. 2. RT isothermal magnetic loop of MnBi epoxy oriented sample exhibiting high coercivity and rectangular shape.

Acknowledgements. *This work is partially supported by European Commission (REFREEPERMAG project) – GA-NMP3-SL-2012-280670.*

References

[1] N. V. Rama Rao, A. M. Gabay, G. C. Hadjipanayis, J. Phys. D: Appl. Phys. **46** (2013) 062001
[2] J. Cui, J P Choi, G Li, E Polikarpov, J Darsell, N Overman, M Olszta, D Schreiber, M Bowden, T Droubay, M J Kramer, N A Zarkevich, L L Wang, D D Johnson, M Marinescu, I Takeuchi, Q Z Huang, H Wu, H Reeve, N V Vuong, J P Liu, J. Phys.: Condens. Matter **26** (2014) 064212

* gjoka@ims.demokritos.gr