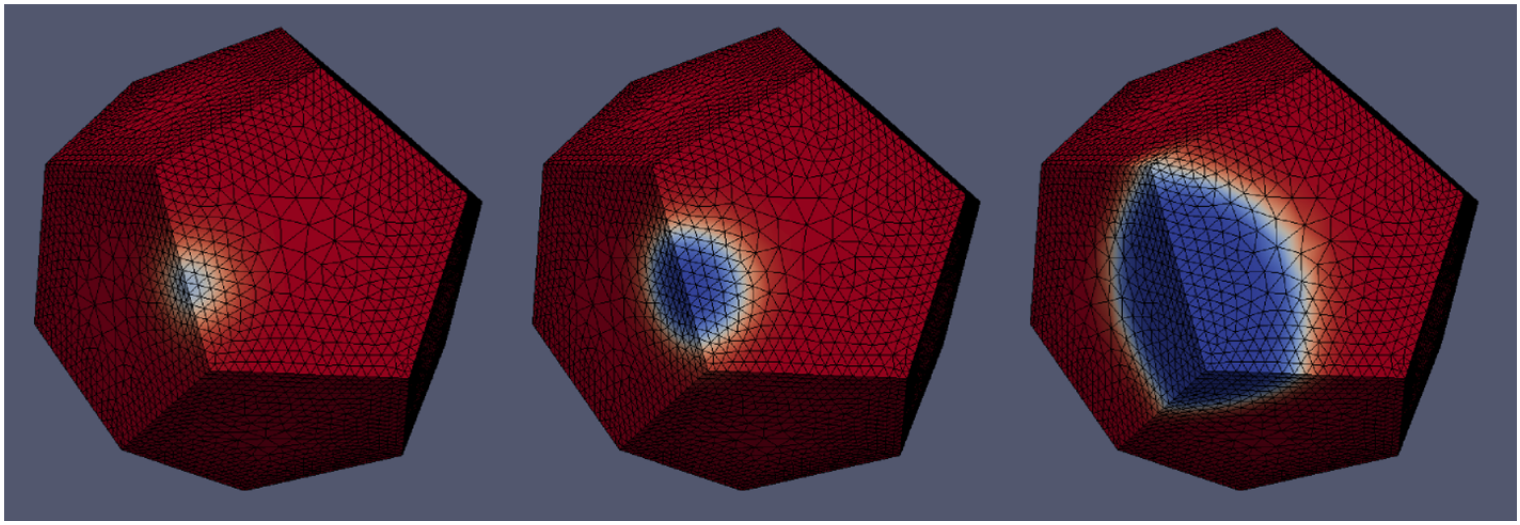
SEVENTH FRAMEWORK PROGRAMME

Replacement and **O**riginal **M**agnet **E**ngineering **O**ptions

ROMEO



Micromagnetic simulation of the reversal of a 50 nm $Nd_2Fe_{14}B$ grain under an increasing applied reverse field. The simulation has been performed using a newly developed fast micromagnetic simulator (Source: FHSTP).

ROMEO *NEWS*

Edition February 2015

Foreword

Permanent magnets (PM) are vital components in an enormous number of domestic and industrial devices, and they are particularly crucial within the rapidly-developing renewable energy sector, where the motors for electric vehicles and the generators in wind turbines require strong highly coercive magnets to operate at temperatures well over 100°C and to withstand high demagnetizing reverse fields. Currently, these magnets are based on rare earth elements predominantly mined and produced in China (>95%).

This dependence of Europe's magnet industries on imports of rare earths from China - particularly for heavy rare earths such as dysprosium that are currently required to assure the high temperature performance of the magnets - is especially critical due to the Chinese export taxes on rare earth raw materials, that severely handicap European producers.

Prof. Dr. Spomenka Kobe, Coordinator ROMEO Project

R&D activities

- Materials Modelling
  - Atomistic modelling of intrinsic properties
  - Micromagnetic modelling of microstructure
  - Analytical modelling of coercivity
  - High-throughput data mining of new Heusler compounds
- Novel Magnets
  - Fabrication of novel ferromagnetic alloys
  - Nd/Dy free ball-milled magnets
  - Hot extruded, rare earth free MnAlC magnets with enhanced properties
- Advanced Characterisation
  - Analysis of basic material properties, magnetic measurements and Electron Holography
  - Characterisation of grain orientation and grain growth processes
  - Corrosion testing
- Microstructure Engineering
  - Electrophoretic deposition
  - Grain-boundary diffusion in thick films
  - Novel particle-coating techniques to reduce oxidation
  - Consolidation of nano-grained materials
  - Study of novel grain-boundary phases
  - Development of original coercivity mechanisms
- Manufacturing Prospects for New Materials
  - Specification of demonstrator concept
  - Preparation of demonstrators with new materials
  - Assessment of large-scale production options and recyclability
- Assessment of Materials for Technical and Lifetime Properties
  - Validation of demonstrators on electrical machines
    - Electromobility
    - Machines for industrial applications for automation
  - Assessment of materials for energy applications (e.g. PM generators)

ROMEO's Structured Approach

In accordance with EU objectives to remove, or greatly reduce, the need for heavy rare earths in permanent magnets, ROMEO

- researches and develops several novel microstructural-engineering strategies that will dramatically improve the properties of magnets based purely on light rare earth elements
- develops a totally rare-earth-free magnet,

aiming to drastically reduce Europe's dependence on Chinese imports while shifting emphasis in magnet manufacturing from a raw-materials-dependent business to one that is essentially knowledge-based, and flourishing in Europe.

The newly developed magnets will be beneficial not only for the industrial partners in ROMEO, but for the whole sector.

The ROMEO consortium assembles the best European academic expertise in permanent magnetism together with world-leading magnet developers, manufacturers and end-users in Europe, while external advisory board members in the USA and Japan bring special expertise and global reach to the ROMEO consortium.

Prof. Dr.
Spomenka Kobe
Jožef Stefan Institute
Department for
Nanostructured Materials

First promising results

Fast micromagnetic simulator for computing hysteresis properties of permanent magnets with complex geometries developed; simulation demonstration of hardening by a superhard shell to negate the effects of surface defects and thermal activation; contributions to total magnetization calculated from first principles showing agreement with experiment.

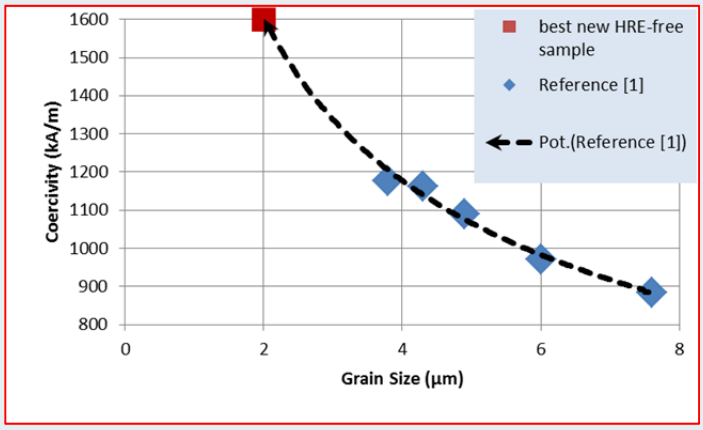
A 30% increase in coercivity (H_CJ) with only 0.6 wt.% of Dy achieved by combining electrophoretic deposition of DyF_3 with a modified grain-boundary diffusion process.

With one HRE lean system, a remanence B_r > 1.3T, and a coercivity H_CJ > 2000 kA/m was achieved.

NdFeB films have been micro-patterned by lithography followed by lift-off, to produce model structures for the study of grain-boundary engineering.

Significant increases in coercivity were achieved with powders produced from strip-cast HRE-free alloys with an average particle size of 1.5-2 µm, produced by jet milling.

HRE free samples with an ultrafine microstructure were prepared and coercivities reached up to 1600 kA/m. A grain size reduced by 50% (4 µm → 2 µm) has led to an increase of about 30% in coercivity.



References [1]K. Üstüner, M. Katter, W. Rodewald, IEEE Trans. Magn. 42 (2006) 2897.

Corrosion resistance of NdFeB powders was greatly enhanced by sol-gel coating.

Substantial improvement of reliability of interpreting EELS spectra of Dy-containing NdFeB magnets.

Promising new magnetic Heusler alloys have been identified by database mining. The magnetic database is accessible at http://aflowlib.herokuapp.com/. New ternary magnetic Heusler compounds (e.g. Co_2MnTi) with high magnetization have been fabricated.

Significant increase in coercivity was observed in milled MnAlC powders, anisotropic MnAlC magnets with promising properties have been produced by hot deformation.

Development of hard magnets:

- Ball-milled, partly oriented Y(Co,Fe) alloy powders with energy products of up to 140 kJ/m^3
- Hot extrusion of oriented MnAl alloys with useful energy product.

Possibilities for collaboration

In case of interest of whatever kind regarding the ROMEO project, including ideas for scientific collaboration in future funded projects or for new application fields, please contact Dr. Jürgen Höck (see last page for contact details). The possibilities for interaction or collaboration will be handled case-by-case.

Where to meet and how to approach ROMEO

TMS 2015: Annual Meeting & Exhibition	March 15-19, 2015	Orlando, Florida, USA
Intermag Asia	May 4-8, 2015	Beijing, China
International Symposium on Hysteresis Modeling HMM	May 18-20, 2015	Iasi, Romania
BITs 4th Annual World Congress of Advanced Materials	May 27-29, 2015	Chongqing, China
20th International Conference on Magnetism 2015 (ICM2015)	July 5-10, 2015	Barcelona, Spain

If you want to meet people from ROMEO, please contact Dr. Jürgen Höck for more information.

Project partners

- Jožef Stefan Institute, Slovenia, Prof. Dr. S. Kobe
- Technical University Darmstadt, Germany, Prof. Dr. O. Gutfleisch
- CNRS, Institut Néel, France, Dr. N. Dempsey, Dr. D. Givord
- Trinity College Dublin, Ireland, Prof. M. Coey, Prof. S. Sanvito
- Vienna University of Technology, Austria, Prof. Dr. J. Fidler
- KOLEKTOR GROUP d.o.o., Slovenia, Dr. B. Saje
- SIEMENS, Germany, Dr. M. Rühring
- Vacuumschmelze GmbH & Co. KG, Germany, K. Uestuener
- VALEO, France, J.-M. Dubus
- DAIMLER AG, Germany, Dr. F. Lampmann
- TEMAS AG, Switzerland, A. Gemperli, Dr. J. Höck
- Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden E.V. (IFW), Germany, Dr. T.G. Woodcock
- Fachhochschule St. Pölten GmbH, Austria, Prof. Dr. Th. Schrefl

External Advisory Board

- Technology Metals Research LLC, Dr. G. Hatch
- University of Birmingham, Prof. I.R. Harris
- Intermetallics Co. Ltd, Dr. M. Sagawa
- University of Nebraska, Prof. D. Sellmyer

Project coordination

Prof. Dr. Spomenka Kobe
Jožef Stefan Institute
Department for Nanostructured Materials
SI-1000 Ljubljana
spomenka.kobe@ijs.si

Dissemination and exploitation

Dr. Jürgen Höck
TEMAS AG
CH-9320 Arbon
Phone: +41 71 446 50 30
juergen.hoeck@temas.ch

For further information consult: www.romeo-fp7.eu

ROMEO Project

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