DONAU UNIVERSITÄT KREMS

Magnetization reversal of large granular magnetic materials

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ABSTRACT

The simulation size in micromagnetism is typically in the range of nanometers to a few micrometers. Computing the hysteresis of a magnetic material often requires much larger scales. Evaluation of full scale Electron Backscatter Diffraction (EBSD) maps in 3D requires the following steps:

(A) EBSD slices of the magnetic material
(B) Reconstruction of granular structure as finite element mesh
(C) Computing magnetization reversal of final structure

Although partial solutions are already available, each of the steps A to C is both time-consuming and challenging.

FUNDING:

FWF Austrian Science Fund

Austrian Science Fund (FWF): I 5266-N

DFG Deutsche Forschungsgemeinschaft German Research Foundation

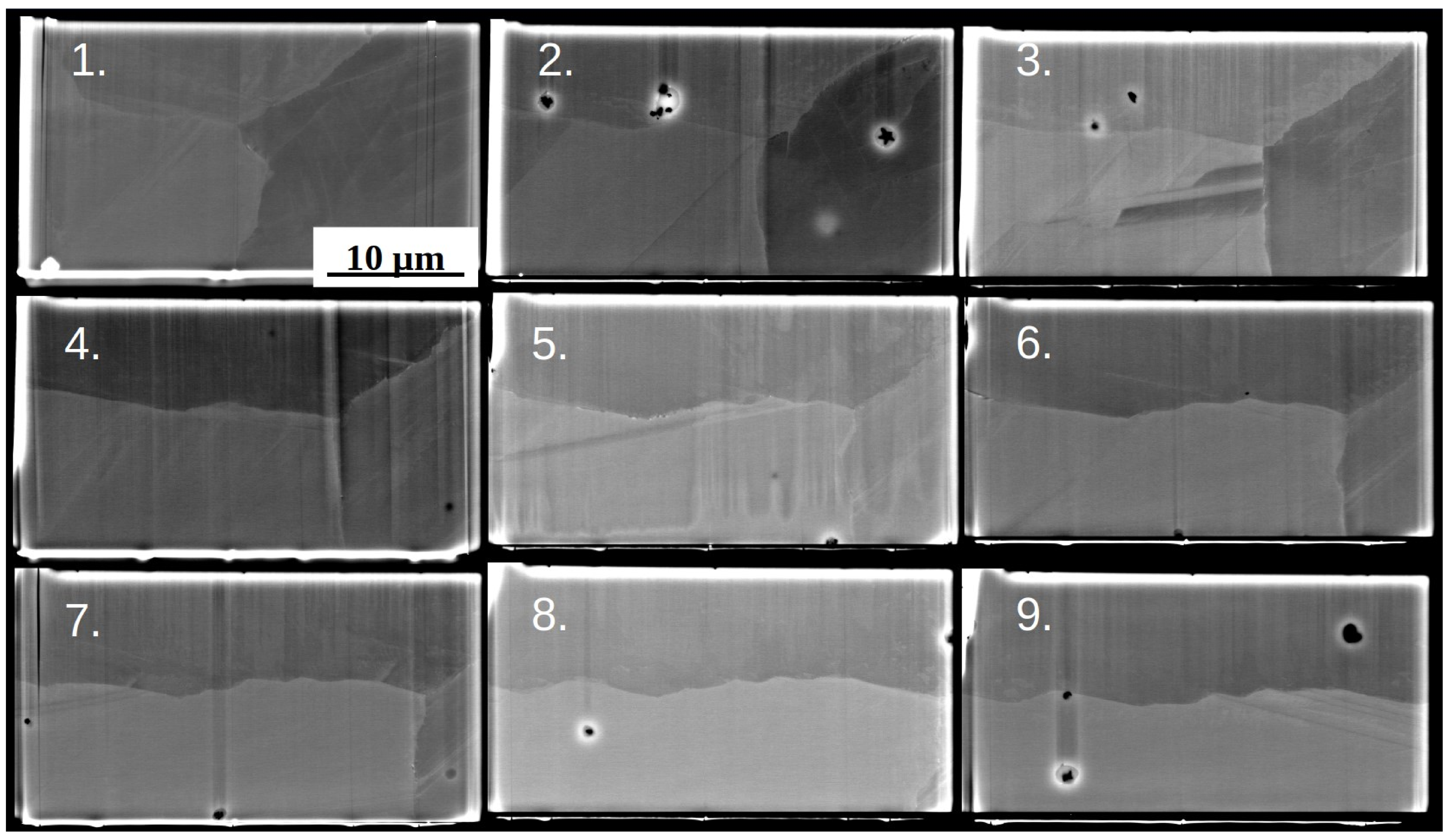
German Research Foundation (DFG): 326646134

Christian Doppler Forschungsgesellschaft

Federal Ministry Republic of Austria Labour and Economy

A) 3D measurement of magnet

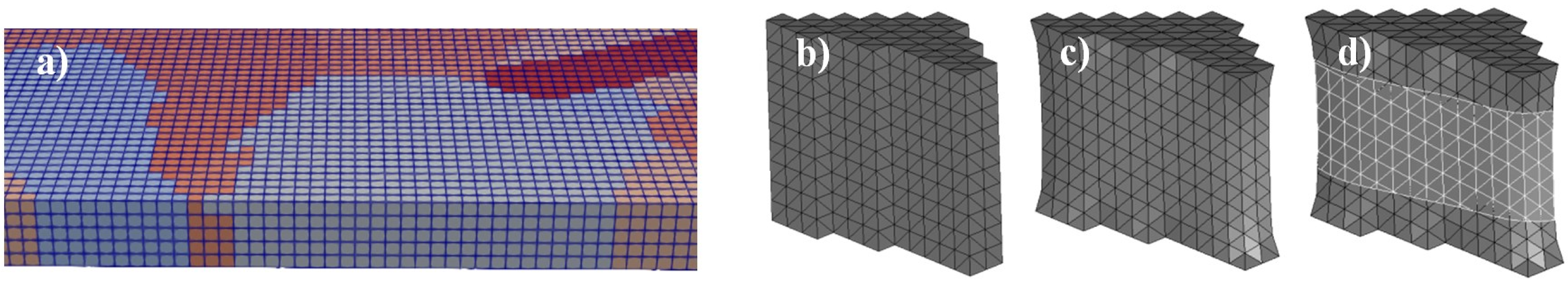
Sequential sectioning is applied using a focused ion beam (FIB) and scanning electron microscope (SEM) on a rotating stage. A major challenge of the method is the correct angular positioning during measurements, while maintaining accurate overlay of Electron Backscatter Diffraction (EBSD) layers.



First successful backscattered electron (BSE) images were taken at IFW Dresden. 9 slices with a distance of about 2 µm are shown from of a sample cube with 30x20x20 μm^3.

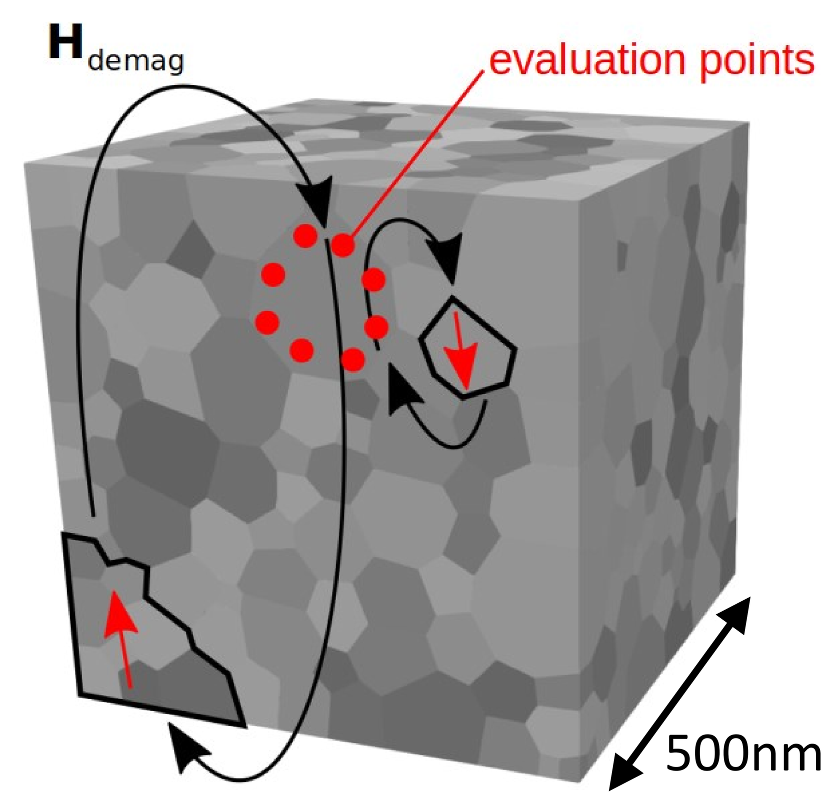
B) Finite element mesh of granular structure

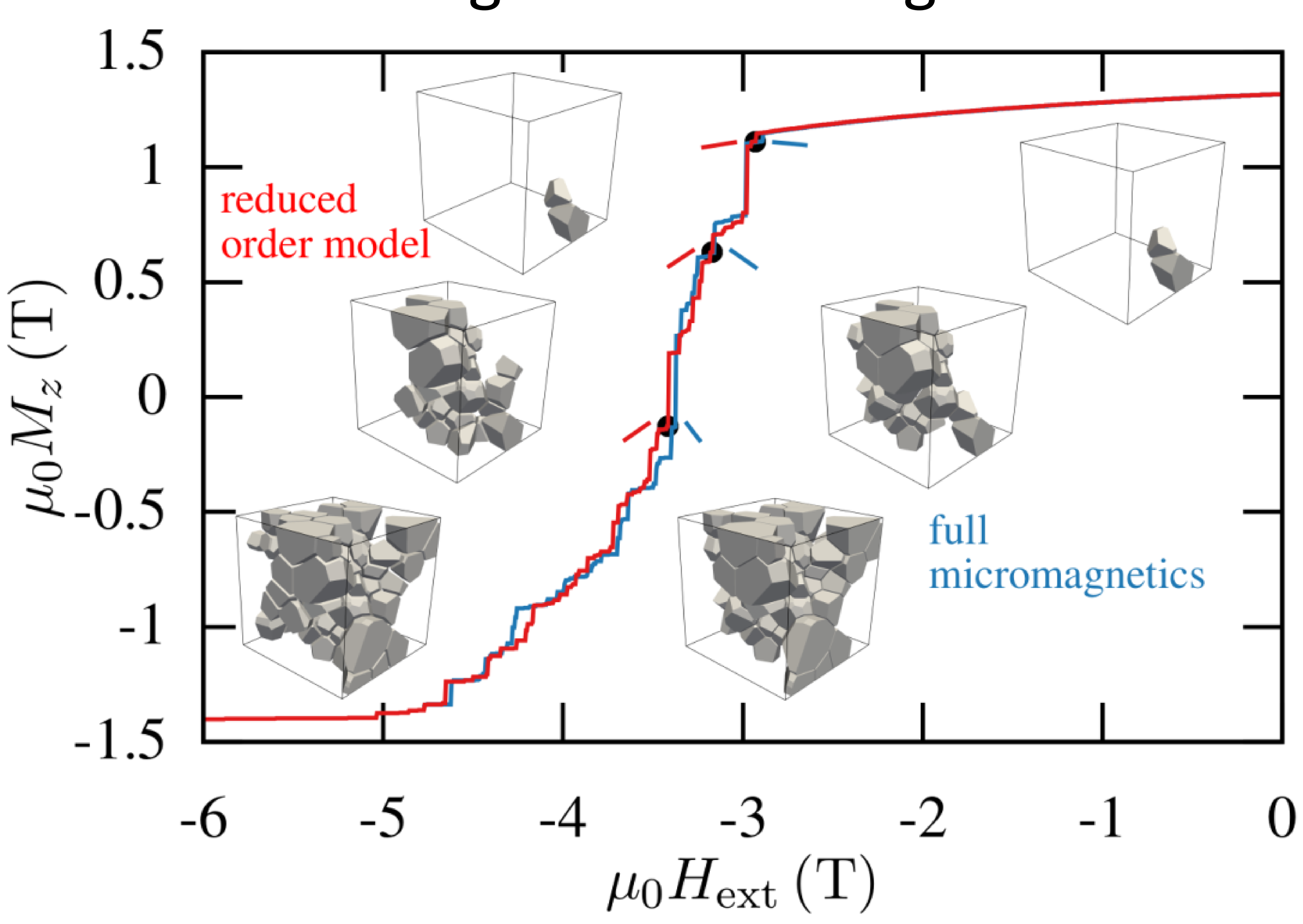
The obtained EBSD layers are stacked with DREAM.3D[1], which results in a voxel dataset[(a)]. The data is organized in solids with the same or similar crystallographic orientation. A simple triangulation is applied whereas a Laplacian smoothing filter reduces sharp edges of the original[(b,c)]. Top and bottom layers still contain sharp edges, which requires postprocessing (cutting, remeshing)[(d)] with the Salome platform[2]. Directly using the triangulation of DREAM.3D is possible as demagnetization effects of the square edges at the top and bottom may be averaged.



C) Reduced order micromagnetic model

Computation of the hysteresis of the generated structure can be done with conventional micromagnetism in small areas of the EBSD data[3]. A reduced order model is able to overcome the size limitation. The model is based on the assumption that a nucleation of a sufficiently large reversed domain immediately leads to the magnetic switching of the entire grain in question[4].





Each grain contains several evaluation points close to the grain boundary, where nucleation typically begins. The total field, as sum of external, demagnetization and exchange field, is computed at each evaluation point to determine the initiation of grain nucleation.

full micromagnetics: 10 h on 3 GPUs
reduced order model: 1.5 h on 1 CPU

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[1] dream3d.bluequartz.net, last visited on 2023-05-22
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