Analysis of magnetization reversal process in polycrystalline ferromagnets by using factor analysis

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Coercivity is an important property to determine the energy conversion efficiency of motors in electric vehicles. To reduce the loss and make electrical vehicle competitive, the control of the coercivity is necessary. However, the description of this parameter based on the microstructure is an open problem due to the many phenomena involved as domain wall pinning. We are interested in developing a machine learning-based formula that describes the microscopic morphology and macroscopic magnetic properties based on the energy of the system. The Landau free energy theory is very hard to be implemented in complex applications. Thus, it is necessary to develop a pseudo free energy that can treat the inhomogeneity in the magnetic domain and metallographic structure to describe the magnetic reversal process in complex polycrystalline systems.

In this work, we use micromagnetic simulation to calculate the external field dependence of magnetization in polycrystalline permalloy and analyze it using unsupervised machine learning. The polycrystals were draw using Voronoi tessellation generators and the boundaries width was fixed for all images. For all simulations, the external magnetic field was set from -0.6T to 0.6T in the x direction. Different grain sizes images (Fig. 1) were used as input to confirm the reproducibility and the accuracy of the method. Later, the image data were processed by FFT and cropped in the high-frequency region to avoid overfitting. To conclude, we use principal component analysis (PCA) and factor analysis to reduce the dimension and find correlations between the images in the data set.

The energy landscape in magnetization reversal process is successfully visualized as a function of features (Fig. 2). It is possible to notice a correlation between the PCA components and the hysteresis loop. The PCA decomposition of the magnetization, in the same direction of the external magnetic field, displays a cleary coercivity dependence. Small grains sizes have smaller components and broader distribution in the feature space, which is inverse proportion to the coercivity. For M_y, the coercivity points are located around the minimum of the feature 1. Our result implies that the magnetic microstructure can display information about the macroscale properties which is the building blocks for the development of the pseudo free energy.

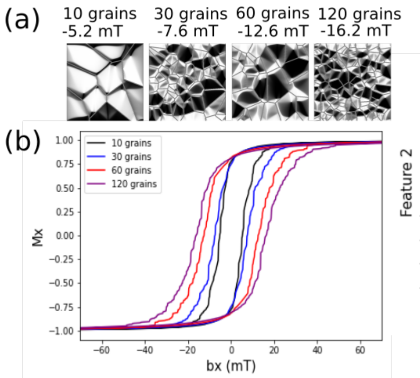

Fig. 1: (a) Magnetic domain structures near coercivity and its respectivite magnetization value. (b) Hysteresis loop.

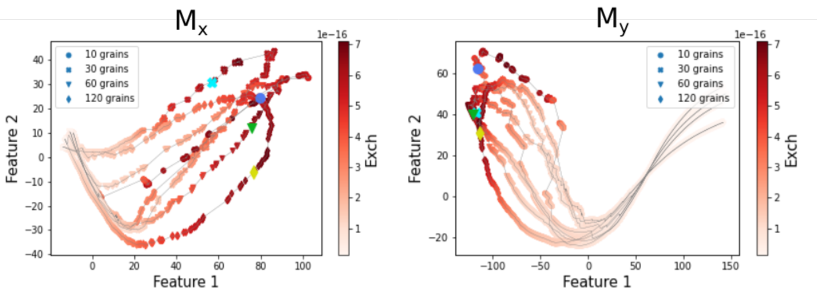

Fig. 2: PCA decomposition of the magnetization reversal process of x and y component. The dark blue, light blue, green and yellow points correspond to the coercivity of 10, 30, 60 and 120 grains permalloy.