Drawing the extended Landau free energy landscape of polycrystalline magnetic thin films

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The understanding of the function of real materials in a heterogeneous system, such as magnetic domain and metallographic structure, has been an outstanding issue in materials science. Thus the development of a consistent and fast analysis method that considers the defects, roughness, crystal sizes, etc. is of utmost importance.[1)] Here, we are developing a machine learning-based formula that can treat the microscopic morphology and describes the macroscopic properties based on the energy of the system. One important application is to describe the coercivity based on the structure and micromagnetic properties.[2)] The Landau free energy theory is arduous to be implemented in complex applications due to the pinning de-pinning process of the domain walls.[3)] Thus, the description of the physics in inhomogeneous polycrystalline systems considering the metallography structure is necessary for advanced material applications.

In this work, we use micromagnetic simulation to calculate the external field dependence of magnetization in polycrystalline permalloy (Fig. 1) and analyze it using unsupervised machine learning to find correlations between the images in the data set. The energy landscape in the magnetization reversal process is successfully visualized as a function of features (Fig. 2). It is an observed correlation between the reduced feature space and the hysteresis loop. The map of the data in lower dimension space of the magnetization, in the same direction of the external magnetic field, displays a clear coercivity dependence. Small grains sizes have smaller components and broader distribution in the feature space, which is inverse proportion to the coercivity. Moreover, the landscape map allows us to access and predict the total energy of the system. Our result implies that the magnetic microstructure can display information about the macroscale properties.

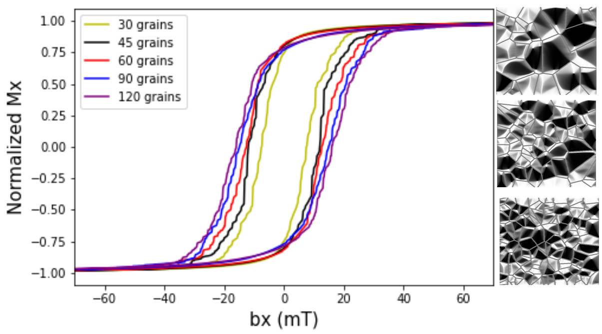

Fig. 1. Hysteresis loop for different grain sizes and magnetic domain structures near coercivity for 30, 60 and 120 grains.

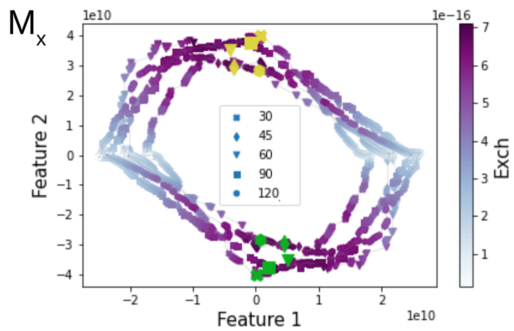

Fig. 2. Reduced feature space of the magnetization reversal process of the x components. The green an yellow points correspond to the positive and negative coercivity.

Reference

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