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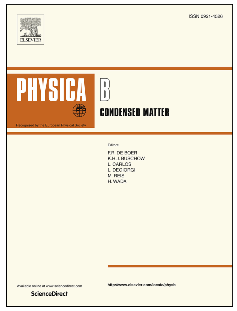

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K.G. Efthimiadis, N. Ntallis

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On the role of the grain size in the magnetic behavior of sintered permanent magnets

K.G. Efthimiadis*, N. Ntallis

Department of Physics, Aristotle University, Thessaloniki, 54124, Greece

**Corresponding author email: kge@auth.gr*

Abstract

In this work the finite elements method is used to simulate, by micromagnetic modeling, the magnetic behavior of sintered anisotropic magnets. Hysteresis loops were simulated for different grain sizes in an oriented multigrain sample. By keeping out other parameters that contribute to the magnetic microstructure, such as the sample size, the grain morphology and the grain boundaries mismatch, it has been found that the grain size affects the magnetic properties only if the grains are exchange-decoupled. In this case, as the grain size decreases, a decrease in the nucleation field of a reverse magnetic domain is observed and an increase in the coercive field due to the pinning of the magnetic domain walls at the grain boundaries.

Keywords

Micromagnetic simulation; Sintered magnets; Grain size; Coercivity

1. Introduction

A well known and widely used method for increasing the coercive field in sintered permanent magnets is to reduce the size of the constituent magnetic grains. There are many and extensive experimental reports [1 - 9] concerning the increase of the coercive field in Fe, Co, Ni or MnBi metal powders, ferrites, and RCo_5, R-Fe-B or Fe-Pd intermetallics, when the grain size is refined by using various techniques, such as ball milling, HDDR, chemical coprecipitation, sol-gel, etc. From the experimental data, empirical relationships between the coercive field (H_c) and the grain size (D) predict inverse linear ($H_c \propto 1/D$) [1] or potential ($H_c \propto 1/D^n$) [7] or logarithmic dependence ($H_c = a - b\ln D$) [4].

There are also many theoretical approaches interpreting the role of the grain size. Ramesh and Srikrishna [10], using a statistical model, predict a logarithmic relationship between the coercivity and the average number of defects on the grain surface. The model is oversimplified, because it draws conclusions by considering the grains as isolated magnetic particles. Herzer [11] assumes that the domain wall pinning at the grain boundaries determines the coercivity, and quantitatively predicts, from the micromagnetic energy balance, an inverse linear relationship between the coercive field and the grain size. But, (a) he does not mention the reason why the grain boundaries become pinning centers and (b) he considers the grains as single domain particles. Schrefl et al. [12] estimate, by numerical micromagnetic calculations, the nucleation field of a reverse magnetic domain in two-dimensional magnetic microstructures. One of the conclusions is that nonmagnetic boundary phases prevent the expansion of a reversed domain nucleus into the neighboring grains. This conclusion is further accepted [13, 14], and it is generally established that the exchange decoupling of the grains improves the coercivity. In this work however (a) the coercive field is qualitatively associated with the nucleation field of a reverse magnetic domain and (b) in the calculations the grain size is related to the sample size, so that the role of the first is not clearly evident. In the work of Sepehri-Amin et al. [15], micromagnetic simulations of the magnetization reversal in sintered anisotropic magnets with exchange-coupled grains demonstrate