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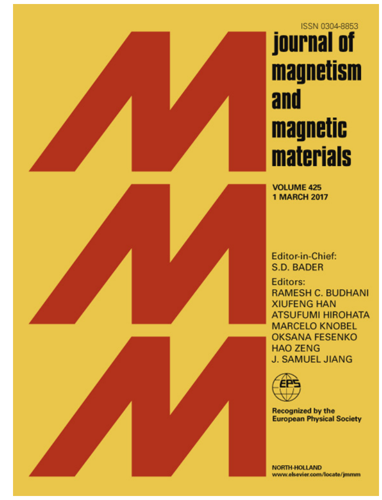

Manipulating the magnetic anisotropy and magnetization dynamics by stress: Numerical calculation and experiment

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Manipulating the magnetic anisotropy and magnetization dynamics by stress: Numerical calculation and experiment

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Abstract

We perform a theoretical and experimental investigation of the magnetic properties and magnetization dynamics of a ferromagnetic magnetostrictive multilayer grown onto a flexible substrate and submitted to external stress. We calculate the magnetic behavior and magnetoimpedance effect for a trilayered system from an approach that considers a magnetic permeability model for planar geometry and a magnetic free energy density which takes into account induced uniaxial and magnetoelastic anisotropy contributions. We verify remarkable modifications of the magnetic anisotropy with external stress, as well as we show that the dynamic magnetic response is strongly affected by these changes. We discuss the magnetic features that lead to modifications of the frequency limits where distinct mechanisms are responsible by the magnetoimpedance variations, enabling us to manipulate the resonance fields. To test the robustness of the approach, we directly compare theoretical results with experimental data. Thus, we provide experimental evidence to confirm the validity of the theoretical approach, as well as to manipulate the resonance fields to tune the MI response according to real applications in devices.

Keywords: Magnetic systems, Ferromagnetic multilayers, Magnetization dynamics, Magnetoimpedance effect

1. Introduction

Magnetoelastic properties in thin films and multilayers have attracted increasing attention in recent decade due to a wide variety of applications in magnetic memory elements [1, 2, 3] and acoustic generation of resonant spin-wave excitations [4, 5]. Moreover, magnetostrictive films and multilayers grown onto flexible substrates appears as remarkable candidates as ground for spintronic devices, mainly due to the manipulable magnetic and mechanical properties [6, 7, 8]. This explains the recent interest in controlling and handling of properties as magnetic anisotropy, dynamic magnetic response, magnetostrictive properties and stress in ferromagnetic flexible nanostructures.

Nowadays, the progress in this field is highly driven by the emergence of magnetic or magnetoelectric devices operating at high frequencies [9, 10]. However, irrespective on the future technological application, the study of the electrical and magnetic properties of magnetostrictive films and multilayers grown onto flexible substrates is essential. In this context, the comprehension of the mechanisms that control the magnetization dynamics is of fundamental importance to understand the basic physical properties in these systems as well as to provide new roads to applications. Traditionally the main technique employed for the characterization of the dynamic magnetic response in nanostructures is the ferromagnetic resonance (FMR). In particular, FMR experiments may provide important information on the magnetic properties and high-frequency magnetic behavior in the saturated regime. On the other side, insights on the dynamic properties in the unsaturated magnetization regime are important to explore local anisotropies, mainly when their manipulation is the focus for technological application [8]. With this spirit, magnetoimpedance (MI) effect arises as an useful tool in the understanding of fundamental properties of the magnetization dynamics [11].

The MI effect corresponds to the change of the complex electric impedance $Z = R + iX$ of a ferromagnetic conductor submitted to an external magnetic field H. Thus, in a typical MI experiment, besides the external field, the sample is also submitted to an alternating magnetic field associated with the probe electric current

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