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S.G. Greculeasa, G. Schinteie, L.M. Hrib, V. Stancu, I. Pasuk, A. Kuncser, V. Kuncser

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Complex exchange coupling mechanisms in SRO/BFO/Fe heterostructures

S.G. Greculeasa, G. Schinteie, L.M. Hrib, V. Stancu, I. Pasuk, A. Kuncser, V. Kuncser

National Institute for Materials Physics, P.O.Box MG-7, 77125, Magurele, Romania

Abstract

Temperature dependent interfacial coupling mechanisms in SRO/BFO/Fe layered structures were investigated. The BFO/Fe heterostructures were prepared by PLD and sputtering, respectively, on the STO(0 0 1) substrate with a 20 nm SRO buffer layer. An annealing treatment in external magnetic field was further applied. Complex characterizations with X-ray diffraction, atomic force microscopy, Transmission Electron Microscopy, Mössbauer spectroscopy, magneto-optic Kerr effect and SQUID magnetometry were performed. Before annealing, the films show good crystallization and epitaxy of the SRO and BFO layers with smooth interfaces. Two coupling mechanisms of the ferromagnetic layers (top Fe and bottom SRO, respectively) to the epitaxial BFO film with mainly antiferromagnetic structure were evidenced in the as deposited samples at low temperatures. Negative exchange bias fields of up to 67(10) Oe and 37(5) Oe at low temperatures were observed for the two ferromagnetic components, respectively, depending on the thickness of the Fe layer. The field annealing treatments induce a specific morphology and magnetic spin structure at the interface of the spacer BFO layer, giving rise to a long range magnetostatic coupling between the two ferromagnetic films, in addition to the interfacial couplings. However, the experimentally evidenced Fe clusters penetrating the BFO/Fe interface toward the BFO layer give support for this interaction. As an additional consequence, a considerable enhancement of both uniaxial and unidirectional anisotropies as well as an increased blocking temperature of exchange bias were obtained. The involved exchange coupling mechanisms were discussed in detail.

Keywords: multiferroic heterostructures, exchange bias, magnetometry, Mössbauer spectroscopy

Corresponding author: V. Kuncser

National Institute for Materials Physics, P.O. Box MG 7, 77125, Magurele, Romania

e-mail: kuncser@infim.ro