Magneto-optical indicator film study of the magnetization of a symmetric spin valve

V.I. Nikitenko, V.S. Gornakov, L.M. Dedukh, Yu.P. Kabanov, A.F. Khapikov
Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka, Moscow District, 142432, Russia

L.H. Bennett, P.J. Chen, R.D. McMichael, M.J. Donahue, L.J. Swartzendruber, A.J. Shapiro, H.J. Brown, W.F. Egelhoff, Jr.
National Institute of Standards and Technology, Gaithersburg, MD, 20899, USA

Abstract - **A magneto-optical indicator film (MOIF) technique is used for direct experimental study of the magnetization reversal process in a symmetric NiO/Co/Cu/NiFe/Cu/Co/NiO spin valve. It is shown for the first time that the reversal of the free center layer proceeds by nonuniform magnetization rotation. The observed switching mechanism is presumed to be associated with the influence of the nonuniform magnetostatic field that follows from surface roughness and the polycrystalline structure of the magnetic layers.**

I. INTRODUCTION

Since the discovery of the giant magnetoresistance (GMR) effect in magnetic multilayers [1], materials with GMR have attracted interest due to their importance both for a fundamental understanding of spin-dependent electron transport and for device applications. Among these materials, symmetric spin valve structures are one of the prime candidates for such applications [2]. They consist of three magnetic layers with different coercivities separated by two non-magnetic spacers. Ideally, the outer two magnetic layers are magnetically pinned while the center magnetic layer is free to switch. Many characteristics that are important for application of symmetric spin valves, such as the switching field, coercivity, and Barkhausen noise, are governed by the magnetization reversal process in the center magnetic layer. Therefore, improvement of these characteristics requires that the magnetic microstructure of the center magnetic layer and its behavior during magnetization reversal be determined and understood. This situation emphasizes the necessity of the development of methods whereby such information can be obtained. In this paper we show that the magneto-optical indicator film (MOIF) technique [3] can be successfully used for a study of the magnetization reversal of the symmetric NiO/Co/Cu/NiFe/Cu/Co/NiO spin valve and, in particular, of its center layer.

II. EXPERIMENTAL

The NiO substrates used in this work were 50 nm thick polycrystalline films, deposited on a Si wafer. The metal films were deposited at room temperature by dc-magnetron sputtering in an Ar pressure of 2 mTorr in a system with a background pressure of 1 x 10^{-8} Torr. The top NiO layer was deposited by sputtering a Ni target with an 85/15 mixture of Ar/O_2.

Magnetic properties of the spin valve were studied with a SQUID magnetometer, magnetoresistance measurements, and the MOIF technique. The MOIF technique places an indicator film (Bi-substituted iron garnet with in-plane anisotropy) on the sample to reveal the domain structure of the sample. The magnetization vectors in the garnet film, which are in the plane in the absence of external fields, develop out-of-plane components if normal components of the stray magnetic field from the sample are present. Stray field components are revealed by the magneto-optical Faraday effect as polarized light is passed through the garnet film and reflected back by an Al underlayer. Viewed in a polarizing microscope, the resulting Faraday picture of the sample gives information about its domain structure. A background subtraction has been carried out for image enhancement [3].

The magnetoresistance measurements were made using a four-point probe with the applied magnetic field parallel to both the direction of current flow and the plane of the foil. All results presented here were obtained at room temperature.

III. RESULTS AND DISCUSSION

Fig. 1 presents a schematic cross section of the symmetric spin valve under study. In this structure the center permalloy layer is free to switch while the outer two cobalt layers are magnetically pinned by antiferromagnetic NiO. Fig. 2 shows

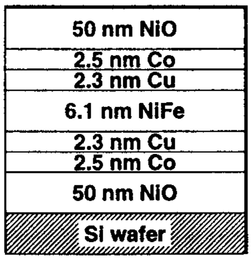
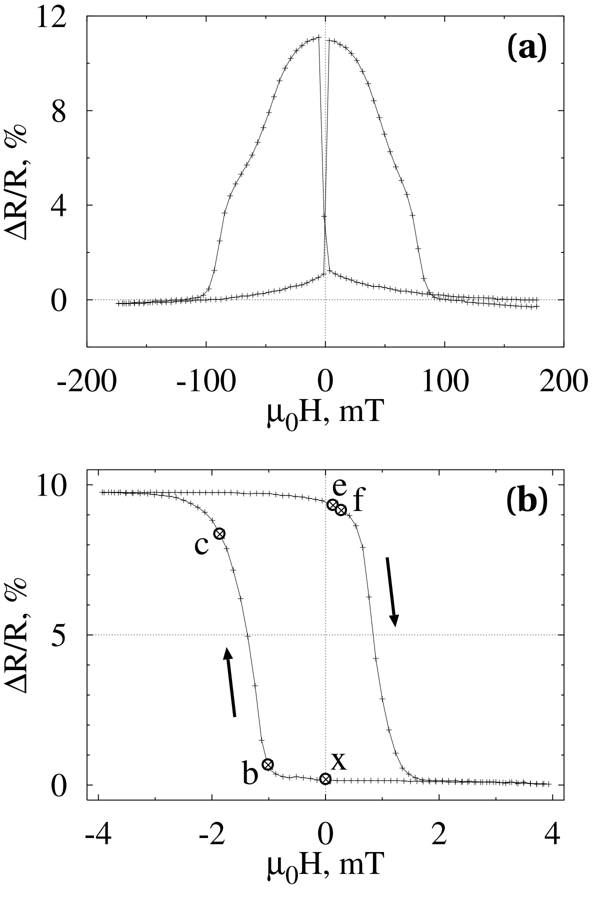


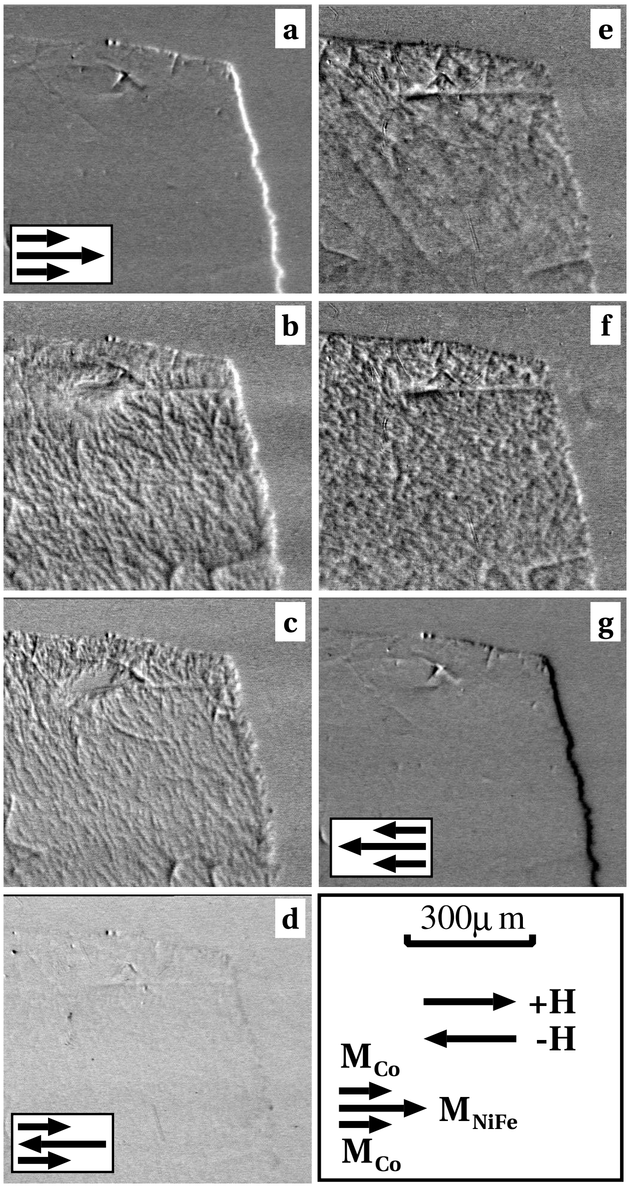
Fig. 1. A schematic cross section of the symmetric spin valve studied in the present investigation.

Manuscript received March 1, 1996.

L.H. Bennett, e-mail bennett@seasva.gwu.edu, phone 703-729-8299, fax 703-729-8251

This work was supported in part by The Russian Foundation for Basic Research under Grant No. 94-02-03815.


(a)
ΔR/R, %
12
8
4
0
-200
-100
0
100
200
μ_0H, mT
(b)
ΔR/R, %
10
5
0
-4
-2
0
2
4
μ_0H, mT
c
b
x
e
f


a
e
b
f
c
g
d
300μ m
+H
-H
M_{Co}
M_{NiFe}
M_{Co}