Current induced domain wall motion in cylindrical nanowires

Current Induced Domain Wall Motion in Cylindrical Nanowires.

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The ability to move magnetic domain walls using spin-polarized currents has spurred considerable interest in the field of data storage devices, particularly in three-dimensional devices. The magnetic racetrack memory is an example of a three-dimensional data storage concept wherein data is stored on magnetic stripes [1]. Regions within the stripe with differing magnetization, which correspond to the 0 and 1 bits, are separated by domain walls (DWs). These stripes can be lithographically patterned either in a vertical fashion or horizontal stripes can be stacked one on top of the other. Even though the concept is appealing and considerable progress has been made towards its realization, the lithographic fabrication as well as the limitation to the speed of a DW within these structures restrict its performance. We utilize the process of electrodeposition into Anodic Aluminium Oxide templates to fabricate vertically standing multisegmented cobalt / nickel (Co/Ni) nanowires [2]. The resulting vertically aligned cylindrical nanowires overcomes the lithographic limitations faced in the realization of a nanostripe-based device. In addition to the ease of fabrication and low cost, the cylindrical nanowires have been predicted to exhibit an absence of Walker breakdown phenomenon, which would otherwise limit the speed of operation [3]. An important step towards the realization of a cylindrical nanowire-based device relies on the demonstration of pinning sites for DWs as well as its pinning and depinning phenomenon. In this paper we report current induced DW motion in cylindrical nanowires with interfaces between cobalt and nickel segments acting as pinning sites. Multisegmented Co/Ni nanowires of 80 nm diameter and a total length of 25 μm, with segments of 800 nm were fabricated by electrodeposition. To perform Magnetoresistance (MR) measurements, single nanowires were isolated and Au electrodes patterned onto them as seen in Fig. 1(a). Using Energy Dispersive X-ray Analysis, the Ni and Co segments within the nanowire were identified (Fig. 1(b)). The MR measurements give an insight into the magnetization reversal process of the nanowire, including the pinning and depinning of DWs. In order to measure the nanowire's MR, current was applied through the outer electrodes, voltage was measured in between the inner electrodes and MR obtained as a function of the applied field (Fig. 1 (a)). The MR of cylindrical nanowires such as Co and Ni display a step in the switching field, resulting from a change of the magnetization direction, which happens with a DW passing through the nanowire. In addition to this, the MR measurements in the Co/Ni nanowires display an interruption of the switching step, indicating the pinning of a DW, which propagates only upon further increase of the applied field as depicted in the black MR curve in Fig. 2. Here, the interruption of the switching indicates a DW pinned at the Co/Ni interface due to the larger stray field emanating from the Co segments [4]. In order to study current induced DW motion, magnetic field and voltage pulses were applied as shown in the bottom of Fig. 2. The blue MR curve in Fig. 2 displays the MR measurement upon application of voltage pulses. Here the nanowire was saturated in one direction with a magnetic field (B-) as seen in the nanowire schematics in Fig. 2. The magnetic field was then gradually reversed (B+) leading to a low nanowire resistance state. At this stage, the magnetization in the Ni segments is oriented in the direction of the initial applied field (B-) whereas in the Co segments, the magnetic structure consists of a vortex like state along the NW, depicted in gray color in Fig. 2, with a core parallel to the direction of the initial applied field. At this low resistance state, the external magnetic field was kept constant and a voltage pulse (5 V_{pp}, 4.7 mA, 600 ns) was applied. Upon the application of the pulse, pinning of a DW was observed (Fig. 2). In order to move this DW to the next pinning site, the external magnetic field was kept constant and a second pulse was applied 10 seconds later. The second pulse leads to another step in the resistance indicating the motion of the DW. Finally the external field's magnitude was continuously increased to saturate the nanowire in the opposite direction (B+). In this paper we utilize multisegmented Co/Ni nanowires to demonstrate for the first time current induced domain wall motion in cylindrical nanowires. The interfaces between the cobalt and nickel segments act as pinning sites and we experimentally demonstrate that the application of a voltage pulse leads to the motion of a domain wall from one pinning site to another pinning site. The demonstration of current induced domain wall motion in cylindrical nanowires is of importance both from a fundamental and technological point of view and could lead towards the realization of a low cost and fast operational three dimensional data storage device.

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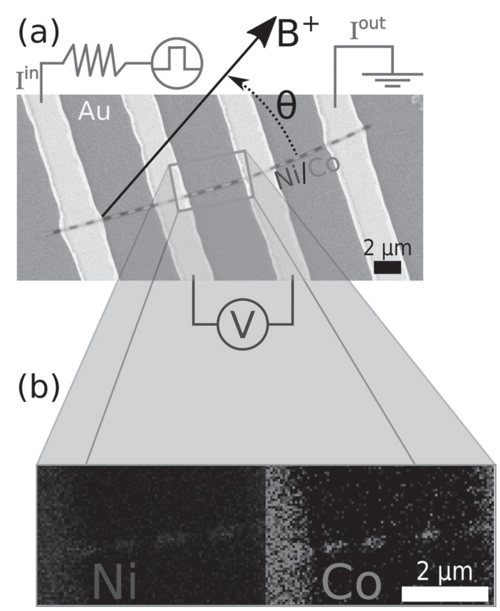

Figure 1. (a) False color SEM image of a multisegmented Co/Ni wire with Au electrical contacts. Current (I) is applied through the outer electrodes and voltage (V) is measured between the inner electrodes. (b) Energy Dispersive X-ray analysis of the area between the inner electrodes.

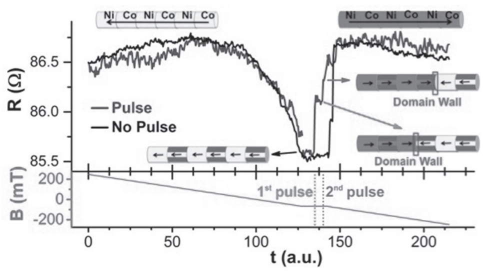

Figure 2. Top: Evolution of the nanowire magnetoresistance without applying a voltage pulse (black curve) and with voltage pulses (blue curve). Bottom: Evolution of the magnetic field during magnetoresistance measurements. Nanowire schematics represent a possible evolution of the magnetization.