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Magneto-resistance in a lithography defined single constrained domain wall spin valve

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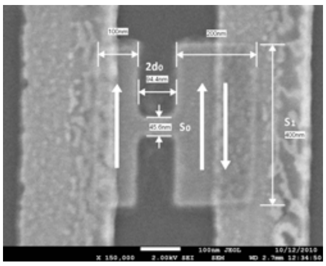
In 1999, Bruno[1] proposed that in nano-structured devices the domain wall width can be constricted by geometric means. A sudden large expansion of the magnetic area will constrict the domain wall as the cost of increasing the area of the domain wall outweighs the exchange interaction. In this work we report the experimental realisation of this proposed structure and show magneto-resistance in a lithographically defined constrain domain wall structure in between two independently switching single magnetic domains. This is the first in-plane transport measurement of an individual magnetic structure completely at the nano-scale using lithography.

Fig. 1 shows the scanning electron microscopy image of the Ni domain wall structure and the Au contact lines, both defined by e-beam lithography and lift-off. The Au structure allows a four point measurement technique to be employed in the measurement of the domain wall structure such that only the Ni structure contributes to the resistance.

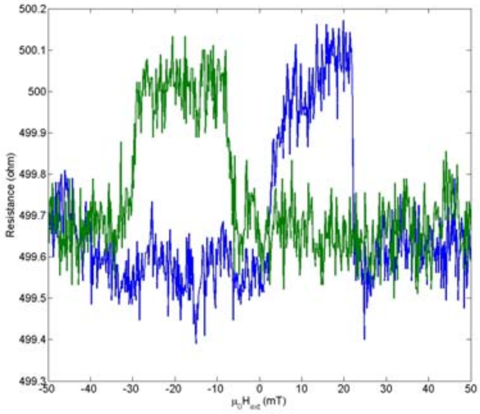
Fig. 2 shows the room temperature magneto-resistance effect of the nano-bridge. The resistance-field pattern shows the typical step-like behaviour of a spin-valve like MR structure in which both sides switch independently. The high coercive side (100 by 400 nm2 domain; left side in Fig. 1) switches at around 25mT and the low coercive side (200 by 400 nm2 domain) switches near 5 mT. These experimental values are slightly smaller than those derived from an OOMMF simulation. Nevertheless, a clear plateau is identified in the MR curve in which the domains are anti-parallel leading to a domain wall in the nano-bridge and hence domain wall magneto-resistance of around 0.1% or 0.4 Ohm.

We have previously shown [2] using a micromagnetic simulation that the domain wall width can be reduced by scaling the geometrical size of the bridge either through a reduction of the s0=s1 ratio or through limiting the bridge length 2d0. Using the experimental ratio of s0=s1 = 0:10, we can calculate the value of the domain wall width once demagnetisation effects are taken into account. The calculated value of the domain wall width is 42 nm and using the equation for domain wall magneto-resistance by Ieda[3], this gives a resistance change of 0.4 Ohm, in agreement with the experiment. Further reduction of the length of the bridge will significantly enhance the magneto-resistance.

[1] P. Bruno, Physical Review Letters 83, 2425 (1999) [2] H. Fangohr, J. P. Zimmermann, R. P. Boardman, D. C. Gonzalez, and C. H. de Groot, Journal of Applied Physics 103, 07D926 (2008). [3] J. Ieda, S. Takahashi, M. Ichimura, H. Imamura, and S. Maekawa, Journal of Magnetism and Magnetic Materials 310, 2058 (2007).



FEG-SEM topview image of H-shaped Ni magnetic domain wall structure with Au leads for four point measurement



Domain Wall Magneto-Resistance curve showing the resistance plateaus corresponding to the anti-parallel alignment of the legs of the H-shaped Ni structure