Domain structure and current induced switching in synthetic antiferromagnetic thin films of CoGd

Synthetic antiferromagnetic multilayers of CoGd with opposite net magnetic moment are grown and investigated by means of Kerr microscopy. The composition is optimized for compensation to be near the room temperature for optimal spin-orbit-torque switching in patterned structures. The effect of charge current pulses on magnetization processes is observed.

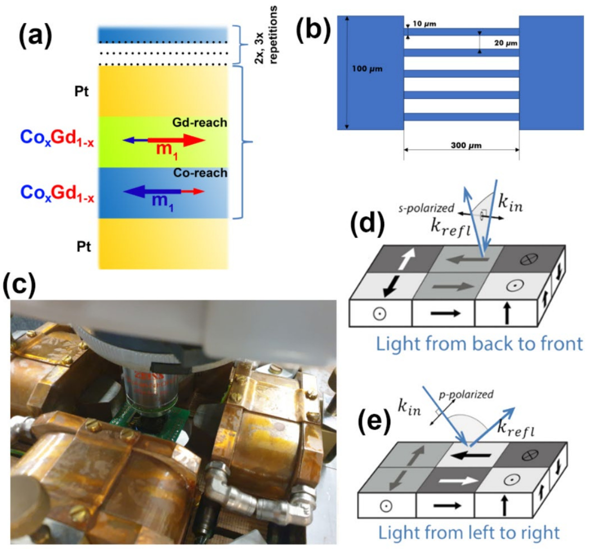
Antiferromagnets (AF), possessing relatively small susceptibility and demonstrating no stray fields are possible candidates for breakthrough on the memory density with no inter-bit influence [1]. However, direct write and read in true antiferromagnets are associated with certain difficulties. Synthetic antiferromagnetic, composed of ferrimagnetic layers with opposite net magnetic moments are more suitable for such memory applications.

Recently, spin orbit torque was shown to be applicable for switching of magnetic state in bilayers of CoGd [2,3]. Two layers of CoGd with different compositions (Co-rich and Gd-rich) grown between thin Pt layers were patterned in cross bars and charge current was passed through. Most of the current flows within the Pt layer and generates a spin torque on CoGd bilayer from top and bottom side, large enough to switch the magnetic state of bilayers, detected as change in Hall resistance.

In our study we have prepared films with the bilayer stack repeated 2 or 3 times (Fig. 1a), which should allow for higher efficiency of spin torque. The thickness of Pt layer was always 2 nm and thickness of independent CoGd layers was from 3 nm (for structures with 3 repetition) to 4 nm (for that with 2 repetition). We have optimized the composition of CoGd layers to have compensated films near the room temperature and patterned films in a shape of wires to apply current pulses (Fig. 1b). Magnetic domains were observed by means of magneto-optical Kerr microscopy with opportunity for selective sensitivity [4], determined by polarized light incidence (Fig. 1 d,e). All-directional field application within the sample plane was realized with help of quadrupole coil (Fig. 1 c).

This report presents results on a film with compensation temperature at around 305 K. Fig. 2a demonstrates typical domain structure, observed in zero field after demagnetization in AC field (Kerr sensitivity is shown by red arrow). Optically measured magnetization loop along the wires direction in absence of charge current is presented in Fig. 2b (black curve).

To investigate the influence of the presence of spin orbit torque effect from charge current in Pt and possibility for field-free switching of the magnetization we have applied to the patterned chip the charge current pulses at constant repetition rate of 100 Hz, varying the duration of the pulse (in percent of duty cycle) and its amplitude. Typical pulse profile can be seen in the inset to Fig. 2d: black curve is voltage applied to structure and red curve is actual current passed through. Pulse width was varied from 2 µs to 50 µs.



resistance of the chip is around 500 Ohm). To

Fig. 1 (a) Layer stacks; (b) patterned bar (c) experimental setup for Kerr observations; (d, e) Sensitivity principle in Kerr microscopy evaluate such an opportunity, a series of experiments with pulses of the same amplitude, but different pulse duration and thus different heat per pulse have been performed. As it can be seen from Fig. 2d for the pulses with drastically diverse heat per pulse the coercivity values are not so divergent if the pulse amplitude is kept at the same level, while as a function of current amplitude Hc demonstrates a clear linear trend. This allows to conclude that the reduction in coercive field is associated rather with effect of charge current passing the wires and exciting the magnetization oscillations at domain boundaries.

The resistivity of Pt is usually orders of smaller than that of CoGd, thus the current mostly flows through the Pt layer, what creates additional Oersted field in adjacent CoGd layer. This field is, however, compensated by field of opposite sign generated by Pt layer from other side of CoGd layer. Oersted field emerging from the neighbouring wires is completely compensated for the wire in a middle of the structure as it comes from symmetry reasons (in total we have 5 wires at 20 µm distance from each other) and as we observe no difference in behaviour between the middle wire and wire on a side we may deduct, that the influence of Oersted field on side wires can be also neglected.

The direct effect from charge current pulses on domain structure can be unequivocally seen if pulses are applied in absence of the external field. For that purpose a certain domain pattern was prepared (Fig. 2a) and saved as a reference image. Then a pulse train was sent through the chip and by subtracting the reference image with original domains from live image we can observe only the change in domain structure (Fig. 2 e and f).

These findings allow the deduction that the grown multilayers of CoGd/Pt demonstrate the possibility for current induced switching and can be investigated by means of Kerr microscopy. Further study is in progress.

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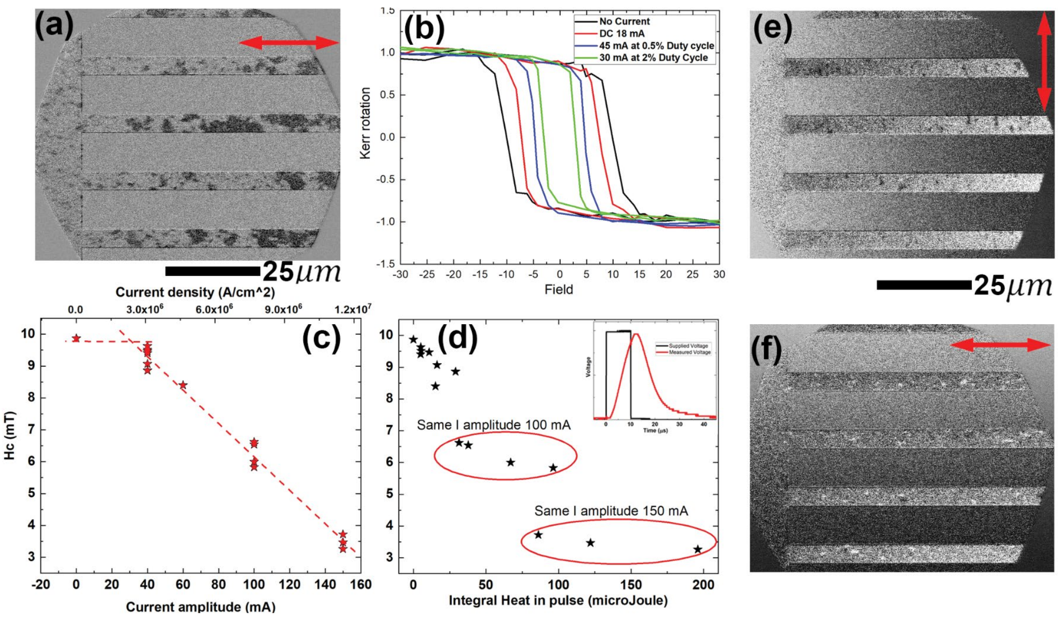

Fig. 2 (a) typical domain structure in demagnetized state; (b) magnetization loops measured along the wire; (c and d) coercive field as a function of current pulse amplitude and Joule heat in pulse; (e and f) change in domain structure after current pulse observed in longitudinal and transversal sensitivities (shown as red arrows).

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