LARGE VOLUME, HIGH PERFOMANCE ELECTROPLATED CO-PT MICROMAGNETS FOR MEMS APPLICATIONS

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Permanent magnet microelectromechanical systems (MEMS), especially hybrid actuators that incorporate both soft and hard magnetic materials, are becoming increasingly important. They offer several advantages over electrostatic actuators such as low voltage and power consumption, large actuation forces and distances, and better reliability in adverse operating conditions [1].

However, incorporating permanent magnets (PM) into MEMS devices is hampered by the challenges associated with finding PM with suitable magnetic characteristics that can be fabricated with relatively large volume by a process integrable/compatible with other surface- and bulk-micromachining. A viable method consists in fabricating the PM by electrodeposition, which is a low temperature, economical, CMOS compatible process that involves only an additive step. Despite the limited high magnetic performance alloys which can be electroplated from aqueous solutions, recently has been successfully demonstrated both as thin films [2] and patterned micromagnets [3] that by employing suitable deposition conditions, Co-Pt (20 at % Pt) alloys with remarkable magnetic characteristics could be deposited.

In this work, large volume Co-Pt micron-size magnets have been deposited by electrodeposition in a photolithographically defined mold. Electroplating was carried out galvanostatically (I =10-50 mA/cm^2) from a quiescent amino-citrate bath [2], with pH=8 and temperature T= 65 ºC. The underlayer consisted of well-textured Cu(111) sputter deposited onto hydrogen terminated Si(110). The mold has a thickness of approximately 20 μm, a length (L) of 1000 μm while the width (W) was varied from 120 to 180 μm in order to study the influence of aspect ratio (H_{mag}/W). Also, the distance between neighboring magnets was varied from 20 to 50 in order to investigate the role of magnetostatic interactions on magnetic properties.

As shown in Fig. 1, large volume micron-size magnets with height (H_{mag}) of about 15 μm were successfully fabricated by batch electroplating.

Magnetic properties of as deposited Co-Pt magnets were measured using a Vibrating Sample Magnetometer (VSM, Lake Shore). Because we expected [3] these magnets to have perpendicular anisotropy, only out-of plane hysteresis curves were acquired. A typical example is shown in Fig.1(a), specifically for magnets with dimensions: L=1000 μm, W=120 μm and H=15 μm. As can be observed, due to the limited magnetic field available, the sample is not saturated, therefore true magnetic saturation, remanence, and at some extent, possibly even coercivity were not determined. However, with this proviso, it is noted the very high coercivity achieved at low temperature for as-deposited Co-Pt micron-size magnets. The separation between magnets and current density do not play a significant role in terms of magnetic properties. Due to the reduction of the demagnetizing field, the increase in the aspect ratio H/W increases moderately the coercivity, reaching values as high as 4.6 kOe.

Although it is difficult so far, to quantify the true retentivity with available data, the values obtained for coercivity (highest reported for plated PM) together with the advantages of plating, make this alloy a very promising candidate for permanent magnet MEMS applications.

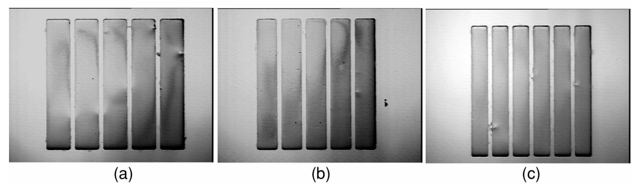

Fig.1 Optical image of electroplated Co-Pt micromagnets with L=1000 μm, H_{mag} =15 μm, and W=180 μm, 150 μm, and 120 μm, (a), (b), and (c), respectively. The separation between magnets is 30 μm.

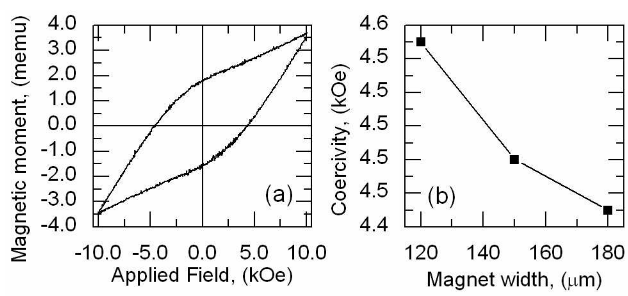

Fig.2 (a) Hysteresis loop in the perpendicular direction for micromagnet with dimensions L=1000 μm, W=120 μm and H_{mag} =15 μm. (b) Evolution of coercivity in the perpendicular direction as a function of magnet width (W).

REFERENCES

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