Hybrid Spintronic-MEMS Devices

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Abstract

This work reports on our latest developments about the integration of spintronic sensors with micro- and nanoelectromechanical systems (MEMS and NEMS) devices, including (i) state-of-art magnetic tunnel junctions (MTJ) embedded in flexible probes for non-planar geometry applications, (ii) magnetic field modulators based on large displacement micromechanical actuators, (iii) micromachined silicon tips with spin valves for brain activity recording and monitoring, and (iv) atomic force microscopy (AFM) cantilevers with sub-µm magnetic sensors at their tips for scanning magnetoresistance-based applications. To illustrate some of those results here, we managed to integrate for the first time MTJ sensing devices with magnetoresistance responses above 150% on flexible substrates, as opposed to previous attempts in which figures below 53% have been obtained [1]-[3]. These are able to bend and conform to non-planar geometries, non-conformal and hard-to-reach regions of space for magnetic sensors processed in conventional rigid substrates, paving the way for new spintronic applications. Their fabrication process is based on polyimide (PI) materials due to their flexibility, thermal stability, chemical resistance, high mechanical modulus, and biocompatibility. Magnetoresistive performance is characterized in terms of controlled mechanical load conditions. The fabrication summarized in Fig. 1 begins with the definition of the MTJ sensors on a PI layer atop SiO_2/Si. The MTJ stack is patterned by photolithography/ion milling and annealed to obtain magnetic sensors as detailed elsewhere for rigid substrates [4]. The subsequent step is another PI coating acting as encapsulation. The PI layers are patterned to define the shape of the flexible device and probes are finally detached from the rigid substrate by means of HF vapor that selectively removes the underlying sacrificial layer. The overall flexible probe thickness is slightly larger than 20 µm. Layouts of devices fabricated using such technology are shown in Figs. (2) and (3), corresponding to long magnetic sensing stripes and neural insertion probes, respectively. The stripes consist of ca. 50-mm-long, 4.5-mm-wide structures with MTJ arrays located at their centers, each MTJ connected in a 4-wire configuration, and are used to analyze magnetoresistive performance as a function of mechanical loading. As for the neural insertion/magnetic recording probes, Fig. (3), they consist of ca. 30-mm-long devices with an opening of 90 µm at one end, compatible with surgery tools used for brain insertion. Devices comprising square-shaped impedance electrodes with 30 µm and MTJ sensors with pillars ranging from 4 to 20 µm have been processed, Figs. (4) and (5). Figure (6) shows the transfer curve of a sensor with area (pillar dimension), A, of 8x8 μm^2 in a released, unloaded probe with resistance, R_{min}, magnetoresistance ratio, MR, and sensitivity, dV/dH, of 145 □, 171% and 250 µV/Oe, respectively.

References

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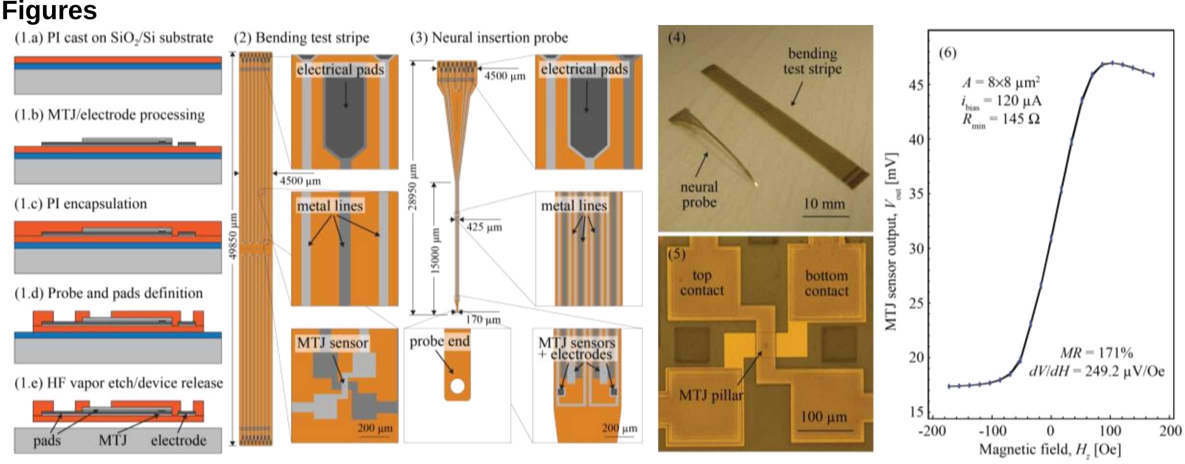
Figures



Figures (1). Fabrication schematics of flexible probes with magnetic sensors, (2)-(3) representative layouts, (4)-(5) fabricated devices and (6) output curves.