Challenges in spintronic platforms for biomedical applications

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Abstract

Integrated spintronic biochip platforms are being developed for portable, point-of-care, diagnostic and cytometric applications [1,2]. Hybrid systems incorporating magnetoresistive sensors are applied to neuroelectronic studies and biomedical imaging, namely magnetoencephalography and magnetocardiography. Lab-on-a-chip MR-based platforms are under development to perform biological studies at the single molecule level. This review introduces and discusses the potential and main characteristics of those MR-based biomedical devices, comparing to the existing technologies, while giving particular examples of targeted applications. Applications to the detection of DNA hybridization events (DNA-chips) [3] and antibody-antigen recognition at immunoassays (immuno-chips) [4] are discussed. Particular examples for cell free DNA and genomic sequences detection, for pathogen (*Salmonella enteritidis*, see Fig.1) detection and for flow cytometry (separation and counting) of CD34+ magnetically labeled cells coming from bone marrow or cord blood samples are given. Moreover, lateral immuno-assay configurations where analytes are labeled with magnetic nanoparticles are discussed. For biomedical imaging applications, field sensitivity is being pushed towards 1pT/sqrt(Hz) and below in hybrid devices incorporating flux guides with the magnetoresistive element allowing the direct detection of bio-magnetic fields (from brain and heart). For neuroelectronic applications, sensors are being incorporated in microelectrode arrays (Si and polyimide) to record spontaneous or stimulated neural activity (in vitro and in vivo, see Fig.2).

References

[1] P. P. Freitas, F. A. Cardoso, V. C. Martins, S. A. M. Martins, J. Loureiro, J. Amaral, R. C. Chaves, S.Cardoso, L. P. Fonseca, A. M. Sebastião, M. Pannetier-Lecoeur and C. Fermon “Spintronic platforms for biomedical applications”, Lab Chip, 12, 546-557 (2012)

[2] V.C. Martins, J. Germano, F.A. Cardoso, J. Loureiro, S. Cardoso, L. Sousa, M. Piedade, L.P. Fonseca, P.P. Freitas “Challenges and trends in the development of a magnetoresistive biochip portable platform” Journal of Magnetism and Magnetic Materials, 322, 1655-1663 (2010)

[3] V.C. Martins, F.A. Cardoso, J. Germano, S. Cardoso, L. Sousa, M. Piedade, P.P. Freitas, L.P. Fonseca “Femtomolar Limit of Detection with a Magnetoresistive Biochip” Biosensors and Bioelectronics, 24, 2690-2695 (2009)

[4] Sofia A. M. Martins, Verónica C. Martins, Filipe A. Cardoso, Paulo P. Freitas, Luís P. Fonseca, “Waterborne Pathogen Detection Using a Magnetoresistive Immuno-Chip”, in Molecular Biological Technologies for Ocean Sensing (Sonia Tiquia, ed.), Springer Protocols Handbooks series, Humana Press, 263-288 (2012)

Figures

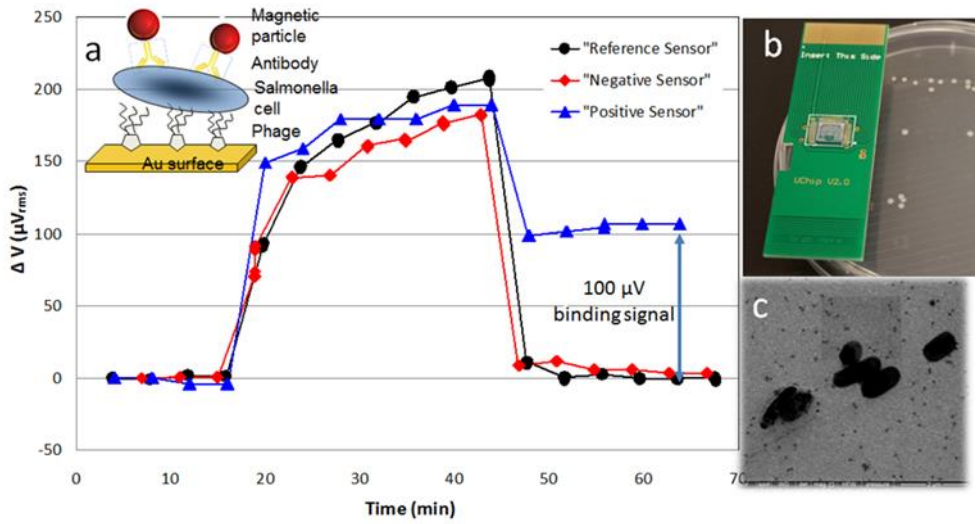

Figure 1 Phage-based magnetoresitive biochip measurements performed on an electronic reader. (a) Measurement curves for different sensors (Reference sensor – no probe; Positive sensor – specific phage for *Salmonella*; Negative sensor – phage for Campylobacter) on the same chip for a *Salmonella* sample analysis. (b) Picture from the biochip over a culture plate with grown Salmonella colonies. (c) SEM picture from a gold surface with immobilize bacteriophage recognizing *Salmonella* cells.

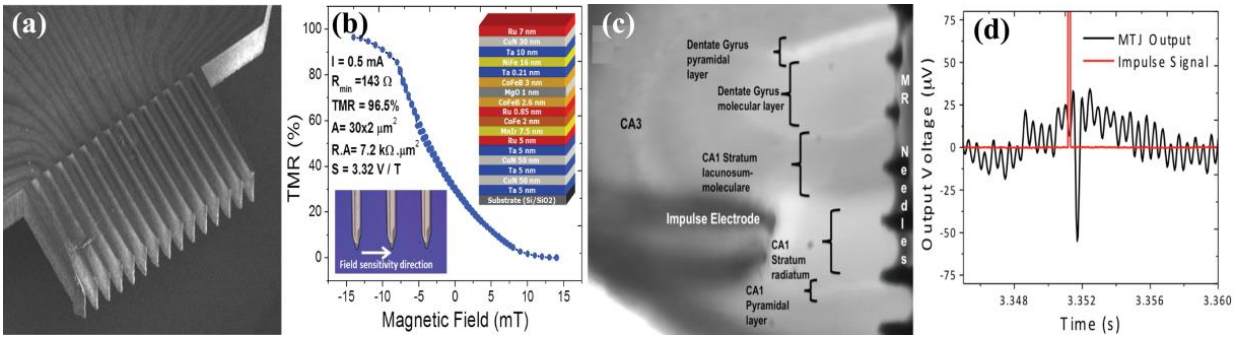

Figure 2. (a) SEM image of the probe shafts with MR sensors, (b) transfer curve of a used MTJ sensors and its structure. (c) MR needles array with respect to the different hippocampus structures and (d) sensor output after an impulse in the CA1 brain region.