

Sujet : Lecture de mémoires magnétiques au niveau des cellules bits sans utiliser l'accès électrique conventionnel



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Contexte



Décryptage

Documentation en ligne

Methodology of backside preparation applied on a MRAM to lead a logical investigation with a near-field probe

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an MRAM Cell, Following a Backside Opening, to Extract Logical Data

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Abstract

This paper presents a method for the preparation of a magnetic random access memory (MRAM) whose data are stored in magnetic tunnel junctions (MTJ) as resistance states, in order to read them by near-field probing. The goal is to be able to visualize a difference of resistance between bits at '0' and at '1' thanks to the current passing through several MTJs. To do so, the MRAM needs to be prepared to create an electrical access to both sides of the MTJs. The main issue is the polishing of both sides as the stack of metallization being less than 10 μm thick. A chemical etch would in that case be encouraged by literature but we take a different approach since we choose to open further than the transistors. The preferred method is a backside preparation technique that creates a bevel allowing us to access the bottom side of the MTJs through vias and the top of them thanks to the bitlines. Since the resulting chip no longer has electrical connections, we also create a dedicated electrical path thanks to a focused ion beam (FIB) operation. At the end, it is then possible to collect the current flowing through the MTJs with a near-field probe.

To probe the MTJs resistance, two near-field techniques are investigated: conductive atomic force microscopy (C-AFM) and scanning spreading resistance microscopy (SSRM). C-AFM provides a quite high resistivity probably due to its sensitivity to contact resistance. Using SSRM, a resistance of 12 - 16 kΩ and 17 - 22 kΩ were determined for '0' and '1' bits, which is in agreement with literature.

1. Introduction

Among memory devices, the magnetic random access memory (MRAM) is attractive because it offers a low-consumption memory point that does not need systematic refreshing thanks to the last technology developments in the field. This makes this memory category able to preserve a data in absence of any power supply, to guarantee a very low access time, and to give a certain immunity regarding energetic radiation compared to traditional memories [1]. Thanks to its advantages, MRAM is used increasingly. The need to study it then arises for data protection and deciphering aspects.

The MRAM is read by a current passing through it thanks to the integrated operations on data content of such embedded memory. It is extremely complex, and generally, electrical operations on data content of such embedded memory are banned for any abnormal activity (e.g. triggering of data erasure during an unauthorized data access). The goal of this paper is to propose a solution to access the data in order to reveal the physical properties of the technology in order to reveal the data contents. Several ways of investigation, whether it's destructive or not, already exist on various memory devices. For example, for a non-destructive analysis, the use of a SRAM of photoelectric laser stimulation (PLS) [2], photo emission (PE) microscopy [3] and thermal laser stimulation (TLS) [4] are possible. A comparison of the two and of electro-optical frequency mapping (EOPFM) were also compared for a static random access memory (SRAM) readout [5]. A common destructive way to lead a logical investigation is to use passive voltage contrast

(PVC) in a scanning electron microscope (SEM). It relies on the electron-beam charge-up effect that makes the grounded structure brighter than the floating structure; it has been experimented on flash memories [6],[7]. Moreover, electrochemical ways have also been tested such as selective staining followed by SEM imaging on EEPROM and Flash memories [8].

Another solution explored, which we will also describe, is the use of an AFM. Applications on EEPROM have been conducted with scanning kelvin probe microscopy (SKPM) [9], scanning capacitance microscopy (SCM) [10] and scanning nonlinear dielectric microscopy [11] to read its data contents.

However, MRAM have yet to be read without the use of their conventional electrical access.

In this context, the originality of the approach developed further, is to propose a methodology to collect information, contained at bit-cell level, using techniques derived from atomic force microscopy (AFM) and more particularly conductive AFM (C-AFM) and scanning spreading resistance microscopy (SSRM) to probe the conduction state of the MTJ, state which defines the data stored in the MRAM. These electrical modes derived from AFM are particularly suitable to investigate current at bit cell due to their spatial resolution (around a nanometre) and their high current sensitivity (up to 100 fA for C-AFM).

The present study is focused on the investigation of the electrical properties of MTJs integrated in commercial memories using C-AFM, as done on magnetically saturated MTJs [12], or using SSRM classically used to analyse 2D carrier profiles [13]. A sample preparation method has been developed for this purpose and is presented in this paper.

A solution to access the data is to explore the physical properties of the technology in order to reveal the data contents. Several ways of investigation, whether it is destructive or not, already exist on various memory devices. For a non-destructive analysis, static random access memory (SRAM) were investigated by photoelectric laser stimulation (PLS) [1], photon emission (PE) microscopy, thermal laser stimulation (TLS) and electro-optical frequency mapping (EOPFM) [2].

A common destructive way to lead a logical investigation is to use passive voltage contrast (PVC) in a scanning electron microscope (SEM); it has been experimented on flash memories [3]. However, it has not been possible to read the data without using their conventional electrical access.

The originality of the approach developed further is to propose a methodology to collect information, contained at bit-cell level, using nanoprobing and

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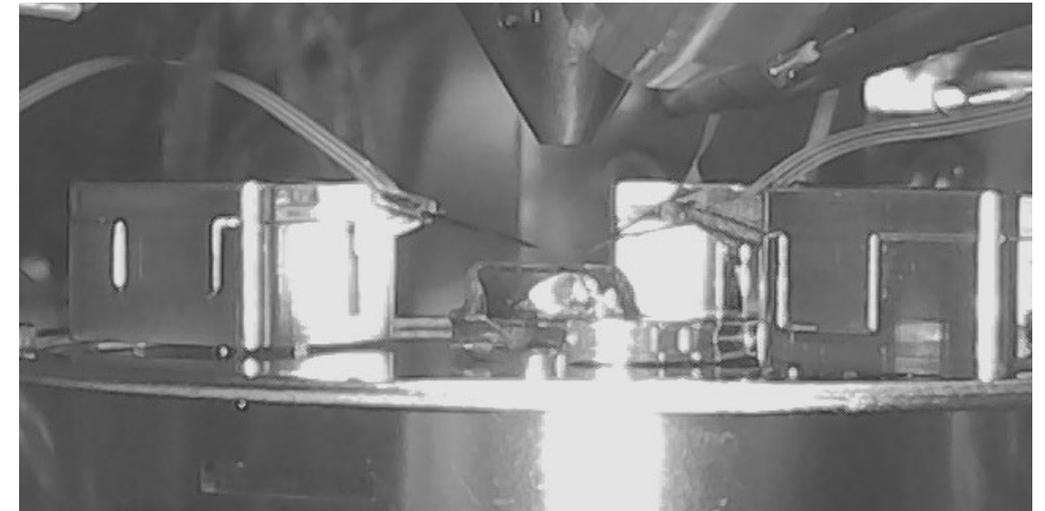
Méthode & Matériel

Préparation de la mémoire : Attaque chimique + Polissage → Destruction de l'accès électrique
Création d'un nouveau → Lecture des informations

Microscope (évolué)



Nanorobots



Point commun : 2 pointes → Contrôle du courant

Résultats avec le Microscope

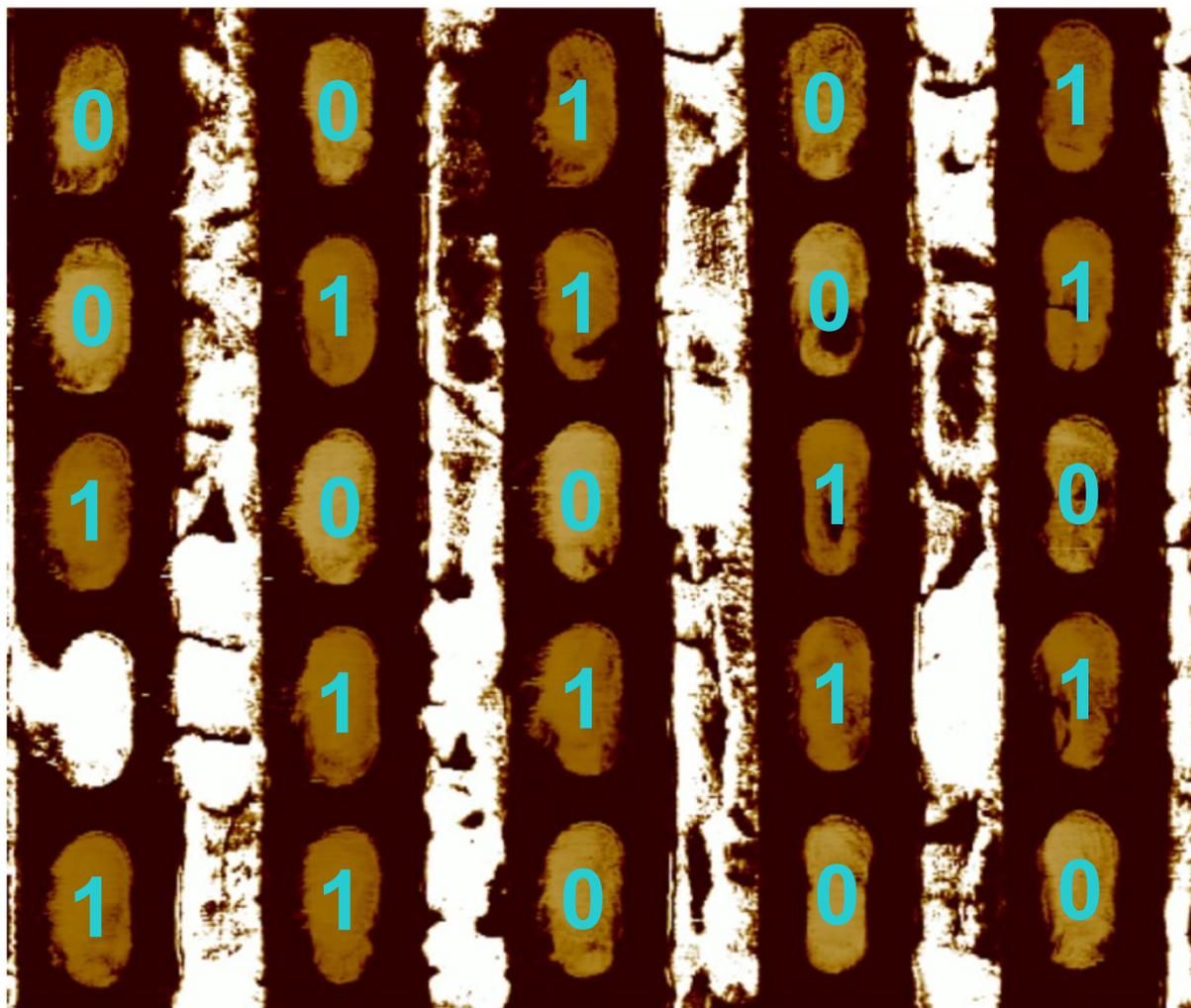


Image de courant : Identification de couleurs



ou



Détails + Nanoprobing → Poster