Magnetic Nanowires for High Density Non-Volatile Memories

With the increasing demand in data storage in mobile applications, the MAGWIRE project proposes a very innovative way in the field of Non-Volatile Solid State Memory. The consortium from the United Kingdom, Germany, Italy, Switzerland and France aims at demonstrating the disruptive concept of the racetrack memory using perpendicular media to pave a new route in data storage applications.

**Main Objectives**

Fast, high capacity, low form factor and low power non-volatile memories are a crucial enabler of today’s ICT. They are already an important part of all electronic systems, representing a growing market segment, and should increase their importance in the future en route towards the “Storage everywhere” society. The market today is divided between Flash NAND and hard disk, which both face severe limitations for the mid term future (2012-2015). The recent discovery that domain walls (DWs) can be moved under a small current without any magnetic field opens a perspective for a paradigm shift in mass storage design. MAGWIRE aims at demonstrating the disruptive concept of the "storage track memory" introduced by IBM, which proposes to store information in DW sequences moving synchronously under current in patterned magnetic tracks. It reproduces the successful data sector memory organization of a hard disk in a solid state device with no mechanically moving parts.

**Outline**

Our project aims at investigating the potential of a race track storage device beyond the 32nm technology node by proposing innovative solutions in the fields of materials with perpendicular anisotropy, DW spin structure engineering, fabrication processes, architecture and CMOS integration. Our ultimate goal is to implement the integrated race track memory device in the standard CMOS 45nm technology node to fully benefit from the cost/scalability economics reflected by Moore’s law. In the EU, pioneering work has been done and key expertise is available but scattered in different academic laboratories of different countries. This project gathers four leading academic experts, the University of Paris-Sud XI in France, EPFL in Switzerland, the Cambridge Cavendish Laboratory in the United Kingdom, and the CNR in Italy, a major semiconductor manufacturer NUMONYX in Italy and a PVD equipment manufacturer for the Magnetic Storage Market, SINGULUS in Germany.
Technical Approach

New successful approaches have to be able to provide higher density portable memory systems at low cost. A novel solution can emerge from approaches based on magnetic domain walls that can be considered as nano-objects separating regions of opposite magnetization in thin ferromagnetic films. Indeed, one crucial breakthrough in spin electronics has recently been achieved regarding the possibility to move magnetic domain walls in magnetic tracks using the sole action of an electrical current (the so-called spin transfer effect) instead of a conventional magnetic field. This important discovery has opened a perspective for a paradigm shift in mass storage design.

Nonetheless several breakthroughs have to be achieved to perform our ultimate objective, which is to investigate and demonstrate the concept of a 2D racetrack memory device, using films with perpendicular anisotropy in the standard CMOS 45nm technology node.

To address this final objective, the implementation of the MAGWIRE project is based on 5 technical work packages: 1) materials, 2) storing/shifting schemes, 3) writing schemes, 4) reading schemes, 5) architectures and CMOS integration. Along this line, our project will pursue the following main objectives: to obtain highly homogeneous materials with perpendicular anisotropy exhibiting low density of intrinsic defects on large scales, to fabricate wires and DW traps compatible with the 45 nm node and beyond, to explore the physical mechanisms of writing, storing, shifting and reading multiple domain walls at low current density and high speed in order to access the capabilities of this technology beyond the 32 nm node, to study integration routes (circuit design, layouts, process flows) for integrated race track memory devices and to study the compatibility of magnetic tracks with CMOS manufacturing processes, to investigate the scalability of this mass storage concept and the related reliability and durability issues due to thermal fatigue and material fatigue in these devices, to realize a demonstrator based on the 45 nm technology node and to compare its performance with conventional mass storage devices (FLASH, HDD) in the same technology, to create a roadmap for the development of race track memory devices, thereby assessing new spin electronic circuit applications.

A STREP is the ideal instrument for the achievement of impacts within the mainstream ICT programme objectives because of its very particular and strong focus on a promising but still immature concept. However, the project faces two main risk elements: emergence of an alternative technology, non reproducibility or lack of scalability, which is a key task that the project must investigate. In any case it will allow building competence on magnetic properties of low-dimensionality structures and new materials, which will be surely useful also for other fields of applications, but if successful in proving that the proposed technology is suitable for mass-storage applications, it could open the way to a very large market considering that the market for NAND Flash alone, used for solid state storage is extrapolate to above 45 billion US$ in 2011 (source: Web-Feet research).

Expected Impact

This project is expected to generate a strong impact in terms of European IPR and mass-storage applications beyond the limits of NAND Flash technology. It will be an essential step in the development of all future ICT applications and in particular for mobile devices.