Doctoral Program in Electronic Engineering (33.th cycle)

Exploring logic-in-memory architectures with skyrmion technology

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Summary

From their experimental verification in 2009 magnetic skyrmions attracted great interest thanks to many intriguing characteristics that this magnetic texture has. Their small dimension suggested a possible application in high density data storage. Their stability and the chance to be moved with low current densities compared with other textures suggested their use as successors of domain walls in racetrack memories. In addition their rich dynamics linked to current stimulus, opened the door to many other applications, starting from boolean logic circuits up to non-boolean computation devices. The vast majority of research on applications of skyrmion technology focused its attention on the proposal of single devices, studying basic logic functions to demonstrate the feasibility of logic with skyrmion technology. At the same time, the study of complex systems based on this technology is still lacking, only few examples in literature have been presented. For other technologies, both electric and magnetic, an important step in their evolution has been the study of the challenges and possibilities that arise from the implementation of logic systems able to solve complex problems. The design of a complex system, indeed, permits to better appreciate the strength of a technology but also to reveal possible drawbacks linked to circuit integration. Moreover, the realization of these systems is useful on one side to have a comparison with already tested and known technologies and on the other to shed light on the design challenges that might appear implementing complex circuits in a specific technology. The presented thesis has the goal to address this issue for skyrmion technology, providing a wider view on skyrmion systems. The thesis starts from the study of possible strategies for complex circuit design, based on skyrmions and later proposes designs in skyrmion technology with increasing complexity. In particular, the design proposals, focuses on logic in memory architectures. Skyrmions are indeed a promising memory technology. This aspect, together with the possibility to realize logic functions, suggests a preferable application in architectures that embeds both non-volatile memory and logic. Finally, another way to design magnetic circuits employing skyrmion technology has been explored. The proposal done in the last chapter is based on a circuit

structure in which different magnetic technologies can successfully communicate and realize different tasks. This connection allows to design circuits in which different operations of the algorithm are accomplished by different technologies, each one optimized for its own application. The proposal in particular focuses on the demonstration of the interface used to put in communication Perpendicular Nanomagnetic Logic and Skyrmion technology. In the proposed interface the skyrmion technology, that is the memory technology, can pass the information stored in form of skyrmion to perpendicular nanomagnetic logic that realize the logic part of the circuit. The opposite conversion is also demonstrated: the information coming from the Perpendicular Nanomagnetic Logic is translated in skyrmion form to be stored back in memory. This direct interface between the two technologies opens interesting scenarios in which magnetic logic can potentially access with very high bandwidth the magnetic storage without any electrical conversion needed.