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COMPACT MODELING AND HYBRID CIRCUIT DESIGN OF CURRENT INDUCED SWITCHING SPINTRONIC DEVICES FOR LOGIC AND MEMORY APPLICATIONS

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ABSTRACT: The shrinking of complementary metal oxide semiconductor (CMOS) fabrication node below 90 nm leads to high static power in memories and logic circuits due to the increasing leakage currents. Emerging spintronic technology is of great interest to overcome this issue thanks to its non-volatility, high access speed and easy integation with CMOS process. Spin transfer torque (STT), a current-induced switching approach, not only simplifies the switching process but also provides an unprecedented speed and power performances, compared with the field-induced switching. This thesis is dedicated to the compact modelling and hybrid circuit design for current-induced switching spintronic devices. Magnetic tunnel junction (MTJ), the basic element of magnetic random access memory (MRAM), and racetrack memory, a novel concept based on current-induced domain wall (CIDW) motion, are particularly investigated. These spintronic devices and circuits are based on the materials with perpendicular-magnetic-anisotropy (PMA) that promises the deep submicron miniaturization while keeping a high thermal stability. Numbers of physical models and realistic parameters are integrated in the compact modeling to achieve a good agreement with experimental measurements. By using these accurate compact models of PMA STT MTJ and PMA racetrack memory, some magnetic logic and memory applications, such as magnetic full adder (MFA) and content addressable memory (CAM), are designed and simulated. We analyze and assess their performance potential in terms of speed, area and power consumption compared with the conventional circuits. Finally, in order to tackle the capacity bottleneck hindering the wide application, we propose two design optimizations: MLC for MRAM and magnetic field assistance for racetrack memory. This MLC design benefits from the STT stochastic behavior to achieve an ultra-high speed while increasing the density. The racetrack memory with magnetic field assistance is based on the observation that CIDW motion can be triggered below the critical current due to "Walker breakdown" effect. This opens a new route to reduce the propagation current and increase the capacity of racetrack memory beyond the improvements of peripheral circuits or materials.

BIOGRAPHY: 张悦博士，目前在法国国家科学院进行博士后研究，2014年获法国南巴黎大学博士学位。主要研究方向包括磁性随机存储器和赛道存储器集成电路的建模和设计等。已在国际期刊和会议上发表学术论文40余篇，邀请论文4篇，合作出版书籍2部，获最佳论文奖2次，2014年国家优秀自费生奖学金。担任IEEE Trans. Electron Devices、Applied Physics Letters等多家知名学术杂志审稿人。