Spintronics devices for nonvolatile VLSI

Hideo Ohno[1-5]

[1] Laboratory for Nanoelectronics and Spintronics, RIEC, Tohoku University, Sendai 980-8577 Japan
[2] Center for Spintronics Integrated Systems, Tohoku University, Sendai 980-8577 Japan
[3] Center for Innovative Integrated Electronic Systems, Tohoku University, Sendai 980-0845 Japan
[4] Center for Spintronics Research Network, Tohoku University, Sendai, 980-8577 Japan
[5] WPI-Advanced Institute for Materials Research, Tohoku University, Sendai 980-8577 Japan

Here I review two- and three-terminal nano-spintronics nonvolatile devices for VLSI integration. VLSIs can be made high performance and yet standby-power free by using nonvolatile spintronics devices [1)]. The most commonly employed device is magnetic tunnel junction (MTJ), a two-terminal spintronic device that can scale beyond 20 nm with perpendicular CoFeB-MgO [2,3)]. I will describe the development of such devices and its performance together with associated materials and physics issues. While two-terminal configuration is suitable for high density applications, three-terminal configuration allows high speed and relaxed VLSI design constraints compared to the two-terminal counterpart. Of particular interest are three-terminal devices that utilize spin-orbit torque (SOT) switching, which does not require an antiferromagnetically aligned pair of magnetic electrodes as in current-induced domain wall motion devices [4)]. On this front, I will discuss high speed operation of an SOT switching device with a target ferromagnetic pillar having an out-of-plane easy axis [5)] or an in-plane magnetic easy axis collinear with the current flow direction in the underneath heavy-metal [6)]. The magnetization switching is achieved with 500-ps pulses, which is not readily available in two-terminal devices utilizing spin-transfer torque (STT) switching, because STT requires switching current inversely proportional to the switching speed in this speed range. I then report the use of an antiferromagnetic material as a source of spin flow as well as the exchange field. Before, structures for fast SOT switching required a small constant external magnetic field to induce switching, which was an obstacle for application. It has been shown in a (Co/Ni)-multilayer/PtMn structure that one can switch magnetization in the absence of external magnetic field using PtMn as a source of spin [7)], removing this obstacle. I summarize my talk by comparing two- and three-terminal device performance.

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