



Electric-field switching of perpendicular MTJs

A magnetic semiconductor device design that allows for switching magnetization without an external field.

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Applications

- Spin based memory and logic devices
- Stochastic spiking neural network
- Non-volatile memory for conventional devices

Key Benefits & Differentiators

- **No external field** required for operation: ultra-low power consumption and low risk of device breakdown.
- **Bi-directional switching** with electric field only.
- **Wafer scale production**, compatible with current CMOS technology.
- **Geometry**: layered structure similar to today's integrated devices; offers easy fabrication and implementation.

Problem addressed

Writing operations in magnetic tunnel junction (MTJ) structures requires current passing through the tunnel barrier. Currently, electric-field switching of perpendicular-MTJs either use an external magnetic field or spin transfer torques to break the time-reversal symmetry for switching. Novel methods for switching of perpendicular-MTJs without using external fields can aid in lowering power consumption and device breakdowns.

Switching magnetization without external field

Prof. Jianping Wang's group has designed a **synthetic-antiferromagnetic perpendicular magnetic tunnel junction (SAF p-MTJ) structure and electric-field (E-field) switching device that allows for switching magnetization without any externally applied field.**

Unlike existing technologies, this new design relies completely on E-field (without external field and current flow), thereby reducing the switching current density of p-MTJs and realizing spintronic devices with ultra-low power consumptions. As operation of the device does not require passing current through the tunnel barrier, this design reduces the risk of device breakdown. Moreover, the geometry of the design is similar to current integrated devices and is compatible with standard CMOS fabrication technology. Furthermore, by tuning the magnetic anisotropy of the ferromagnetic layer and its thermal stability, researchers have demonstrated telegraphic switching in p-MTJs by the E-field. This thermal-driven telegraphic switching property can be exploited for generating random bit streams for applications in stochastic computing or stochastic spiking neural network systems. Lastly, such E-field-induced thermal driven magnetization switching is preferred for memory applications as it offers scalability and high stability.

Phase of Development

Proof of concept: the perpendicular synthetic antiferromagnetic (p-SAF) structure has been demonstrated in FePd/Ru/FePd/Ta/CoFeB stacks. The electric-field (E-field) switching of p-MTJs with FePd p-SAF has been demonstrated by tuning the interface exchange coupling with the E-field. The E-field induced thermal-driven telegraphic switching has been demonstrated in p-MTJs with FePd SAF structure.

Researchers

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[External Link](http://www.cems.umn.edu) (www.cems.umn.edu)

Publications

Bipolar electric-field switching of perpendicular magnetic tunnel junctions through voltage-controlled exchange coupling arXiv preprint arXiv:1912.10289 (2019).

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