# Magnetic Memory Bits with Perpendicular Magnetization Switched By Current-Induced Spin-Orbit Torques

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## SUMMARY

UCLA researchers in the Department of Electrical and Computer Engineering have developed a novel spin-orbit-torque (SOT)-controlled magnetic random access memory driven by in-plane currents.

## BACKGROUND

Magnetization switching by current-induced spin-orbit torques (SOTs) has been attracting great attention for its potential applications in ultra low power memory and logic devices. The use of SOTs in nonmagnetic metal/ferromagnet/insulator structures allows for a significantly lower write current compared to regular spin-transfer-torque (STT) devices. It can also greatly improve the energy efficiency and scalability for new SOT-based devices such as magnetic random access memory (SOT-MRAM). However, practical use of SOT effects is limited by its requirement of an in-plane external magnetic field, in order to switch ferromagnets with a perpendicular (out-of-plane) magnetization.

## INNOVATION

Researchers at UCLA have developed a novel nonmagnetic metal/ferromagnet/insulator structure which provides a SOT, resulting in zero-field current-induced switching of perpendicular magnetization. The device consists of a ferromagnetic free layer, a ferromagnetic fixed layer, a dielectric tunnel barrier, and a high-spin-orbit-coupling material, and has a structural mirror asymmetry along the in-plane direction. The lateral structural asymmetry effectively replaces the role of the external in-plane magnetic field and eliminates the use of external magnetic fields, bringing SOT-based spintronic devices such as SOT-MRAM closer to practical application.

## APPLICATIONS

- Serves as building blocks for SOT-controlled magnetic random access memory (SOT-MRAM)
- Memory applications to provide high integration density
- Layers of SOT-MRAM may be stacked to increase larger effective density

## ADVANTAGES

- No need for any magnetic bias field
- Reduced design complexity
- More practical for wide application

## STATE OF DEVELOPMENT

The described SOT structure has been tested experimentally.

## PATENT STATUS

| Country | Type | Number | Dated | Case |
|---|---|---|---|---|
| United States Of America | Issued Patent | 9,343,658 | 05/17/2016 | 2014-322 |

## ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- Vertical-Stacked-Array-Transistor (VSAT) for Nonvolatile Memory Devices

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## OTHER INFORMATION

### KEYWORDS

Spin-orbit torque, SOT, magnetic random access memory, MRAM

### CATEGORIZED AS

- **Computer**
  - Hardware
- **Engineering**
  - Engineering

### RELATED CASES

2014-322-0

- Vsat Structure for Nonvolatile Memory Device
- A Read-Disturbance-Free Nonvolatile Content Adressable Memory
- A Self-Organized Critical CMOS Circuit for Computation and Information Processing
- Anti-Ferromagnetic Magneto-Electric Spin-Orbit Read Logic



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