

# Researchers achieve significant breakthrough in topological insulator-based devices for modern spintronic applications

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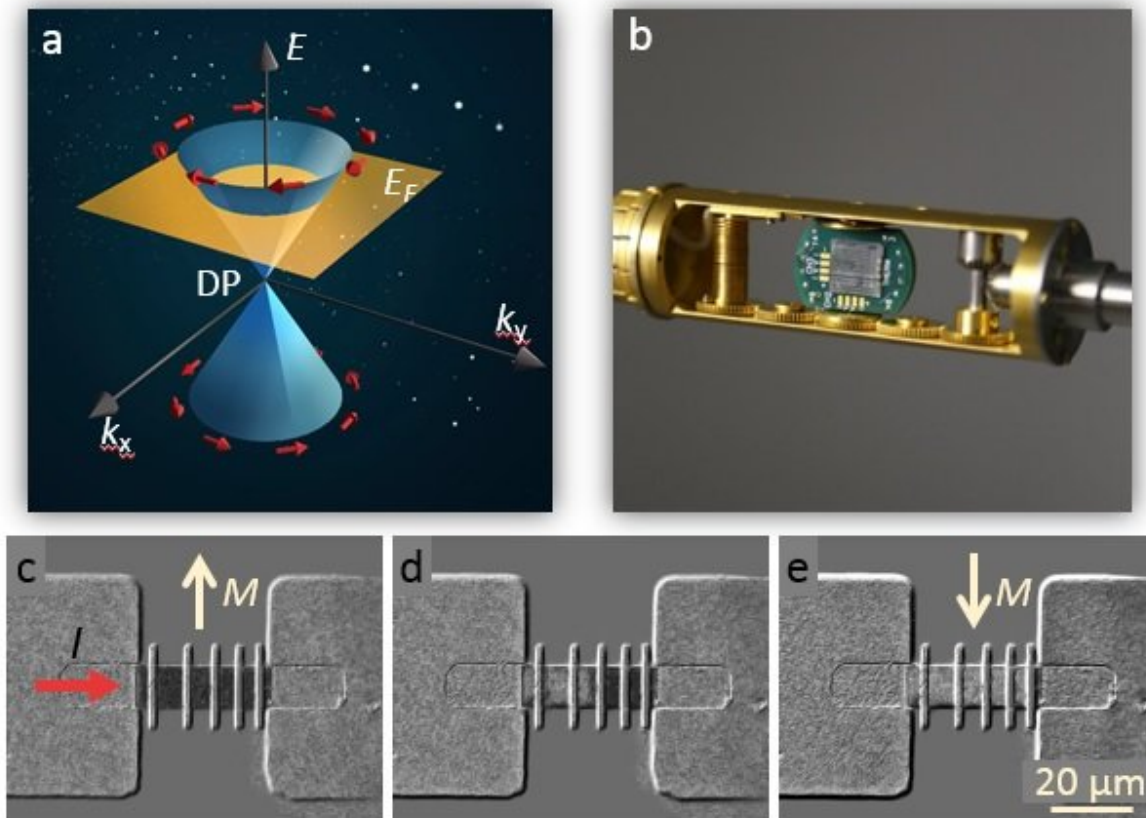


Figure: (a) Schematic diagram illustrating the Dirac cone of topological insulator and spin-momentum locking. (b) Topological insulator/ferromagnet (Bi<sub>2</sub>Se<sub>3</sub>/NiFe) spin-orbit torque devices. (c-e) Magneto-optic Kerr effect (MOKE) images of highly efficient spin-orbit torque driven magnetization switching in Bi<sub>2</sub>Se<sub>3</sub>/NiFe by a pulsed current at room temperature and zero

assistive magnetic field. Credit: National University of Singapore

Realisation of room temperature spin-orbit torque-driven magnetisation switching in topological insulator-ferromagnet heterostructures has promising applications in low power consumption and high integration density memories and logic devices.

The current induced magnetisation switching by spin-orbit torque (SOT) is an important ingredient for modern non-volatile magnetic devices such as magnetic random access memories and logic devices that are required for high performance data storage and computing. As such, researchers around the world are actively searching for novel ways to reduce the present high switching current density in order to achieve highly efficient SOT driven magnetisation switching. Researchers from the National University of Singapore (NUS) have recently made a significant breakthrough in this field of research.

Led by Associate Professor Yang Hyunsoo from the Department of Electrical and Computer Engineering, the NUS research team has, for the first time, successfully demonstrated [room temperature](#) magnetisation switching driven by giant SOTs in topological insulator/conventional ferromagnet ( $\text{Bi}_2\text{Se}_3/\text{NiFe}$ ) heterostructures with an extremely low current density, that can address the issue of scalability and high power consumption needed in modern spintronic devices.

The findings were published in the scientific journal *Nature Communications* on 8 November 2017.

Assoc Prof Yang said, "Our findings can solve the fundamental obstacle of a high switching current in present heavy metal based SOT applications, and this is a big step towards room temperature topological

insulator based spintronic [device](#) applications with ultralow power dissipation and high integration density. We believe our work will greatly invigorate topological insulator-based global research activities from diverse disciplines."

## **Employing novel quantum matter: topological insulators**

Topological insulators are electronic materials that have a bulk band gap like an ordinary insulator, but still support conducting states on their surface, possessing a strong spin-orbit coupling and spin-momentum-locked topological surface states (TSS), on which the electron momentum and spin polarisation directions are strongly locked.

"Due to spin-momentum-locked properties, as charge current flows in the TSS, all electron spins will be fully polarised in a perpendicular direction to the direction of the moving electron. Therefore, a very high efficient spin current generation and thus a giant SOT efficiency are expected in [topological insulators](#)," explained Dr Zhu Dapeng, who is a co-first author of the study and a Research Fellow at the Department.

Taking advantage of TSS is crucial to realise high performance topological insulator based SOT devices. However, in typical topological insulators such as Bi<sub>2</sub>Se<sub>3</sub>, the parasitic bulk states and two dimensional electron gas can contaminate and/or wash out the high SOT efficiency in TSS. In order to overcome this, the research team has identified the TSS dominated SOT effect in ultrathin Bi<sub>2</sub>Se<sub>3</sub> films ( $\leq 8$  nm), exhibiting a large SOT efficiency up to 1.75 at room temperature, which is much larger than the values of  $\sim 0.01$ – $0.3$  in conventional used heavy metals.

## **High performance topological insulator based devices for data storage and computing**

In the traditional heavy metal (such as Pt or Ta)/ferromagnet SOT devices, the current density required for the magnetisation switching is still high, in the order of  $\sim 10^7$ – $10^8$  A/cm<sup>2</sup>, which hinders their use in high performance SOT applications.

The team demonstrated the high efficient current induced magnetisation switching at room temperature using topological insulator Bi<sub>2</sub>Se<sub>3</sub> (8 nm), which can be grown in a wafer scale using molecular beam epitaxy (MBE), with a conventional 3-D ferromagnet NiFe (6 nm), which is widely utilised in various industries.

"Our work successfully presents a significant reduction of switching [current density](#) for the magnetisation switching by utilising the giant SOT effect in Bi<sub>2</sub>Se<sub>3</sub>. The value is about  $6 \times 10^5$  A/cm<sup>2</sup>, which is almost two orders of magnitude smaller than that of heavy metals. This is a major milestone for the ultralow power consumption and high integration density SOT device applications. Moreover, our devices work robustly at room temperature, which breakouts the limit of ultralow working temperature in previous TI device." said Dr Wang Yi of the Department, who is the other co-first author of the study.

"Our magnetisation switching scheme does not require an assistive magnetic field. This makes the topological [insulator](#)/ferromagnet material systems easy to integrate into the well-established industrial technology for magnetic devices," added Assoc Prof Yang.

Moving forward, Assoc Prof Yang and his team are conducting experiments to further decrease the switching current by further refining the materials and structures of the systems, and they are also planning to incorporate and test the technology in core magnetic memory devices. The team hopes to work with industry partners to further explore various applications with this novel material systems.

**More information:** Yi Wang et al. Room temperature magnetization switching in topological insulator-ferromagnet heterostructures by spin-orbit torques, *Nature Communications* (2017). [DOI: 10.1038/s41467-017-01583-4](https://doi.org/10.1038/s41467-017-01583-4)

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