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Scientists develop the next generation of highly efficient memory materials with atom-level control

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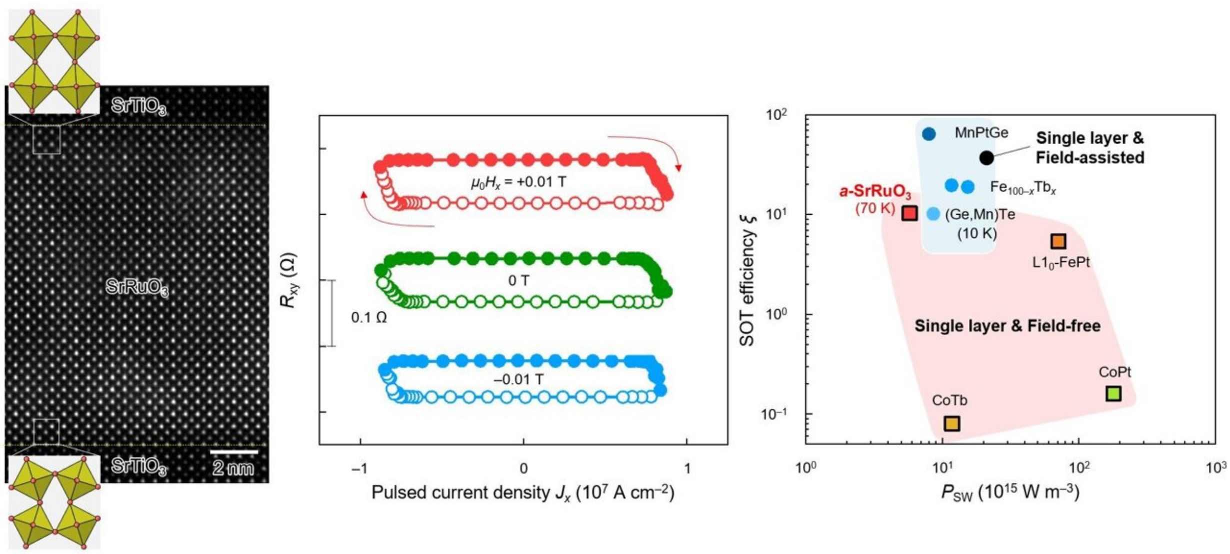

Atomic structure of asymmetric $SrRuO_3$ thin films and spin-orbit torque magnetization switching results controlled at the atomic layer level. Credit: POSTECH

Like the flutter of a butterfly's wings, sometimes small and minute changes can lead to big and unexpected results and changes in our lives. A team of researchers at Pohang University of Science and Technology (POSTECH) has made a very small change to develop a material called "spin-orbit torque (SOT)," which is a hot topic in next-generation

DRAM memory.

This research team, led by Professor Daesu Lee and Yongjoo Jo, a Ph.D. candidate, from the Department of Physics and Professor Si-Young Choi from the Department of Materials Science and Engineering at POSTECH, achieved highly efficient field-free SOT magnetization switching through atom-level control of composite oxides. Their findings were published in *Nano Letters*.

SOT arises from the interaction between the spin (magnetic property) and motion (electrical property) of electrons. This phenomenon controls the magnetic state through the movement of spin when current flows. By utilizing magnetic information instead of electrical information, memory power consumption is reduced, making it advantageous for non-volatile memory which retains information even when powered off.

Researchers have been actively exploring various materials including semiconductors and metals for these applications. Particularly, there is significant interest in discovering materials that exhibit both magnetism and the "spin-Hall effect."

The study of efficient magnetization switching via SOTs has garnered much attention. However, a challenge remains: opposite spin currents generated within a single layer tend to cancel each other out.

In this study, Professors Daesu Lee and Si-Young Choi from POSTECH addressed the problem by systematically modifying the material's seemingly insignificant structure. Strontium ruthenate ($SrRuO_3$), a complex oxide known for exhibiting both magnetism and spin-Hall effects, has been widely used in SOT research.

The team synthesized $SrRuO_3$ with asymmetric spin-Hall effects on the top and bottom surface layers by minutely adjusting the atomic lattice structure of these layers. By creating an imbalance in the spin-Hall effect with a strategically designed asymmetric surface structure, they were able to control the magnetization in a specific direction.

Building on this approach, the team successfully achieved efficient magnetization switching without the need for a magnetic field. By incorporating SOT into a device based on $SrRuO_3$, they could reorient the magnetic domain using only an electric current to write and read data.

The resulting memory device demonstrated the highest efficiency (2 to 130 times greater) and lowest power consumption (2 to 30 times lower) compared to any known single-layer, field-free system to date. This magnetization switching was accomplished without a magnetic field while preserving the conventional properties of $SrRuO_3$ used in previous studies.

Professor Daesu Lee of POSTECH says, "The asymmetric $SrRuO_3$ synthesized by the team is a crucial platform for studying the interaction between ferromagnetism and the spin-Hall effect." He added, "We look forward to further research to uncover new SOT mechanisms and develop highly efficient, room-temperature, single-phase SOT materials."

More information: Yongjoo Jo et al, Field-Free Spin–Orbit Torque Magnetization Switching in a Single-Phase Ferromagnetic and Spin Hall Oxide, *Nano Letters* (2024). DOI: 10.1021/acs.nanolett.4c01788

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