Energy-saving servers: Data storage 2.0

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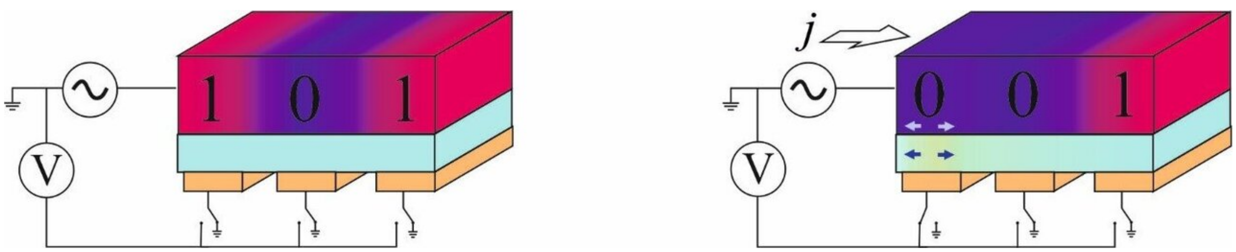

Diagram of a device architecture which employs the piezoelectric effect. Credit: Universitaet Mainz

Whether it's sending the grandparents a few pictures of the kids, streaming a movie or music, or surfing the Internet for hours, the volume of data our society generates is increasing all the time. But this comes at a price, since storing data consumes huge amounts of energy. Assuming that data volumes continue to grow in future, the related energy consumption will also increase by several orders of magnitude. For example, it is predicted that energy consumption in the IT sector will rise to ten petawatt-hours, or ten trillion kilowatt-hours, by 2030. This would be equivalent to around half of the electricity produced worldwide.

But what can be done to reduce the amount of power needed by servers to function? Data is usually stored in a storage layer with the help of magnetization. To write or delete the data, electric currents are passed through ferromagnetic multilayer structures, where the flowing electrons generate an effective magnetic field. The magnetization in the storage layer 'senses' this magnetic field and changes its direction accordingly. However, each electron can only be used once. An important step forward in energy-efficient data storage involves the construction of a ferromagnetic storage layer that includes a heavy metal such as platinum. As the current flows through the heavy metal, the electrons switch back and forth between the heavy metal and the ferromagnetic layer. The great advantage of this technique is that the electrons can be re-used multiple times, and the current required to write the data decreases by a factor of up to a thousand.

Doubling the efficiency of the storage process

A team of researchers at Johannes Gutenberg University Mainz (JGU) working in collaboration with researchers from Forschungszentrum Jülich has now found a way to double the efficiency of this storage process once again. "Instead of using simple silicon as a substrate as is usual practice, we employ a piezoelectric crystal," explained JGU scientist Mariia Filianina. "We attach the heavy metal layer and the ferromagnetic layer to this." If an electric field is then applied to the piezoelectric crystal, it generates mechanical strain in the crystal. This in turn increases the efficiency of the magnetic switching of the storage layer, which is the element that provides for data storage.

The extent of enhancement of efficiency is determined by the system and the strength of the electrical field. "We can directly measure the change in efficiency and consequently adjust the appropriate field strength—actually on the fly," said Filianina. In other words, it is possible to directly control the efficacy of the magnetic switching process by means of adjusting the strength of the electric field to which the piezoelectric crystal is exposed.

This not only comes with a significant reduction of energy consumption but also makes possible the use of complex architectures for information storage. The researchers propose that if the electric field is only applied to a small area of the piezoelectric crystal, the switching efficiency will only be increased at that location. If they now adjust the system so that the spin torques of the electrons can only be switched when the strain is amplified in the piezoelectric crystal, they can change the magnetization locally.

"Using this method, we can easily realize multilevel memories and complex server architectures," stated Filianina, a doctoral candidate at the Materials Science in Mainz Graduate School of Excellence and the Max Planck Graduate Center.

"I am pleased that the collaboration with our colleagues at Jülich is working so well. Without the help of their theoretical analysis we would not be able to explain our observations. I am looking forward to continue to work with them in connection with the recent jointly-obtained ERC Synergy Grant," emphasized Professor Mathias Kläui, who coordinated the experimental work.

More information: Mariia Filianina et al, Electric-Field Control of Spin-Orbit Torques in Perpendicularly Magnetized W/CoFeB/MgO Films, *Physical Review Letters* (2020). DOI: 10.1103/PhysRevLett.124.217701

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