Brain-Inspired Materials Will Transform Computer Technology

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Courtesy of SynEvol
Credit: Texas A&M University

In order to create materials for more effective computing, a group of scientists from Texas A&M University, Sandia National Laboratories – Livermore, and Stanford University are studying the human brain. The newly discovered class of materials is unique in that it spontaneously propagates an electrical signal along a transmission line, simulating the behavior of an axon. These discoveries might have a significant impact on artificial intelligence and computers in the future.

Any electrical signal flowing in a metallic conductor loses amplitude due to the metal’s intrinsic resistance. Approximately thirty miles of tiny copper wires can be found inside modern graphics processing units and central processor units (CPUs) to move electrical impulses around the chip. The pulse integrity must be preserved by amplifiers since these losses mount up quickly. The interconnect-dense chips of today perform differently due to these design limitations.

The researchers looked to axons for insight on how to overcome this constraint. In vertebrates, axons are the parts of nerve cells, or neurons, that have the ability to carry electrical impulses away from the nerve cell body.

According to lead author Dr. Tim Brown, a post-doctoral fellow at Sandia National Lab and a former PhD student in materials science and engineering at Texas A&M, "we want to transmit a data signal from one place to another, more distant location" frequently. For instance, it might be necessary to send an electrical pulse from a CPU chip's edge to some transistors that are close to its center. Resistance at ambient temperature constantly diminishes sent signals, even for the best conducting metals. Therefore, we usually cut into the transmission line and enhance the signal, which consumes energy, time, and space. Biology operates differently: certain signals in the brain are also conveyed over centimeters, but they do so via axons composed of organic matter that is far more resistant, and they do so without ever stopping and strengthening the signals."

Axons are the communication highway, according to Dr. Patrick Shamberger, an associate professor in Texas A&M's Department of Materials Science and Engineering. They transfer signals from one nearby neuron to another. The axons function as fiber optic cables, carrying signals from one neuron to its neighbor, while the neurons are in charge of processing signals.

The materials found in this study are primed, just like the axon model, which enables them to spontaneously amplify a voltage pulse as it travels down the axon. The electronic phase transition in lanthanum cobalt oxide, which increases the material's electrical conductivity when heated, was exploited by the researchers. A positive feedback loop is created when this feature interacts with the little amounts of heat produced as a signal travels through the material.

As a result, a variety of odd phenomena such as the amplification of tiny disturbances, negative electrical resistances, and abnormally high phase shifts in ac signals are found that are not seen in common passive electrical components such as resistors, capacitors, and inductors.

Shamberger claims that these materials are special because they exist in a "Goldilocks state" that is semi-stable. Electrical pulses do not break down or show signs of thermal runaway. If the material is kept at a steady current, however, it will naturally oscillate. The scientists discovered that they could use this phenomenon to produce spikes and increase the strength of a signal that is transmitted across a transmission line.

"Essentially, we take advantage of the material's inherent instabilities, which reinforce an electrical pulse as it travels through the transmission line. Despite our co-author Dr. Stan Williams' theoretical predictions, this is the first evidence of the behavior's existence.

The future of computers, which is driving an increase in energy use, may depend on these discoveries. By 2030, data centers are expected to consume 8% of the nation's electricity, and artificial intelligence may significantly raise that need. Over time, this is a step toward comprehending dynamic materials and applying biological inspiration to encourage computing that is more efficient.