How Lower Temperatures Cause Next-Generation Electronics to Break

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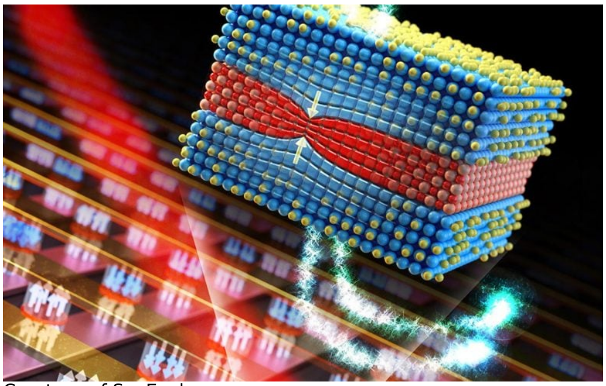

Courtesy of SynEvol
Credit: University of Minnesota

Researchers at the University of Minnesota Twin Cities have conducted a new study that sheds light on how next-generation electronics, such as computer memory components, malfunction or deteriorate over time. Understanding the reasons for degradation could help enhance efficiency of data storage solutions.

The need for effective data storage solutions is rising as computing technology advances. Promising substitutes for the current generation of memory devices are created by spintronic magnetic tunnel junctions (MTJs), nanostructured devices that harness the spin of electrons to enhance hard drives, sensors, and other microelectronics systems, including Magnetic Random Access Memory (MRAM).

With the potential to be used in AI applications to increase energy efficiency, MTJs are the fundamental components of non-volatile memory found in devices like smartwatches and in-memory computing.

Researchers examined the nanopillars—very tiny, transparent layers within the device—in these systems using a high-end electron microscope. To see how the gadget functions, the researchers passed current across it. They were able to watch in real time as the device deteriorates and eventually dies as they raised the current.

First author of the work and postdoctoral research associate in the Department of Chemical Engineering and Material Sciences at the University of Minnesota, Dr. Hwanhui Yun, said that "real-time transmission electron microscopy (TEM) experiments can be challenging, even for experienced researchers." But workable samples were reliably generated following dozens of errors and improvements.

By doing this, they found that when a constant current is applied over time, the device's layers become squeezed, leading to malfunctions. Although this has been predicted before, this is the first time the phenomena has been observed by researchers. When a device develops a "pinhole" or the pinch, it is beginning to deteriorate. The contraption melts down and burns out completely as the researchers keep feeding it more and more electricity.

The Ray D. and Mary T. Johnson Chair in the Department of Chemical Engineering and Material Sciences at the University of Minnesota, professor Andre Mkhoyan, senior author of the paper, said, "What was unusual with this discovery is that we observed this burn out at a much lower temperature than what previous research thought was possible." "The temperature was nearly half of what was previously anticipated."

Researchers discovered that materials that small have radically different properties, including melting temperature, after taking a closer look at the device at the atomic scale. This indicates that the gadget will malfunction entirely and beyond anyone's previous knowledge at a completely new time frame.

"Under real-time working conditions, like applying current and voltage, there has been a great desire to comprehend the interfaces between layers, but no one has attained this degree of understanding previously," stated Jian-Ping Wang, a senior author of the study, Distinguished McKnight Professor, and Robert F. Hartmann Chair in the Department of Electrical and Computer Engineering at the University of Minnesota.

“We are very happy to say that the team has discovered something that will be directly impacting the next generation microelectronic devices for our semiconductor industry,” Wang added.

The researchers anticipate that by using this knowledge, computer memory units will be designed with greater durability and efficiency.