‘Electron Trapping’ May Impact Future Microelectronics Measurements

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Using an ultra-fast method of measuring how a transistor switches from the “off” to the “on” state, researchers at the National Institute of Standards and Technology (NIST) recently reported that they have uncovered an unusual phenomenon that may impact how manufacturers estimate the lifetime of future nanoscale electronics.

The transistor is one of the basic building blocks of modern electronics, and the life expectancy or reliability of a transistor is often projected based on the response to an accelerated stress condition. Changes in the transistor’s threshold voltage (the point at which it switches on) are typically monitored during these lifetime projections. The threshold voltage of certain types of transistors (p-type) is known to shift during accelerated stresses involving negative voltages and elevated temperatures, a characteristic known as “negative bias temperature instability” (NBTI). This threshold voltage shift recovers to varying degrees once the stress has ended. This “recovery” makes the task of measuring the threshold voltage shift very challenging and greatly complicates the prediction of a transistor’s lifetime.

As semiconductor devices reach nanoscale (billionth of a meter) dimensions, measuring this device reliability accurately becomes more important because of new materials, new structures, higher operating temperatures and quantum mechanical effects. Many NBTI studies show that the accuracy of the measured threshold voltage shift (and consequent accuracy of the lifetime prediction) depends strongly on how quickly the threshold voltage can be measured after the stress is finished.

So, NIST engineers began making threshold voltage measurements at very fast speeds, leaving as little as two microsceconds (millionths of a second) between measurements instead of the traditional half-second interval. What they observed was surprising.

“We found that NBTI recovery not only returned the threshold voltage to its pre-stressed state but briefly passed this mark and temporarily allowed the transistor to behave better than the pre-stressed state,” says Jason Campbell, a member of the NIST team (that includes Kin Cheung and John Suehle) who presented this finding at the recent Symposium on VLSI Technology in Hawaii. The NBTI effect generally is believed to result from the buildup of positive charges, he explained, but the new observations at NIST indicate the presence of negative charge as well. NIST’s ultra-fast and ultra-sensitive measurements revealed that during recovery, the positive charges dissipated faster than the electrons, giving the system a momentary negative charge and heightened conductivity.

To date, Campbell says, transistor manufacturers only consider the accumulation of positive charges to predict the longevity of their microelectronics devices. “But as these systems get smaller and smaller, the electron trapping phenomenon we observed will need to be considered as well to ensure that transistor lifetime predictions stay accurate,” he says. “Our research will now focus on developing and refining the ability to measure that impact.”

Source: NIST