Switching to chemistry

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Researchers at the Weizmann Institute of Science have demonstrated a new kind of electrical switch, formed of organic molecules, that could be used in the future in nanoscale electronic components.
Their approach involved rethinking a phenomenon that drives many of today's high-speed semiconductors. Negative differential resistance (NDR), as the phenomenon is called, works contrary to the normal laws of electricity, in which an increase in voltage translates into a direct increase in current. In NDR, as the voltage steadily increases, the current peaks and then drops off, essentially allowing one to create a switch with no moving parts. But until now, those attempting to recreate NDR at the molecular scale had only managed it at extremely low temperatures.

Prof. David Cahen of the Institute's Materials and Interfaces Department and graduate student Adi Salomon thought research carried out by Salomon and others in Cahen's lab during her M.Sc. studies on connections between metal wires and organic (carbon based) molecules might hold part of the key to usable nanoscale NDR. They had found that, like people, molecules and metal wires need chemistry between them for barriers to be lowered and the juice to really flow. For a given voltage, if the molecules are held to the wire by chemical bonds (in which the two are linked by shared electrons), the current flowing through them will be many times higher than if they are only touching a mere physical bond.

Using this insight, the team designed organic molecules that pass electricity through chemical bonds at a lower voltage, but through physical bonds at a higher voltage. As the voltage approaches the higher level, sulfur atoms at one end of the molecule loosen their chemical bonds with the wire, and the current drops off as the switchover occurs.

But the molecules, once the chemical bond to the wire was broken, tended to move apart, preventing them from switching back to the chemically-bonded state. Prof. Abraham Shanzer of the Organic Chemistry Department, who had worked with the team on the original molecular design, now helped them to create long add-on tails to hold the molecules in place with a weak attraction. Now, the NDR in their molecules was stable, reversible and reproducible at room temperature.

Possible applications include nanoscale electronic memory and heat-sensing switches. The future of miniaturized electronics may lie in methods that combine chemistry with nanoscience, say the scientists. "We don't take human-sized objects and try to scale them down, but create new things from the universe of possibilities open to chemists that are specifically designed to function in the nanoworld."

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