**NANOSCIENCE**

**Designing a robust single-molecule switch**

A single-molecule switch works at room temperature

**By C. Daniel Frisbie**

In molecular electronics, researchers combine atomic control of molecular structure with high-precision nanofabrication techniques to connect individual molecules to tiny electrodes (1). The aim is to understand electrical transport, such as conductivity in individual molecules, and to uncover phenomena with practical utility in nanoelectronic devices. On page 1443 of this issue, Jia et al. (2) report robust, room-temperature optoelectronic switching of a single molecule connected to conducting carbon (graphene) contacts. In terms of the magnitude of the switching effect, its reversibility, and stability at room temperature, the results represent the state of the art for single-molecule electronics.

The electronic properties of all materials, molecules included, reflect their atomic-scale architecture. Molecules thus offer potentially limitless opportunities for tailoring electronic function. In addition, their conduction mechanisms (such as quantum tunneling) can minimize heat dissipation. Combined with the compact size of most molecules, this offers the potential for higher numbers of devices per area, meaning faster computation in smaller computer chips.

However, unlike in silicon microelectronics, there are no firmly established design rules for electronic functions in molecular electronics. Rational design means knowing how structure predicts function. To make headway, molecular electronics researchers must uncover rules for how to assemble functional molecules and how to connect them to electrodes to form junctions with predictable electrical behavior, such as current rectification or switching. Structural design parameters include the choice and location of all atoms in the molecule, the pattern of chemical bonding, the total molecular length, and the type of functional groups used to link the molecule to the electrical contacts (see the figure). Symmetry considerations are also crucial, as is the strategy for making nanoscale contacts.

Jia et al. report a convincing step toward rational design in molecular electronics by describing the creation of a high-performance molecular switch. The main switching component of their junction is the well-known chromophore diarylethene. The open (less conjugated) form of this molecule is insulating. Exposure to ultraviolet light drives a reversible isomerization to a more conjugated—and more conductive—closed structure; irradiation of the conductive closed state with visible light brings the molecule back to the insulating open state. Thus, incorporation of diarylethene into a solid-state molecular junction produces a light-activated toggle switch. Repeatedly exposing the junction to ultraviolet and visible light turns the current on and off. Previous studies have shown this switching behavior (3–5); however, the junctions were not stable, and the on-to-off current ratio degraded over time. In the present study, Jia et al. achieve both high on-to-off current ratios and remarkable device stability at room temperature. They do so by using strong covalent bonds to link the molecule to the graphene nanocontacts and molecular spacers to precisely position the chromophore within the junction (see the figure). Many prior molecular junction studies have reported switching by mechanisms other than light exposure, but these were performed at cryogenic temperatures (6), which limits application possibilities.

The study complements a string of recent...
advances toward rational design in molecular electronics. These include demonstration of quantum interference effects (7), strong current rectification (8), and commercial application (9). In these and other reports, researchers were successful in intentionally creating molecules to produce desired electrical behaviors—a crucial step toward rational design. Theoretical models of molecular junction behavior have also converged, and the current-voltage characteristics of many simple, nonswitching junctions are well understood (10).

The work of Jia et al. also raises questions. As the authors note, the precise mechanism by which electrons are transported through the light-switchable junction is not entirely clear. The mechanisms may even be different for closed and open forms of the molecule. Understanding the mechanistic details of the transport is crucial for further improvements not just in this particular study but more broadly in molecular electronics.

As scientists become more adept at creating molecular junctions with prescribed electrical functions, are there new behaviors that can be envisioned that differ fundamentally from those seen in silicon? Recent efforts to understand spin transport (11), thermoelectric transport (12), and biomolecular electron tunneling (13) in molecular junctions provide possible inspiration. In the broadest sense, however, molecular electronics need not be simply about creating the next tiny switch.

“...Jia et al. achieve both high on-to-off current ratios and remarkable device stability at room temperature.”

The science as exemplified by Jia et al.’s study represents exquisite control over matter at nanometer length scales and is a worthy intellectual pursuit in its own right with broad, long-term benefits.

REFERENCES

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Editor's Summary

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