Observation of quantum transport at room temperature in a 2.8-nanometer CNT transistor

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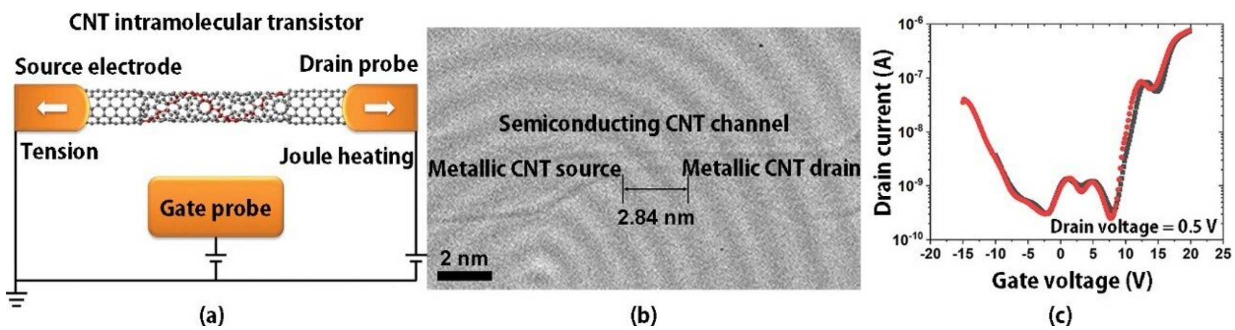

(a) Schematic diagram and (b) a transmission electron microscopy image of a CNT intramolecular transistor. (c) Current–voltage characteristics of the transistor. Credit: Daiming Tang National Institute for Materials Science

An international joint research team led by the National Institute for Materials Science (NIMS) has developed an in situ transmission electron microscopy (TEM) technique that can be used to precisely manipulate individual molecular structures. Using this technique, the team succeeded in fabricating carbon nanotube (CNT) intramolecular transistors by locally altering the CNT's helical structure, thereby making a portion of it to undergo a metal-to-semiconductor transition in a controlled manner.

Semiconducting CNTs are promising as the channel material for energy-efficient nanotransistors which may be used to create microprocessors superior in performance to currently available silicon microprocessors. However, controlling the electronic properties of CNTs by precisely manipulating their helical structures has been a major challenge.

This joint research team succeeded for the first time in controllably manipulating CNTs' electronic properties by locally altering their helical structures using heat and mechanical strain. Using this technique, the team was then able to fabricate CNT transistors by converting a portion of a metallic CNT into a semiconductor, where the semiconductor nanochannel was covalently bonded to the metallic CNT source and drain. The CNT transistors, with the channel as short as 2.8 nanometers in length, exhibited coherent quantum transport at room temperature—wave-like electron behavior usually observed only at extremely low temperature.

The molecular structure manipulation technique developed in this research may potentially be used to fabricate innovative nanoscale electronic devices. The team plans to use this technique to engineer material structures with atomic-level precision to fabricate electronic and quantum devices composed of individual atomic structures or molecules.

The research was published in *Science*.

More information: Dai-Ming Tang et al, Semiconductor nanochannels in metallic carbon nanotubes by thermomechanical chirality alteration, *Science* (2021). DOI: 10.1126/science.abi8884

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