Controllable unzipping for intra-molecular junctions of graphene nanoribbons and single-walled carbon nanotubes

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As an indispensable component in graphene-based electronics, the formation of junctions with other materials not only provides utility functions and reliable connexions, but can also improve or alter the properties of pristine graphene, opening up possibilities for new applications. Here, we demonstrate an intramolecular junction, which combines a graphene nanoribbon (GNR) and single-walled carbon nanotube (SWNT) in a one-dimensional nanostructure. This junction shows a strong gate-dependent rectifying behavior. As applications, we demonstrate the use of the junction in prototype directionally dependent field-effect transistors, logic gates and high-performance photodetectors, indicating its potential in future graphene-based electronics and optoelectronics.

1. METHODOLOGY:

1st step: to grow an SWNT on a SiO_2/Si substrate

2nd step: to pattern PMMA on one side of the SWNT

3rd step: to expose the substrate in zinc sputtering

4th step: to remove zinc and PMMA by HCl and acetone treatments, resulting in an SWNT/GNR intramolecular junction.

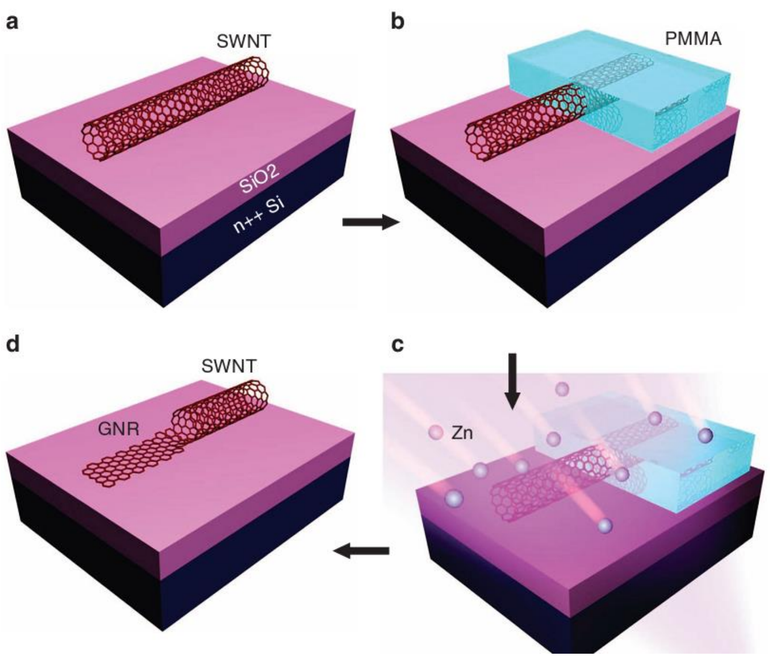

Figure 1. Patterned unzipping of an SWNT for producing an SWNT/GNR intramolecular junction

2. RESULTS:

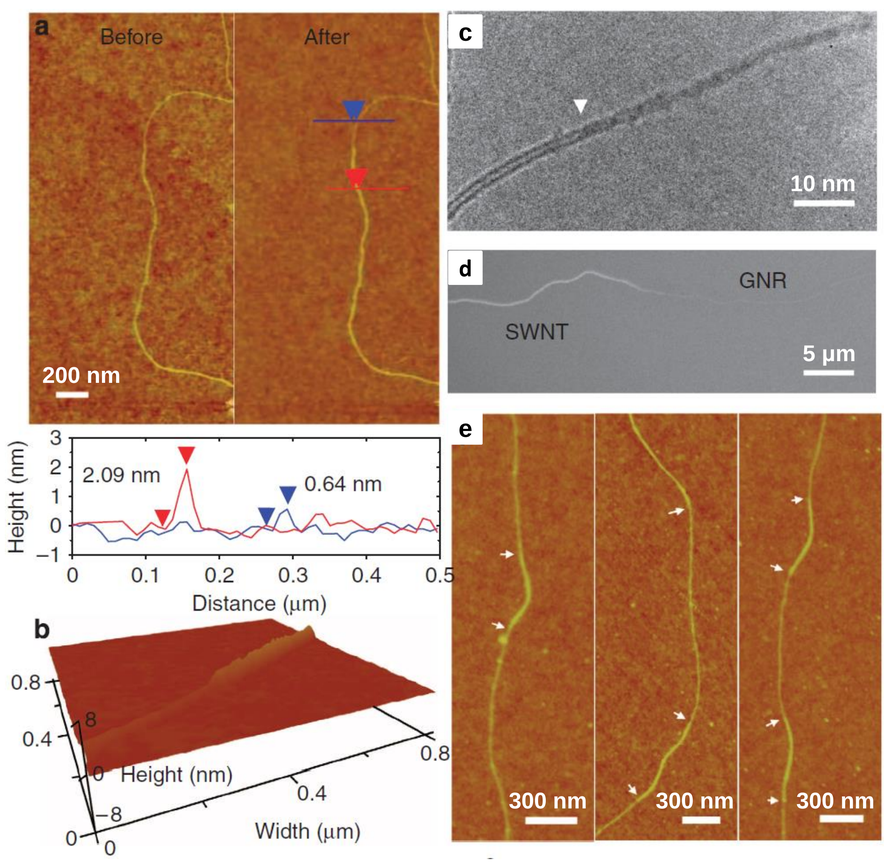

Figure 2. **a.** AFM images of an SWNT before and after patternedly unzipping. **b-d.** 3D AFM (**b**), TEM (**c**), and SEM (**d**) image of an SWNT/GNR junction. **e.** AFM images of the products with 2, 3, and 4 SWNT/GNR junctions on one nanotube.

3. ELECTRICAL PROPERTIES:

Gate-dependent rectifying behavior

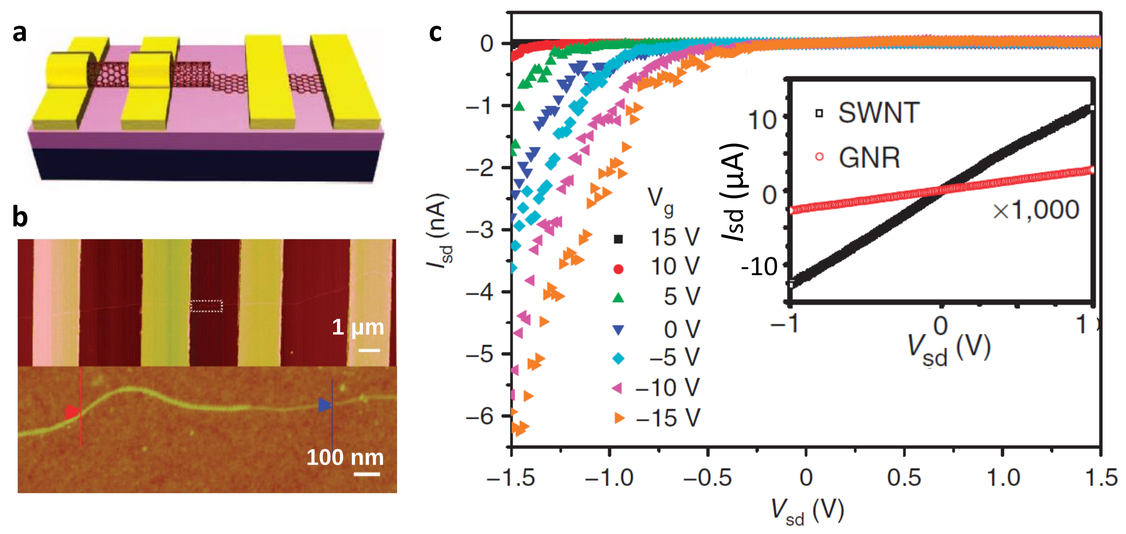

Figure 3. **a.** Schematic Bird's-eye view and **b.** AFM images of a SWNT/GNR junction device. **c.** Gate voltage-dependent I_{sd}–V_{sd} curves of a SWNT/GNR device. The inset shows I_{sd}–V_{sd} curves of the SWNT segment and the GNR segment.

4. PHOTODETECTORS:

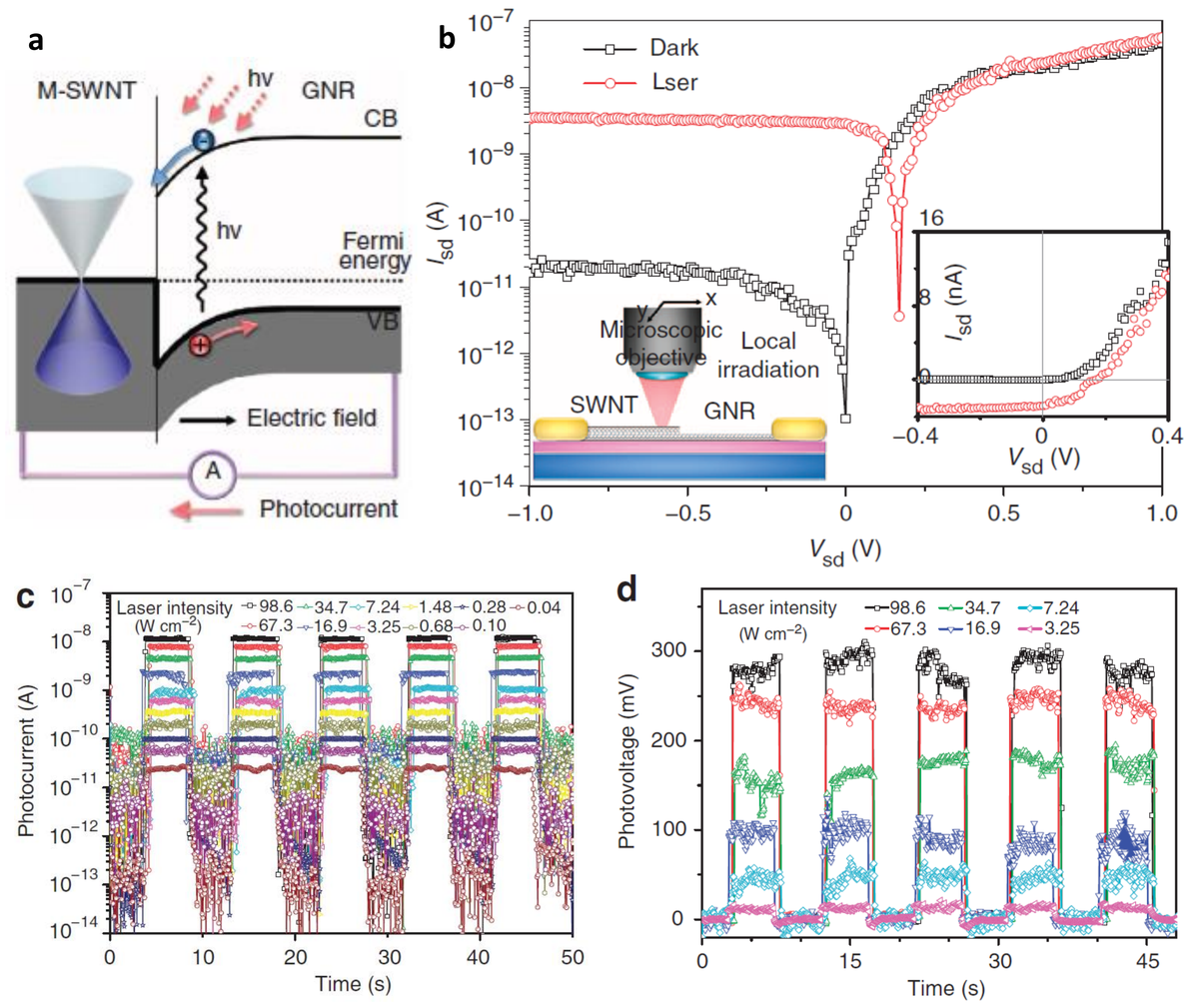

Figure 4. **a.** Schematic band diagram at the junction under irradiation. **b.** I_{sd}–V_{sd} curves of the SWNT/GNR device in dark and when a 34.7 kW/cm^2 laser beam was focused at the junction. **c,d.** Photocurrent and photovoltage response when the laser beam was switched on and off.

A photocurrent up to ***11.6 nA*** and a photovoltage up to ***270 mV*** were achieved. The external photo-responsivity was about ***3 mA/W***, indicating their potential application in high-performance photodetectors.

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