Electronic devices with one-dimensional heterostructures based on single-walled carbon nanotubes

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We have realized the synthesis of one-dimensional (1D) van der Waals heterostructures with single-walled carbon nanotube (SWCNT) as a template. A typical 1D heterostructure is composed of SWCNT, boron nitride nanotube (BNNT), and molybdenum disulfide nanotube (MoS_2NT), coaxially grown by serial chemical vapor deposition (CVD) steps [1]. We can also remove SWCNT from SWCNT@BNNT by gentle oxidation process because BNNT is thermally more stable than SWCNT [2]. By comparing optical properties of BNNT@MoS_2NT and SWCNT@BNNT@MoS_2NT, we found the strong photoluminescence (PL) from monolayer MoS_2NT [3] and quenching of PL by SWCNT through thin BNNT [2]. The prominent population of free charges and inter-tube excitons are proved by the ultrafast optical spectroscopy [4,5]. We can realize various hetero-nanotubes in different morphologies such as SWCNT thin film, pillar-suspended SWCNT, chirality separated SWCNT deposited on TEM grid, and bulk SWCNTs grown on zeolite-supported catalysts [6]. Simply with SWCNT@BNNT in a thin film form, the enhanced thermal conductance [7] is very promising for macroscopic applications of heterostructures. In order to fabricate a practical electronic or optoelectronics devices, micro-meter long 1D van der Waals heterostructure SWCNT@BNNT@MoS_2NT were prepared between Si pillars. After transferring to SiO_2 substrates and fabricating metal electrodes, we have examined various device characteristics. The naturally p-doped SWCNT and n-type MoS_2NT becomes a radial semiconductor–insulator–semiconductor (S-I-S) tunneling heterojunction diode [8].

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