# Molecular nanowire with pi-stacking structure for opto-electronic applications

*Yutaka Wakayama*[1], *Ryoma Hayakawa*[1], *Toyohiro Chikyow*[1] *and Kenji Kobayashi*[2]

[1]*Advanced Electronic Materials Center, National Institute for Materials Science*
*1-1 Namiki, Tsukuba 305-0044, Japan*
*WAKAYAMA.Yutaka@nims.go.jp*

[2]*Department of Chemistry, Faculty of Science, Shizuoka University*[1]
[1]*836 Ohya, Suruga-ku, Shizuoka 422-8529, Japan*

We demonstrate a comprehensive study of self-assembled molecular nanowires, including molecular design, one-dimensional wire growth, resistivity measurement of individual wire and photoconductivity. Additionally, particular emphasis will be put on a multi-level switching of a multi-channel field-effect transistor.

6,13-bis(methylthio)pentacene (BMTP) was synthesized, where the methylthio substituents ($SCH_3$) were attached on both sides of pentacene. These substituents are effective to modify intermolecular interaction, resulting in a highly pi-stacking structure in crystal [1] (Fig.1). The molecules deposited in vacuum showed anisotropic crystal growth to form one-dimensional wires on nanometer scale. X-ray diffractometry revealed that the long-axis of the wires coincides with that of the pi-stacking (Fig.2), so that high conductivity in this direction is expected. Resistivity of the individual wire was measured by a so-called nanostenciling technique [2], which enabled AFM observation, electrode deposition and electrical measurement in vacuum. The resistivity was determined to be $5x10^6$ Ωcm, which is relatively lower than those of other organic semiconductors. This is a result of highly pi-stacking and single-crystalline structure of the wire. The nanowires were found to have high photoconductivity. As a result, optical switching with a ratio of 100:1 was achieved (Fig.3). Next, double wires were connected in parallel with common source/drain electrodes and electrical current through each wire were controlled by respective gate electrodes. Each gate electrode can apply the bias voltage independently and the current through each channel (wire) can be modulated respectively, achieving multi-value operation (four values: on/on, on/off, off/on and off/off) (Fig.4) [3]. These results demonstrate a potential of molecular nanowires for opto-electronic devices.

References:
[1] K. Kobayashi *et. al.*, Organic Letters **8** (2006) 2385.
[2] S. Egger, *et. al.*, Nano Letters **7** (2007) 3399.
[3] Y. Wakayama, *et. al.*, Nano Letters **8** (2008) 3399.

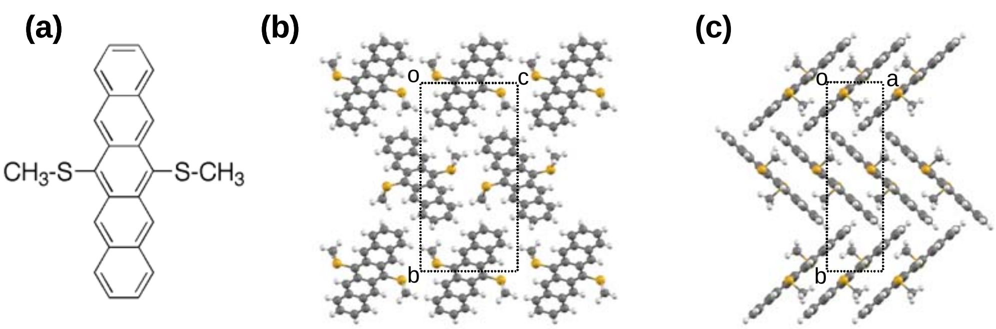


Fig.1 (a) molecular structure of 6,13-bis(methylthio)pentacene (BMTP). Crystal structure of BMTP (b) along the <100> direction and (c) along the <001> direction. The molecules form pi-stacking structure along <100> direction.

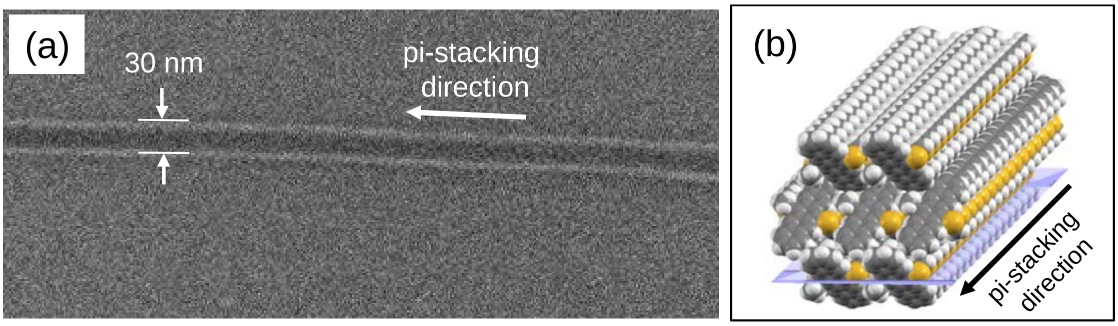


Fig.2 (a) SEM image of BMTP wire on OTS-treated $SiO_2$ surface. (b) Illustration of BMTP wire with pi-stacking structure. The direction of pi-stacking along the <100> direction coincides with the long axis of the wire in (a).

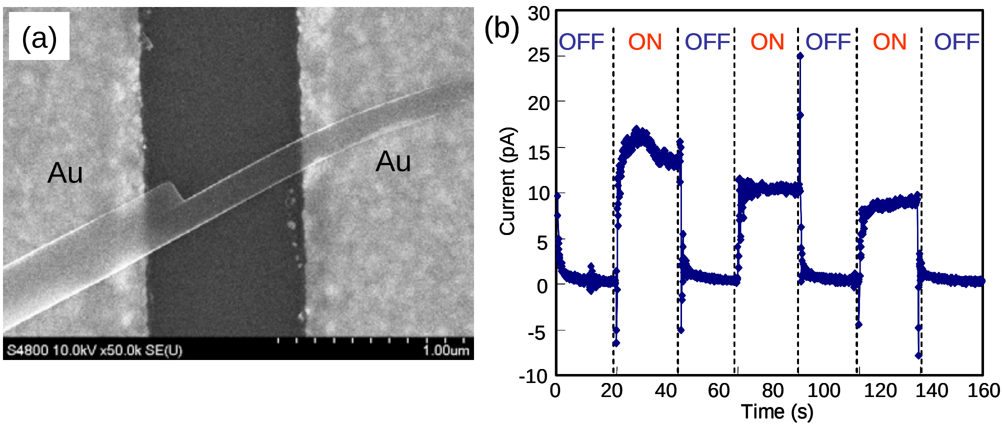


Fig.3 (a) SEM image of BMTP wire with Au electrodes on both sides. (b) Optical switching of electrical current. Electrical current was increased by visible light irradiation.

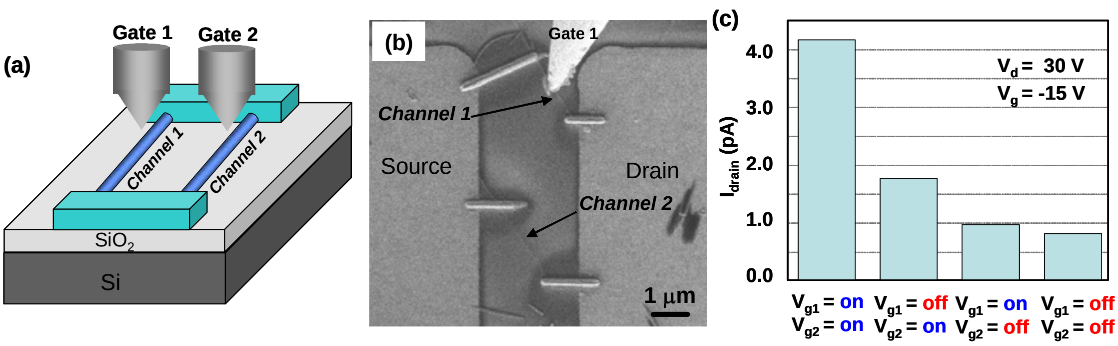


Fig.3 (a) Illustration of a double-channel transistor with top-gate configuration. (b) SEM image of the double-channel transistor. (c) Four-level switching achieved by applying bias voltage from respective gate electrodes at a constant drain bias voltage.