Flexible bio-electronics based on carbon nanotube thin films

Yutaka Ohno

Nagoya University, Nagoya 464-8603, Japan

Wearable devices have the potential to revolutionize preventive medical care and health promotion. Carbon nanotube (CNT) thin films are promising bio-electronic materials for transistors, biosensors, and other passive components to build such wearable devices because of the excellent electronic and mechanical properties and biocompatibility. In this study, we have developed CNT thin film technologies from the growth to device fabrication on flexible and stretchable films. High-mobility flexible thin-film transistors (TFTs) and their integrated circuits have been realized on a transparent plastic film. We have also demonstrated extreme stretching ability of CNT TFTs. Highly-sensitive, flexible biosensors with excellent uniformity in the sensing property have also been realized.

We have developed a method to realize high-mobility CNT thin films, based on a gas-phase filtration and transfer process. [1] This technique enables to form CNT films with high mobility and controllable threshold voltage on a plastic film. A TFT fabricated on a Si substrate with the transfer technique exhibited a high mobility of 634 cm^2/Vs with on/off ratio of $6x10^6$.

CNT films can also be used as electrodes and interconnections, which are flexible, transparent, stable, and free of rare metals. By using CNT transparent conductive films, we realized all-carbon TFTs and ICs, in which the electrodes and interconnections consist of CNT film and the insulators consist of PMMA. [2] The all-carbon device was able to be formed into three-dimensional dome-shape devices by the thermo-pressure forming technique. We also demonstrate extreme stretching ability of all-carbon devices fabricated on PDMS thin film.

We also fabricated CNT TFT-based potentiometric sensors on a plastic film. The device-to-device variation in the drain current was as small as 7%. To detect dopamine, the CNTs were decorated with pyrene-1-boronic acid. The boronic acid chemically react with dopamine, so that, boron is negatively charged. An increase in hole current was observed when dopamine solution was applied. High-sensitivity and wide-range detection of dopamine was confirmed. The limit of sensitivity was 10 pM and the dynamic range was 10^6.

[1] D. M. Sun, M. Y. Timmermans, Y. Tian, A. G. Nasibulin, E. I. Kauppinen, S. Kishimoto, T. Mizutani and Y. Ohno, *Nat. Nanotechnol.* 6, 156 (2011)

[2] D. M. Sun, M. Y. Timmermans, A. Kaskela, A. G. Nasibulin, S. Kishimoto, T. Mizutani, E. I. Kauppinen and Y. Ohno, *Nat. Commun.* 4, 2302 (2013)