CARBON-NANOTUBE-BASED PLASTIC ELECTRONICS

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Flexible devices will change the style of electronics products such as mobile phone and e-papers [1]. Carbon nanotube (CNT) thin films are expected to realize such devices with high performance by simple and low-cost fabrication processes. In the presentation, I will talk about our recent progresses of flexible thin-film transistors (TFTs) and integrated circuits (ICs) based on CNT thin film.

First, we developed the gas-phase filtration and transfer process to form carbon nanotube thin film with high-carrier mobility [2]. The CNTs were continuously grown by atmospheric-pressure floating-catalyst CVD technique [3]. The nanotubes were then collected on a membrane filter for a few seconds at room temperature and atmospheric pressure, and then transferred onto the substrate. The carbon nanotube TFT fabricated on a Si substrate, showing excellent performance with a mobility of >600 cm^2/Vs and on/off ratio of $>10^6$. The high mobility can be attributed to the clean and long nanotubes and unique morphology of the nanotube networks formed by 'Y'-shaped junctions.

ICs, including basic logics (NOT, NAND, NOR), ring oscillators, flip-flops (RS-FF and D-FF), were fabricated on a transparent and flexible plastic substrate. Robust and repeatable operations were obtained for these ICs. The master-slave D-FFs, that consist of 8 NANDs and 2 NOTs, showed the edge-triggered latching behavior. A 21-stage ring oscillator in which 44 TFTs were integrated showed a delay time of 12 μs per stage for a channel length of 100 μm.

We also report all-carbon TFTs and ICs, in which all materials are organics or carbon materials. The active channels and passive elements (electrodes, interconnections) have been formed by CNT thin film. The devices were fabricated on a PEN film substrate. Thick CNT films (transparency: 85 % at 550 nm, sheet resistance: 150 Ω/sq) were used for passive elements. A 660-nm-thick PMMA was used as the gate insulator. The all-carbon TFT showed on/off ratio of $\sim 10^5$ and mobility of 1,027 cm^2/Vs. Various kinds of functional integrated circuits were operated at a relatively low voltage of 5 V. A bending test verified the good flexibility of the all-carbon devices.

We fabricated CNT TFTs by flexo printing technique which is a high-throughput, typographic press with a photopolymer stamp. The contact electrodes were formed by printing Ag-nanoparticle ink by a flexo printer. The throughput of our prototype flexo printer was 6.6 cm/s. The device showed a mobility of 51.5 cm^2/Vs.

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