From Nanomaterials to Flexible Electronic Devices

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Till now, almost all electronic devices are made from semiconductors that are hard and brittle. However, many practical applications require electronic devices to be of flexibility so that the devices are suitable for flexible electronic applications, such as flexible displays, sensors, logic circuits, etc. In this talk, I shall overview recent developments in nanomaterials and nanodevices achieved by my group. We have successfully developed a novel approach with which preformed carbon nanotube (CNT) based integrated circuits (ICs) on hard substrates can be encapsulated into polyimide (PI) and peeled off from the hard substrates to form flexible ICs. The flexible CNT-ICs show promising performance comparable to those circuits formed on hard substrates, Figure 1. [1,2]

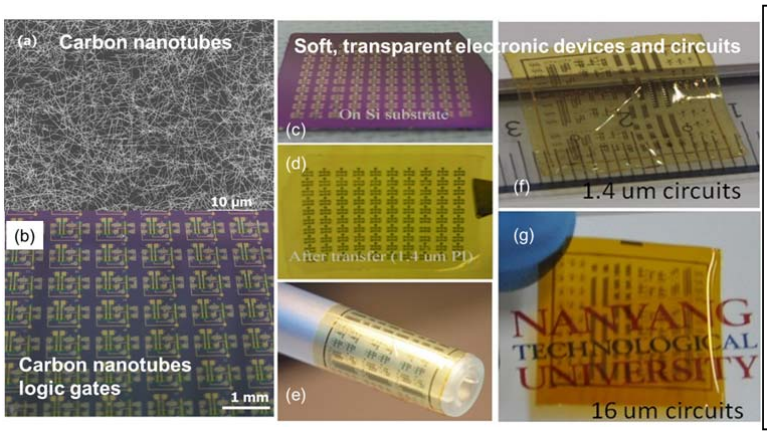

Figure 1: (a) The SEM image of CNT network on a silicon substrate; (b, c) CNT based logic gates on a silicon substrate; (d) Optical image of CNT based transistors, inverters, logic gates etc in a flexible PI sheet with a size of 2×1.8 cm^{-2} and a thickness of ~1.4 μm; (e) the PI sheet with the devices is attached on a pen with radius of 3.0 mm through electrostatic attraction; (f, g) the PI sheet with the devices are transparent. [2]

Single-walled CNT is expected to be a very promising material for flexible and transparent driver circuits for active matrix organic light emitting diode (AM OLED) displays due to its high field-effect mobility, excellent current carrying capacity, optical transparency and mechanical flexibility. Although there have been several publications about CNT driver circuits, none of them have shown static and dynamic images with the AM OLED displays. We have monstrated the first CNT network thin film transistor (TFT) driver circuits for static and dynamic AM OLED displays with 6 × 6 pixels. The high device mobility of ~45 $cm^2V^{-1}s^{-1}$ and the high channel current on/off ratio of ~10^5 of the CNT-TFTs fully guarantee the control capability to the OLED pixels. Our results suggest that CNT-TFTs are promising backplane building blocks for future OLED displays, see Figure 2. [3]

In addition, we have developed novel light weight soft anodes for flexible and stretchable lithium ion batteries. A coaxial flexible Ni/PVDF nanofiber network is used as the freestanding current collector and active amorphous silicon is coated to form a core–shell structure of Si/Ni/PVDF nanofibers.[4] Alternatively, hierarchical 3-D CNT arrays on carbon cloth have been developed as an efficient flexible nanostructure current collector for TiO_2

based anodes.[5] The soft silicon anodes show high specific capacities and good cycling life. The soft battery is capable of powering a LED at different bending states, see Figure 3. [4,5]

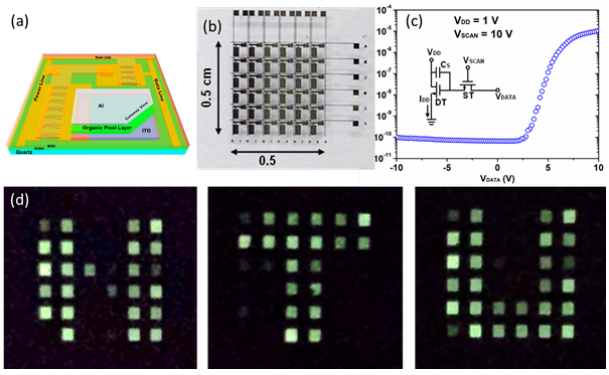

Figure 2: (a) A schematic cross-sectional perspective view of the single AM OLED display unit fabricated on a quartz substrate with CVD-grown SWNT network as the active channel, patterned Ti/Au source and drain electrodes, Si_3N_4 gate dielectric, Ti/Au top-gate electrode, integrated green OLED, and a SiO_2 passivation layer. (b) Photograph of the 6 × 6 driver array (0.5 × 0.5 cm2) before introduction of OLED pixels. (c) Typical transfer (I_{DD}-V_{DATA}) characteristics of a single unit 2T1C circuit when V_{SCAN} = 10 V, V_{DD} = 1 V. Inset: schematic diagram of the single unit 2T1C circuit. (d) The letters "N", "T" and "U" are displayed sequentially on this OLED display.[3]

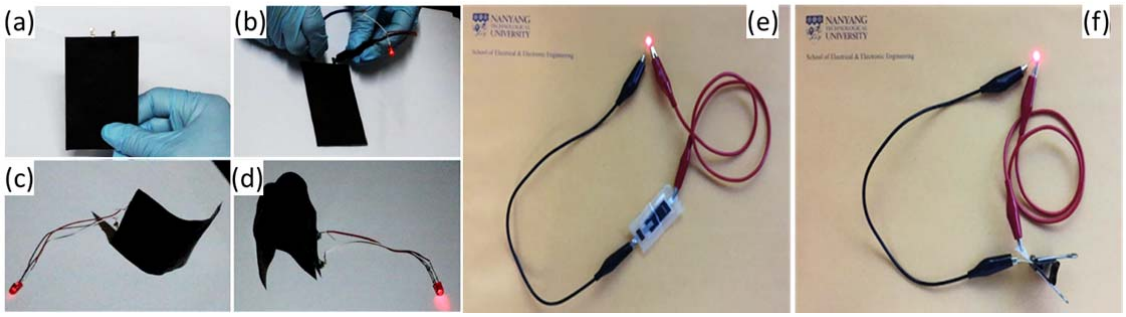

Figure 3: (a-e) Optical photographs of a red LED lightened by the flexible whole battery with Ni/PVDF/coated with thin carbon under flat and folded states.[4] (e,f) Optical photographs of a red LED lightened by the flexible whole battery with 3-D CNT arrays coated with thin TiO_2 under flat and folded states.[5]

References:

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