Hybrid integration of carbon nanotube and amorphous InGaZnO thin-film transistors

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Carbon nanotube (CNT) network thin films have emerged as potential building blocks for macroelectronics due to its high carrier mobility and large current density. However, CNT-based thin-film transistors (TFTs) typically exhibited only p-type characteristics under ambient conditions [1, 2]. Therefore, the implementation of n-type transistors are required to realize various CMOS integrated circuits. In this work, we demonstrate hybrid integrated circuits based on p-type CNT TFTs and n-type InGaZnO (IGZO) TFTs. Highly purified 99% semiconducting CNT TFTs exhibit the normalized on-state current ($I_{ON} \times L/W$) of 2.66 μA defined at V_{GS} = –5 V and IGZO TFTs show $I_{ON} \times L/W$ of 2.83 μA defined at V_{GS} = +5 V. By employing these TFTs, we implemented hybrid complementary inverters with p-type CNT TFTs and n-type IGZO TFTs with supply voltages (V_{DD}s) ranging from 4 to 10 V. The maximum voltage gain of 123 and the maximum power consumption of 98 μW occurs at a V_{DD} of 10 V. Finally, we also show the operations of the two-input NAND and NOR gates fabricated based on the CNT and IGZO TFTs at a V_{DD} of 10 V. As a result, the logic circuits return correct logical functions according to input signals. We believe that the approach of hybrid integration allows to combine the strength of p-type CNT and n-type IGZO TFTs for optimizing CMOS circuit design.

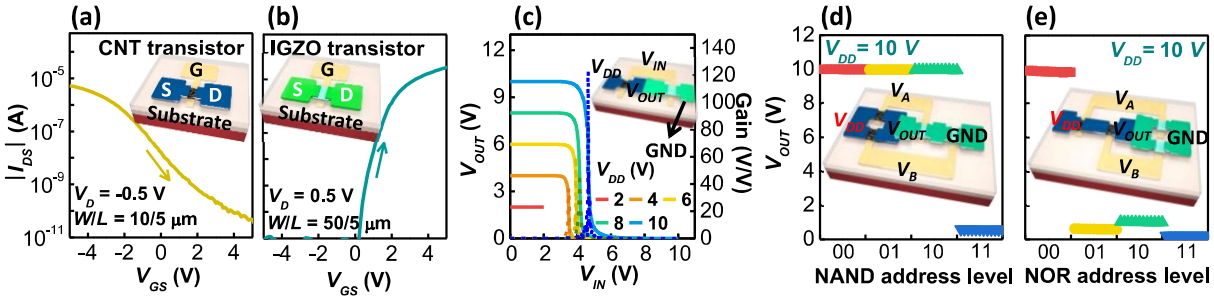

Fig 1. Transfer characteristics of (a) the CNT-TFT and (b) the IGZO-TFT. (c) Voltage transfer characteristics (VTC) of hybrid inverter based on CNT and IGZO TFTs. (c) NAND and (d) NOR logic gates consisting of the CNT-TFTs and the IGZO-TFTs

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