Electronic Supplementary Material (ESI) for Nanoscale.

Supporting information

Fabrication of Air-Stable n-Type Carbon Nanotube Thin-Film Transistors on Flexible Substrates Using Bilayer Dielectrics

Guanhong Li[a,b], Qunqing Li[a,b]*, Yuanhao Jin[a,b], Yudan Zhao[a,b], Xiaoyang Xiao[a,b], Kaili Jiang[a,b], Jiaping Wang[a,b] and Shoushan Fan[a,b]

[a] State Key Laboratory of Low-Dimensional Quantum Physics, Department of Physics & Tsinghua-Foxconn Nanotechnology Research Center, Tsinghua University, Beijing 100084, China. E-mail: qunqli@mail.tsinghua.edu.cn;

[b] Collaborative Innovation Center of Quantum Matter, Beijing, China

1. Consistency and reliability

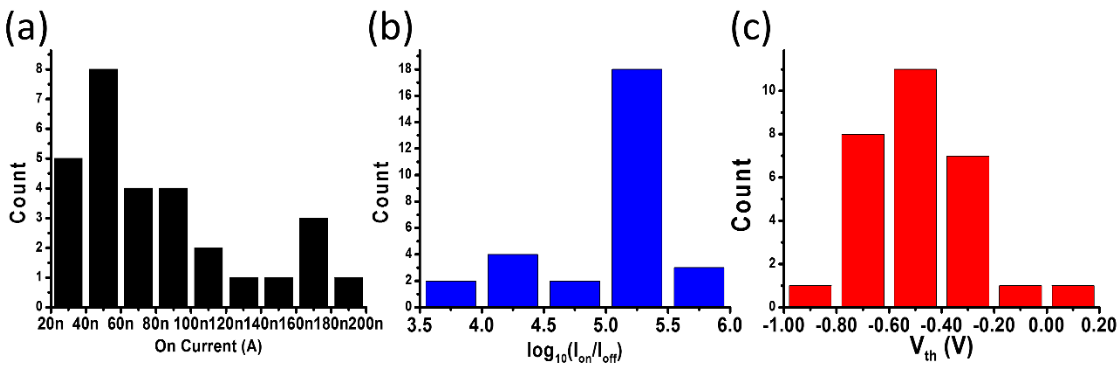

Fig. S1 Histograms of on-state current (a), on/off ratio (b), and threshold voltage (c) of 29 devices from the same batch.

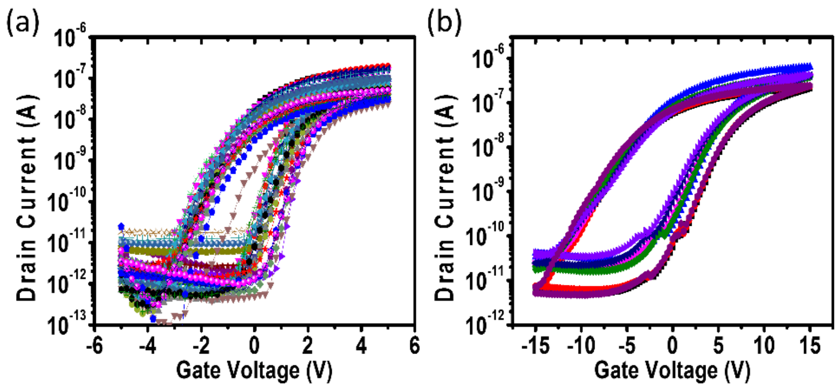

Fig. S2 Transfer characteristics of devices from two different batches.

We have shown successfully polarity switching for 41 devices from 5 batches in total, including the devices in the main text. In fact, we have verified the validity of our method over 9 runs, and all the devices show n-type conducting behaviour. So, the repeatability and reliability is desired.

2. Performance change after n-doping.

Two kinds of SWNTs with semiconducting purity as 99%, and 98% are used to fabricate TFT devices with low density and high density, respectively. The performance change of these devices after n-doping are shown below. The on current and on-off ratio before n-doping in the figures refer to performance of p-type conducting devices, and after n-doping in the figures refer to the performance of the n-type conducting device.

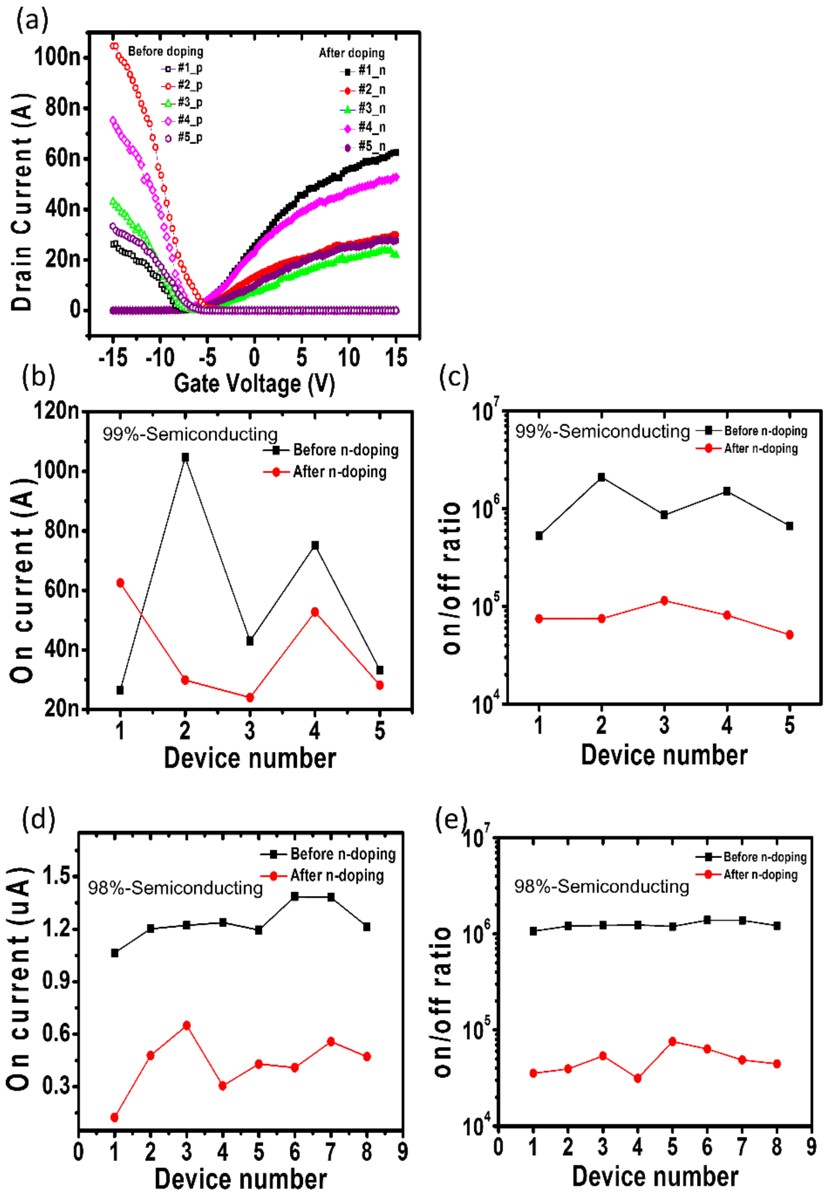

Fig. S3 (a) Transfer characteristics of 5 devices before (hollow symbol) and after (solid symbol) conduction type change, with semiconducting purity as 99% and SWNT thin film at low density. (b), (c) The on current and on/off ratio before and after n-doping for the devices made from sparse CNT network with semiconducting purity of 99%. (d) The on current and (e) on/off ratio before and after n-doping for the devices made from dense CNT network with semiconducting purity of 98%.

3. N-type TFT with MgO/HfO_2 bilayer dielectric.

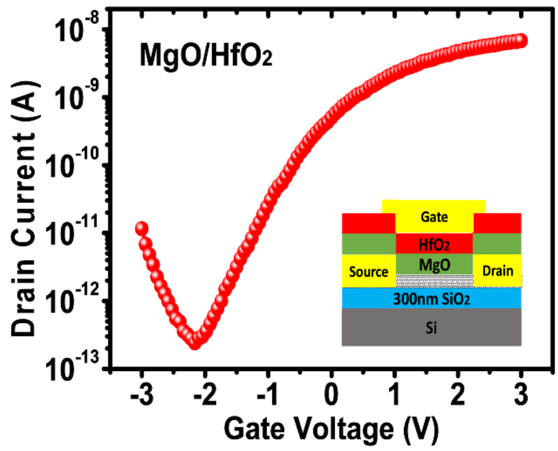

Fig. S4 (a) Transfer characteristics of the n-type TFT with MgO/HfO_2 bilayer dielectric. The HfO_2 layer was deposited at 90 °C

4. Effect of MgO interlayer on the doping of CNT networks at higher temperature of 250 °C

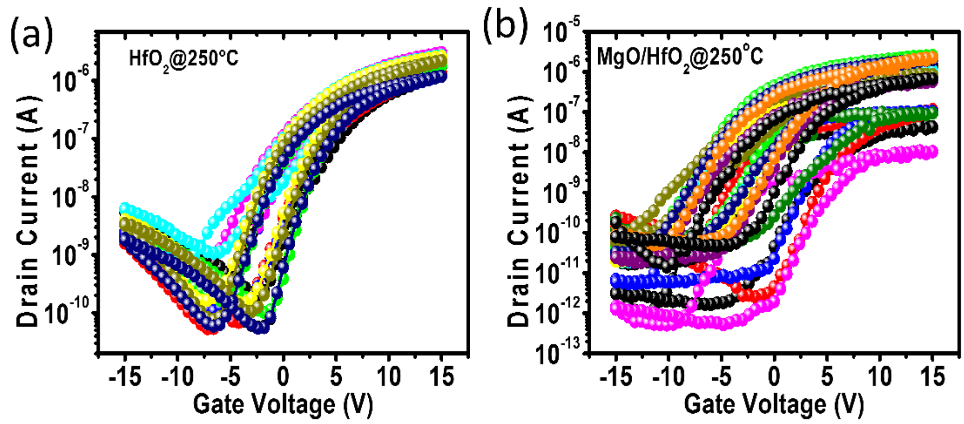

Fig. S5 Transfer characteristics of the TFTs with only HfO_2 (a) and MgO/HfO_2 bilayer (b) as dielectrics. Here, the HfO_2 layer was deposited at 250 °C

Both of the two type devices show n-type conducting behaviours. Moreover, the hole-conduction was suppressed more obviously with MgO interlayer than those without such interlayer. However, the distribution of the on current and off current were quite wider for the devices after n-doping with MgO interlayer. In some devices, there's no obvious difference for the on and off current for the devices through these two different process. But in some devices, both the on and off current decreased with MgO interlayer, compared with the devices with only HfO_2 @250°C. We guess the evaporation process of MgO interlayer need to be improved in the future.

5. Mobility evaluation.

The mobility is evaluated from the results of the devices made by SWNTs with semiconducting purity as 98% and high SWNT density of 7.13 tube/ μ m, the rigorous model is used to calculate the gate capacitance.[1,2] Both the mobility and on/off ratio are comparable to the recent report[3].

Table S1 Key parameters obtained from 11 p-type devices and14 n-type devices

	On current (μA)	Transconductance (μS)	Mobility ($cm^2 V^{-1} s^{-1}$)	$Log(I_{on}/I_{off})$
P-type	1.24 ± 0.13	0.68 ± 0.12	27.4 ± 4.9	6.09 ± 0.04
N-Type	0.54 ± 0.23	0.37 ± 0.13	14.9 ± 5.2	4.73 ± 0.14

6. Flexibility of n-type device on PET substrate.

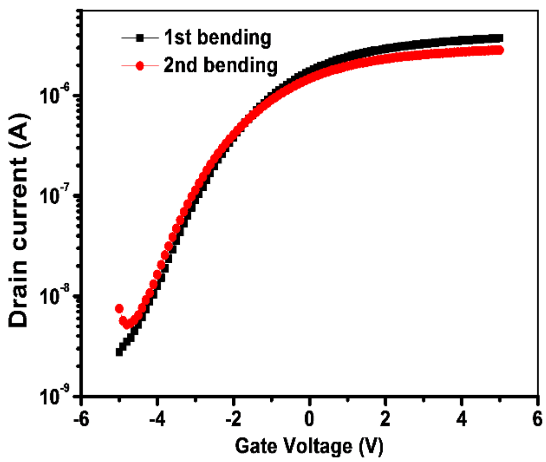

Fig. S6 Transfer characteristics of device after bending one time and two times with radius of 9 mm. The device still works after bending with the electrical property changes very slightly.

1 Q. Cao, M. Xia, C. Kocabas, M. Shim, J. A. Rogers and S. V. Rotkin, *Appl. Phys. Lett.*, 2007, **90**, 23516.

2 C. Wang, J. Zhang, K. Ryu, A. Badmaev, L. G. De Arco and C. Zhou, *Nano Lett.*, 2009, **9**, 4285-4291.

3. T. Ha, K. Chen, S. Chuang, K. M. Yu, D. Kiriya and A. Javey, *Nano Lett.*, 2015, **15**, 392-397.