

Intense pH sensitivity Modulation in Carbon Nanotube-Based Field-Effect Transistor By Non-Covalent Polyfluorene Functionalization

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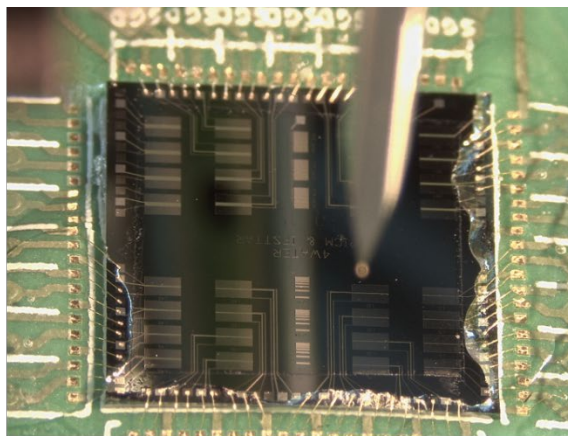
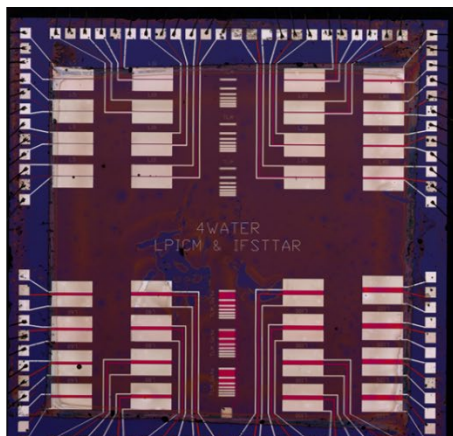
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1. Wirebonded chips on PCB



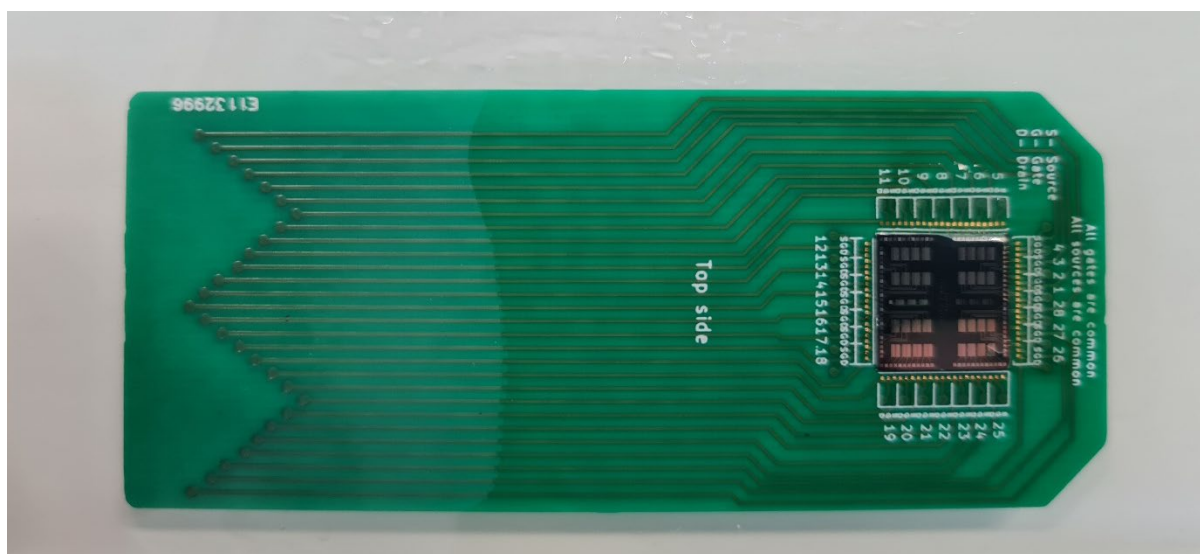


Figure S1. (upper-left) Ink-jet printed CNT-FET device after PMMA deposition process (upper-right) Wire bonded chip, with passivation of the wirebonding by UV resist. (below) Image of a PCB and CNT-FET devices after wire bonding and passivation process.

2. Formulation of the phosphate buffer

Table S1. Detailed amount of Sodium phosphate dibasic heptahydrate and Sodium phosphate monobasic monohydrate for 0.1 M phosphate buffer solution.

pH	Na₂HPO₄·7H₂O (Sodium phosphate dibasic heptahydrate) (g)	NaH₂PO₄·H₂O (Sodium phosphate monobasic monohydrate) (g)	Additional acid or base
3	3.669	11.911	HCl until pH 3
4	3.669	11.911	HCl until pH 4
5	3.669	11.911	HCl until pH 5
6	3.669	11.911	
7	15.483	5.827	
8	15.483	5.827	NaOH until pH 8
9	15.483	5.827	NaOH until pH 9

3. Transfer curves in air

The electrical transfer curves of p-CNTFETs and f-CNTFETs in air before and after passivation were measured (Figure 2). They show hysteresis and charging effect for both types of CNTFETs, with both effects being particularly pronounced for the f-CNTFETs. As expected, passivation reduced the hysteresis and the charging effect.

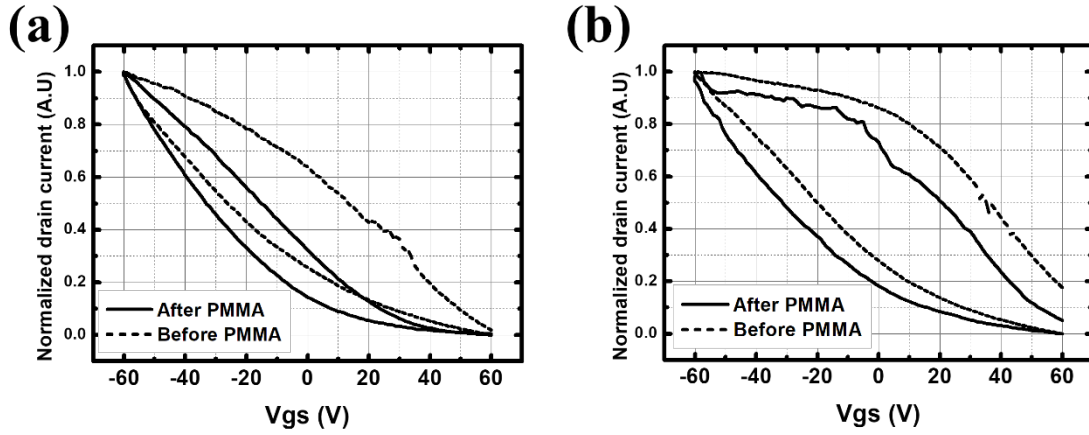


Figure S2. Normalized I-V transfer curve (e.g. I/I_{on} as a function of V_{gs}) of (a) p-CNTFET and (b) f-CNTFET before PMMA deposition (dotted line) and after PMMA deposition (solid line) in air. Channel length of each device is 5 μm .

Figure S3 shows the I_{on}/I_{off} ratio for the p-CNTFET as a function of channel length. It tends to increase up to 60 μm channel length and then stabilizes, with a possible outlier at 10 μm .

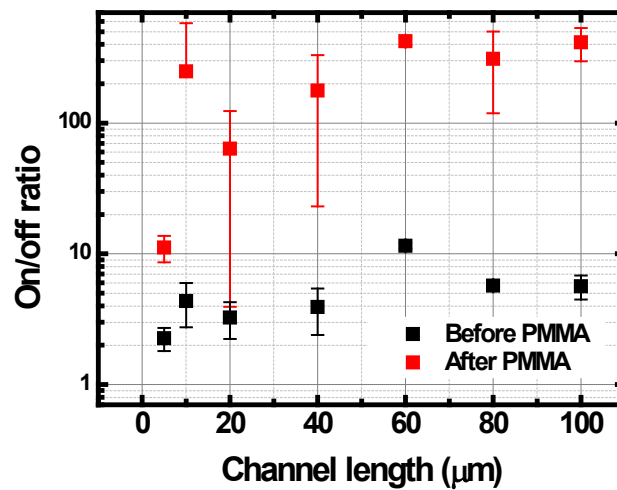


Figure S3. I_{on}/I_{off} ratio of p-CNTFETs before and after PMMA deposition with respect to channel length from 5 μm up to 100 μm .

Figure S4 and Figure S5 show I_{on} and I_{off} for p-CNTFET and f-CNTFET, respectively, as a function of channel length. The stronger effect of passivation on I_{off} than on I_{on} is clear. For p-CNTFET, the threshold channel length at 60 μm is more obvious than for I_{on}/I_{off} .

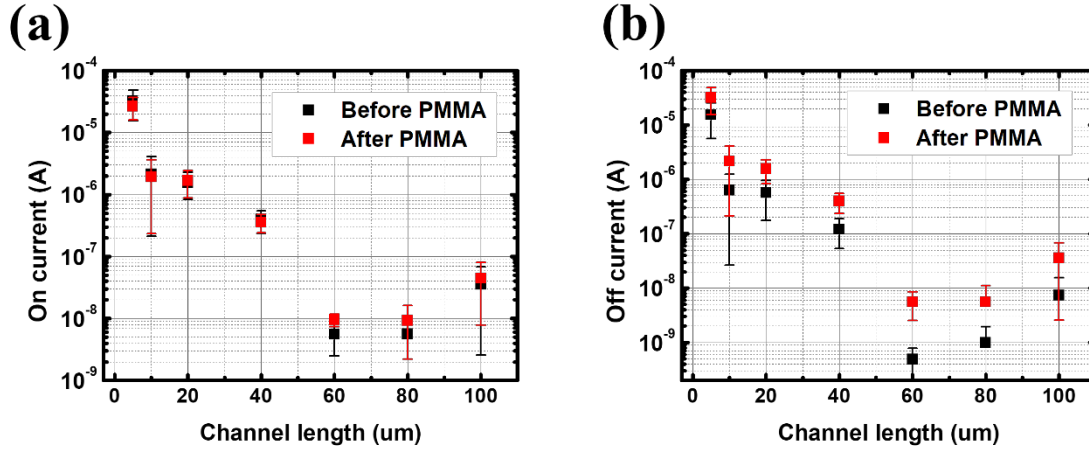


Figure S4. (a) I_{on} and (b) I_{off} of p-CNTFETs before and after PMMA passivation with respect to channel length from 5 μm to 100 μm .

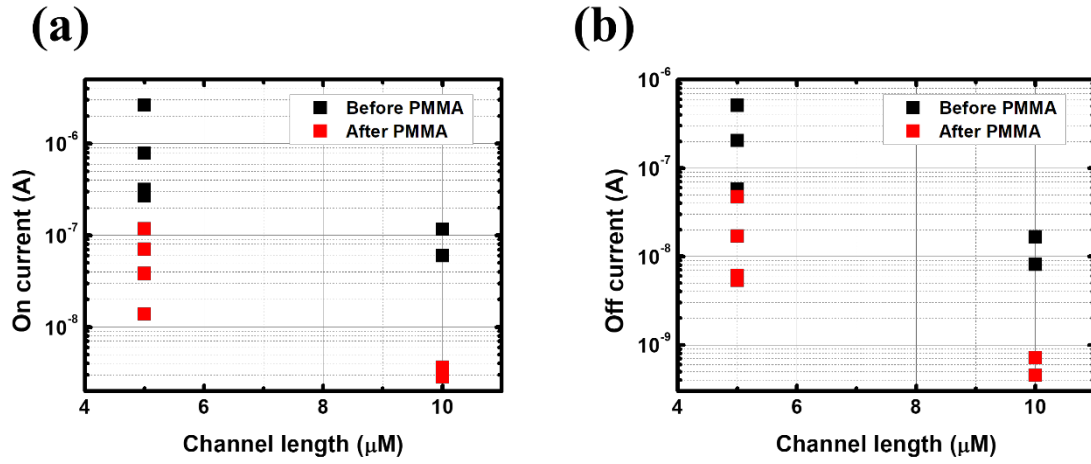


Figure S5. (a) I_{on} and (b) I_{off} of f-CNTFETs before and after PMMA passivation with respect to channel length from 5 μm to 10 μm .

4. CNTFET characterizations in water

Figure S6 shows the comparison of current levels in water at different gate voltages for a device without CNTs and a device with CNTs. The CNTFET clearly shows a transistor behavior in water between -1 V and +1 V. The comparison with the CNT-less chip shows that the transistor effect in water cannot be attributed to the conductivity of the water alone or to disturbances in the chip.

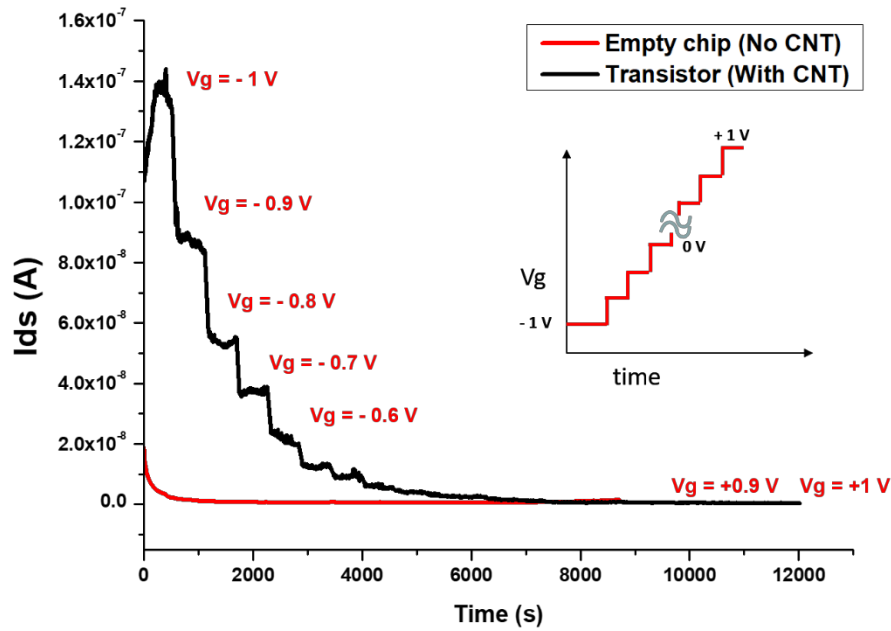


Figure S6. I-V transfer curves in water for p-CNTFET (Black solid line) and non-printed device (Red solid line) as reference.

Figure S7 shows the typical current response of a transistor over a pH step. To account for the stabilization time of the device after each chemical change, only the last 10% of the step is used to calculate the transistor response.

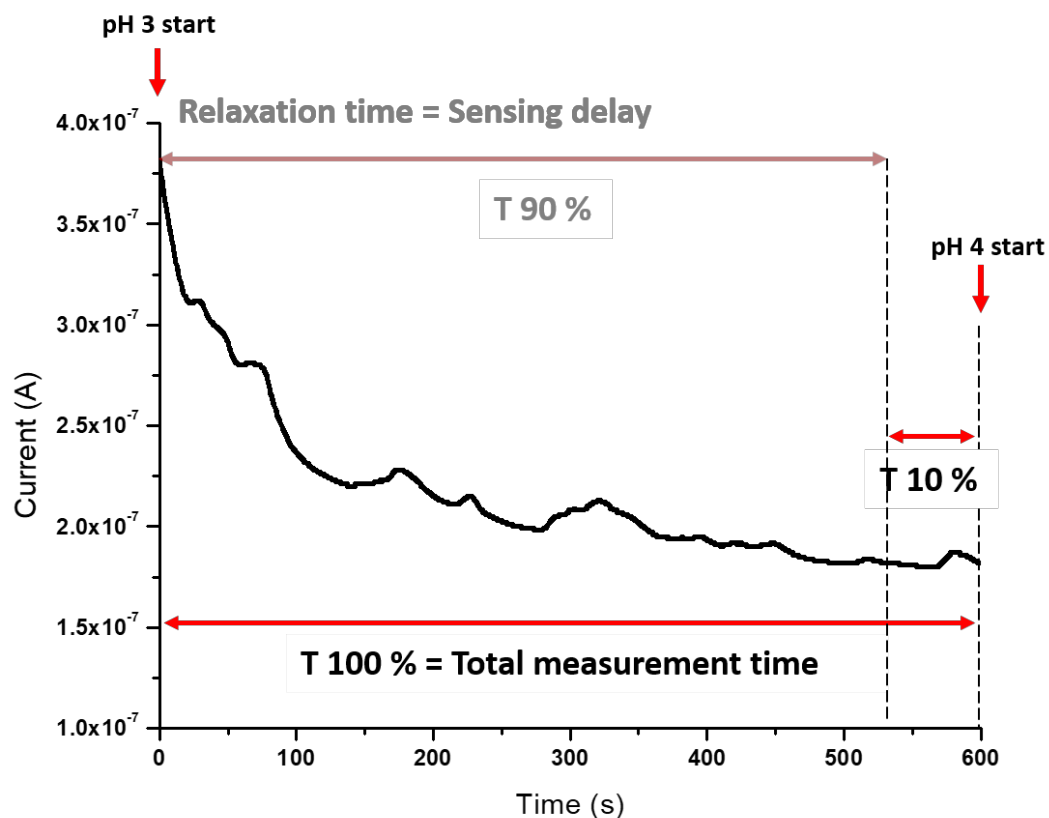


Figure S7. Data treatment process or real-time measured current values at a certain pH. The current response to a given pH step is calculated by averaging the last 10 percent of measured points for each pH step.

Figure S8 shows the I-V transfer curve of both types of CNTFETs in PBS at pH 7 in linear scale. The threshold voltage can be easily observed.

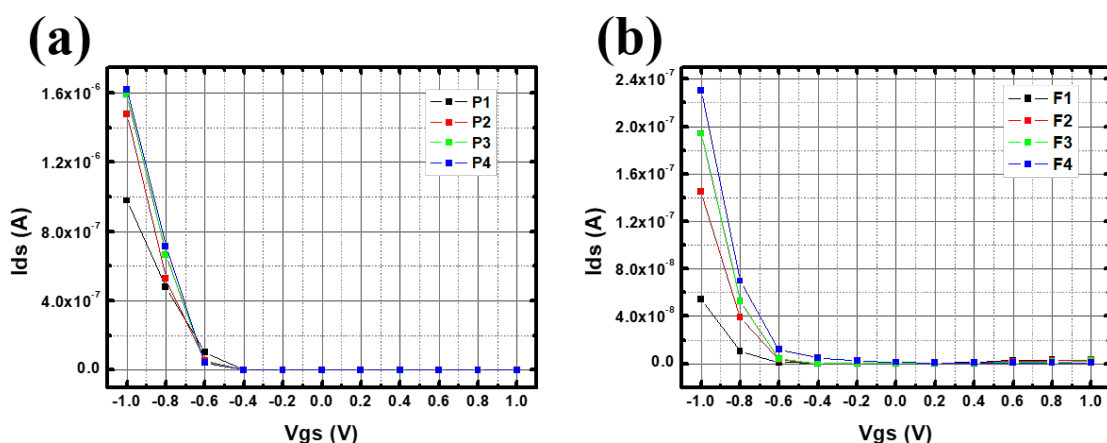


Figure S8. Linear I-V transfer curve of (a) p-CNTFETs and (b) f-CNTFETs in phosphate buffer solution (PBS) at pH 7. All transistors were 5 μm channel devices. V_{ds} was set to +0.8 V and V_{gs} was swept from -1 V to +1 V.

5. I-V Transfer curves at different pH

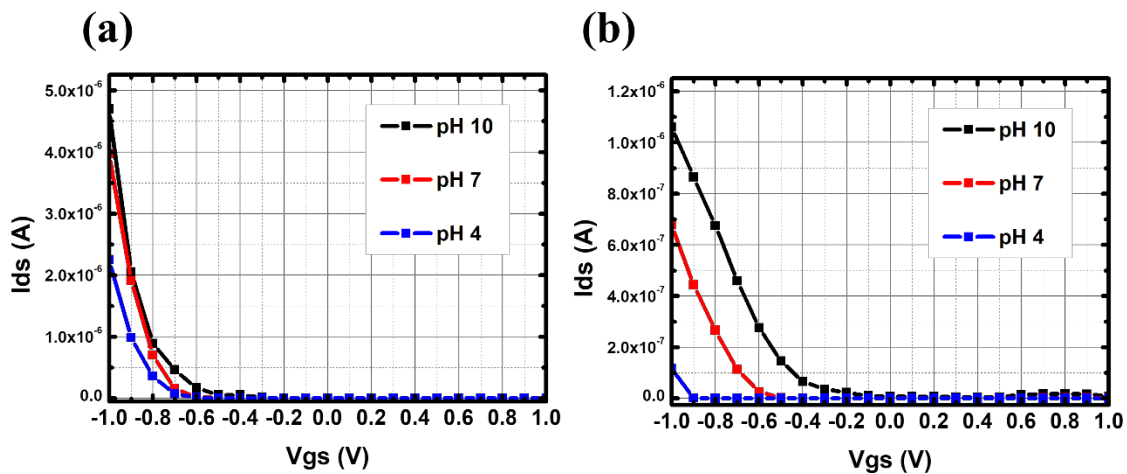


Figure S9. Linear I-V transfer curve of (a) p-CNTFETs and (b) f-CNTFETs in PBS with respect to different pH from pH 10 to pH 4. V_{ds} was fixed at +0.8 V.

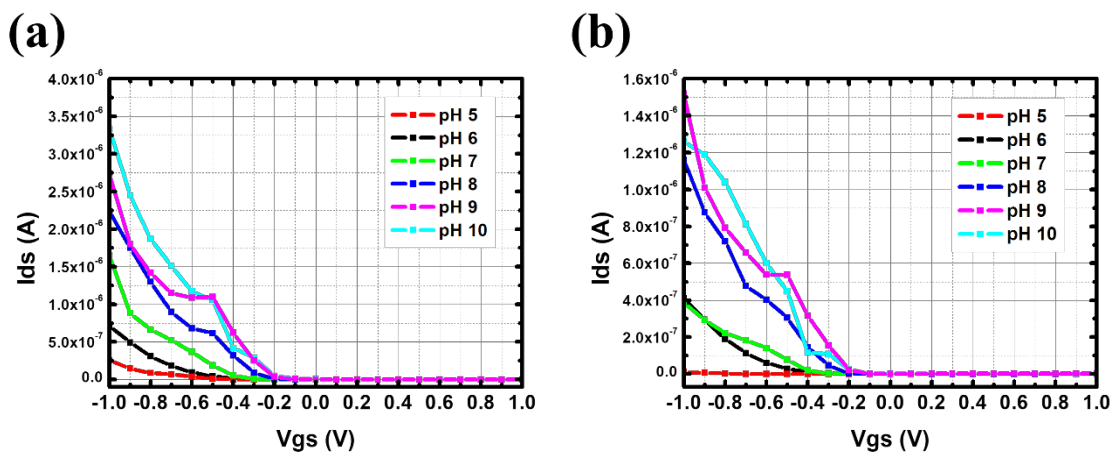


Figure S10. Linear I-V transfer curve of (a) p-CNTFETs and (b) f-CNTFETs in Borate buffer solution (BBS) with respect to different pH from pH 5 to pH 10. V_{ds} was fixed at +0.8 V.