Electronic Supplementary Material (ESI) for RSC Advances.

[Supporting Information]

Ultrasensitive tactile sensors based on planar liquid crystal-gated-organic field-effect transistor with polymeric dipole control layer

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This supporting information contains:

Fig. S1 Photographs for the characteristics of LC (5CB) drop spreading

Fig. S2 The drain current change at peak as a function of nitrogen gas intensity (3 s)

Fig. S3 Illustration of the negative end of dipole in 5CB molecule

Fig. S4 Redisplay of Fig. 4: The brightness of the OM images at the cross-polarization condition (90^o)

Experimental Details: materials, device fabrication and measurements

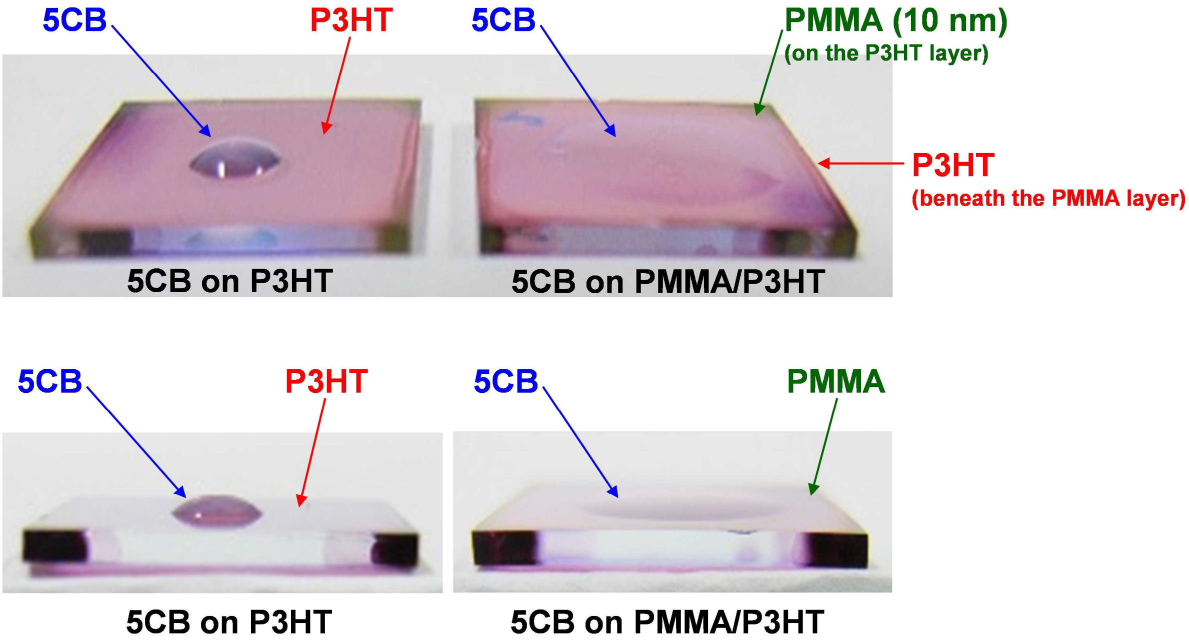

Fig. S1 Photographs for the characteristics of LC (5CB) drop spreading: (left) 5CB drop on the P3HT layer, (right) 5CB drop on the PMMA layer (DCL) that is coated on the P3HT layer. Note that the 5CB drop was well spreaded on the PMMA layer than the P3HT layer, which indicates that.

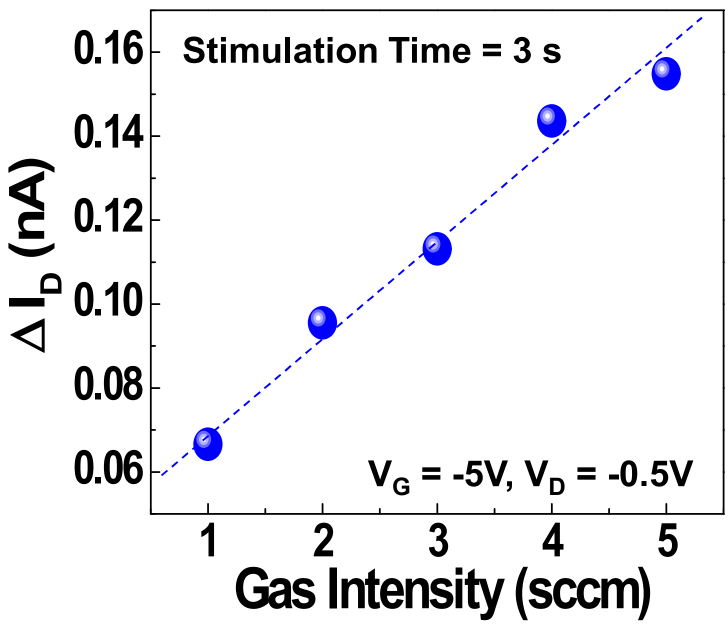

Fig. S2 The drain current change at peak as a function of nitrogen gas intensity (strength). The stimulation time of nitrogen gas flow was 3 s, while the applied voltages were V_G = -5 V and V_D = -0.5 V. Note that the drain current change was linearly increased with the nitrogen gas intensity.

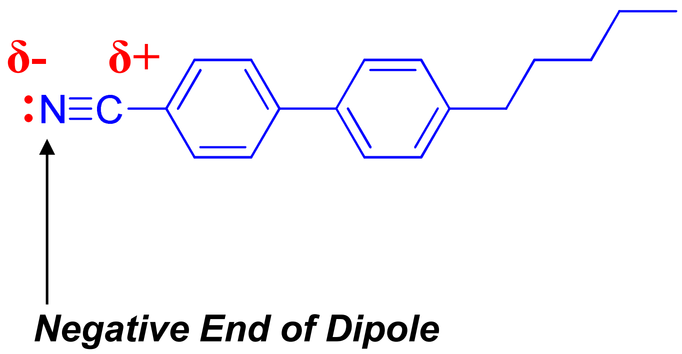

Fig. S3 Illustration of the negative end of dipole in 5CB molecule. The negative ends in the 5CB molecules are considered to contact the surface of the channel (P3HT) layer upon the stimulation of nitrogen gas flow so as to generate positive charges in the P3HT layer.

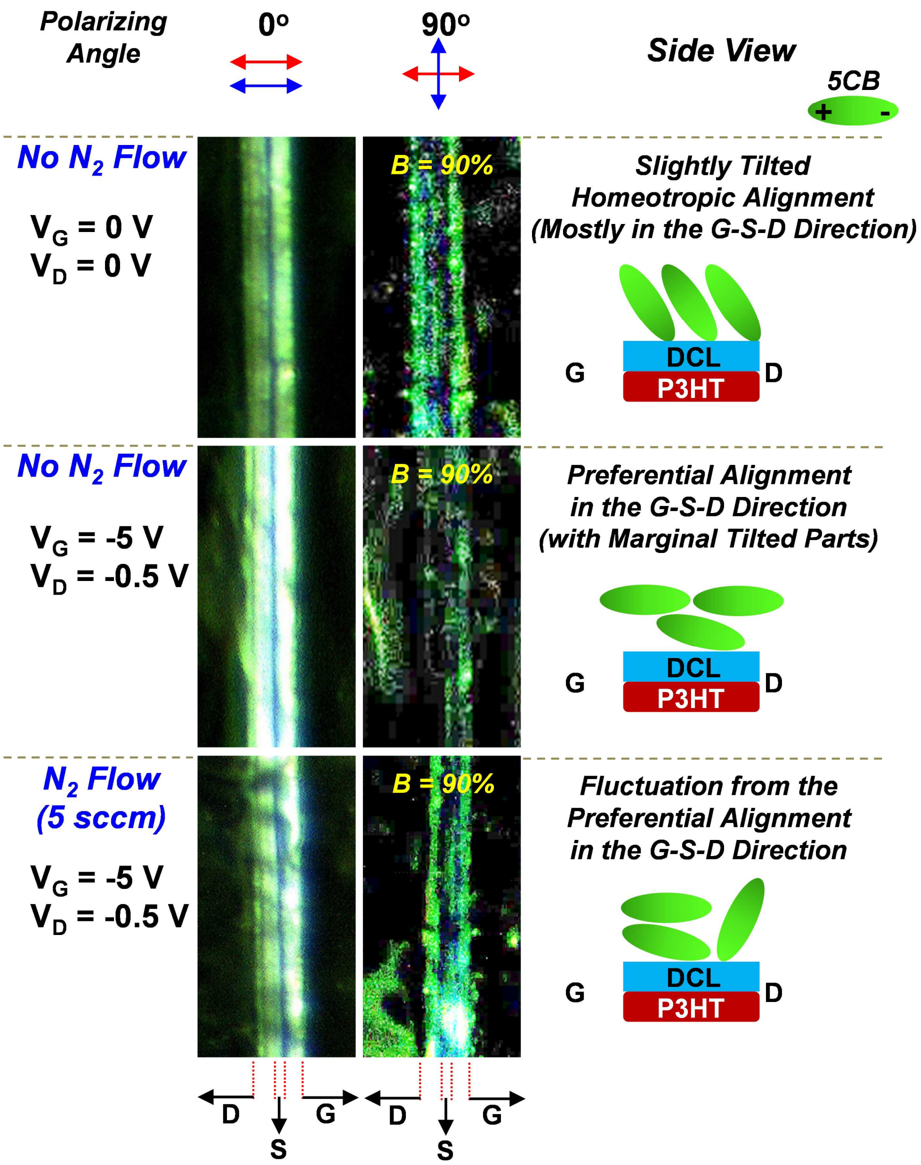

Fig. S4 Redisplay of Fig. 4: The brightness of the OM images at the cross-polarization condition (90°) was increased by 90% in order to increase the visibility of the channel area. Note that the brightness of the OM (90°) images in Fig. 4 was 0%. The brightness-enhanced images here show the different situations according to the voltage and flow conditions.

[Experimental Details]

Materials and Solutions: 5CB (purity = 98%) and PMMA (weight-average molecular weight = 120 kDa) were purchased from Sigma Aldrich (USA), while P3HT (weight-average molecular weight = 30 kDa, polydispersity index = 1.7, regioregularity = 97%) was supplied from Rieke Metals (USA). The polymer powders were dissolved in toluene and n-butyl acetate at a solid concentration of 15 mg/mL (P3HT) and 10 mg/mL (PMMA), respectively. The polymer solutions prepared were subject to stirring just before coating processes.

Device Fabrication: Indium-tin oxide (ITO)-coated glass substrates were patterned to make planar drain-source-gate electrodes by employing a photolithography/etching process. The channel length between the source electrode and the drain electrode was 15 µm. After patterning, all ITO-glass substrates were cleaned using acetone and isopropyl alcohol in an ultrasonic bath. The cleaned ITO-glass substrates were dried with a nitrogen flow. On top of the cleaned ITO-glass substrates, the P3HT layers were spin-coated for the preparation of a channel layer. The P3HT-coated substrates were annealed at 120 ^{o}C for 30 min, which resulted in the 50 nm-thick P3HT layer. Next, the PMMA layers were spin-coated on the P3HT layers in order to make a dipole control layer (PMMA thickness = 10 nm). After finishing all spin-coating processes, the P3HT/PMMA layers were removed from the source – gate (S-G) zone in order to prevent a possible leakage current by the presence of semiconductor (P3HT) between the source electrode and the gate electrode. Then a thin silicone polymer film (10 µm) with a rectangular hole in its center, which was prepared by cutting the center part off, was mounted on the P3HT/PMMA layer. Finally, 5CB was filled inside the rectangular hole and an ultrathin oriented-polypropylene film (thickness = 20 µm) as a cover skin layer was placed on top of the 5CB-filled silicone bank (see Fig. 2a).

Measurements: The surface morphology of the polymer layers was measured using an atomic force microscope (AFM, Nanoscope IIIa, Digital Instruments), while a surface profiler (alpha-step 200, Tencor) was employed for the measurement of the thickness of polymer layers and electrodes. The transistor performances and the sensing performances of devices were examined and measured with a specialized tactile sensor measurement system equipped with a semiconductor analyzer (Keithley 4200 SCS), a polarized optical microscope system (CVI Melles-Griot and PS-M140T-Modusystems) and a nitrogen flow control system (NF system). To measure the sensing performance of the LC-DCL-g-OFET devices, a nitrogen flow (0.5 ~ 5 sccm) was applied on top of the cover layer that is placed on the 5CB layer. The constant nitrogen flow was controlled by using a micro gas control unit (TSC-210, NF system) and an external controller (KRO-4000S, NF system). All measurements were carried out at 25 ~ 27 ^{o}C inside an acryl-boxed probe station system in the tactile sensor measurement system.