Organic Electrochemical Transistors Based on Dielectrophoretically Aligned Nanowire Array

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In the past 20 years, a large amount of research has been progressed in the area of organic thin film transistors (OTFTs) due to the many profits of organic semiconductors such as structural flexibility, low temperature processing, and especially low cost [1]. In recent years, organic electrochemical transistors (OECTs), the subset of OTFTs, have been attracted the area of sensing because of their ability of operating in aqueous environments with relatively low voltage and the integration with microfluidics [2]. Moreover, nanowires are owing to their unique properties and their potential for fabrication into high density nanoscale devices [3]. It needs to be integrated into an existing device for transistors and sensing elements, however, various methods fabricating nanowires between the electrodes have some limitation [3],[4].

In this research, we introduce the fabrication of individually addressable organic nanowires array on a single chip using dielectrophoresis and pH sensing based on OECT. Figure 1 shows the traditional MEMS process for preparation of the electrode array having cantilever shape for synthesis of nanowire [5]. Carbon nanotube based nanowire is synthesized by the dielectrophoresis and surface tension between the patterned cantilever electrodes. The solution which consists of CNT-COOH suspension and organic materials such as monomer of conducting polymer and nafion was place on between electrodes. Applying AC electric field, positive dielectrophoretic force gathered the CNTs with high electric conductivity between the electrodes where the electric field gradient is larger. After removing the solution, remaining CNT solution forms a concave meniscus because of their capillary force and contains CNTs gathered by dielectrophoretic force (Figure 2). Figure 3 shows a SEM image of a polypyrrole-CNT nanowire and polyaniline-CNT nanowire with a few hundreds nanowire thickness. Because the nanowire is synthesized only the electrodes applied electric field, it is possible to synthesize different kind of nanowire individually on a single chip.

As an example of OECT sensor, it is applied to pH sensor using CNT-nafion nanowire. Figure 4 shows the schematic diagram of OECT measurement. A drain-source voltage V_{DS} is applied 0.5V and electrolyte gate voltage V_G is swept from 0 to 0.5V. Figure 5 is the graph of drain source current ratio I_{DS} to current at zero gate voltage I_0 according to some pH buffer solutions. Owing to increase of the gate voltage, the cations are attached CNT-nafion nanowire by the repulsive force and obstruct the current through the nanowire between drain-source electrodes. The incline of the I_{DS} according to the change of V_G is steeper at lower pH because of larger quantity of hydrogen ions. The slope of current ratio is linearly dependent of pH value.

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References

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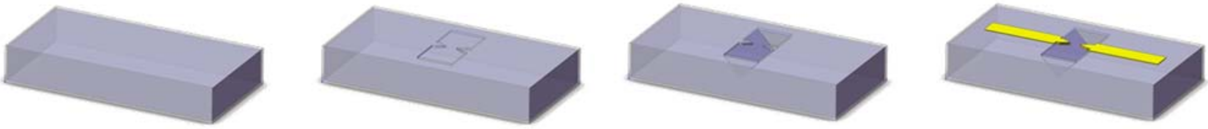
Figures



(a) Silicon nitride deposition (b) RIE etching (c) TMAH bulk etching (d) Electrode deposition

Figure 1. Schematic process of cantilever electrodes fabrication

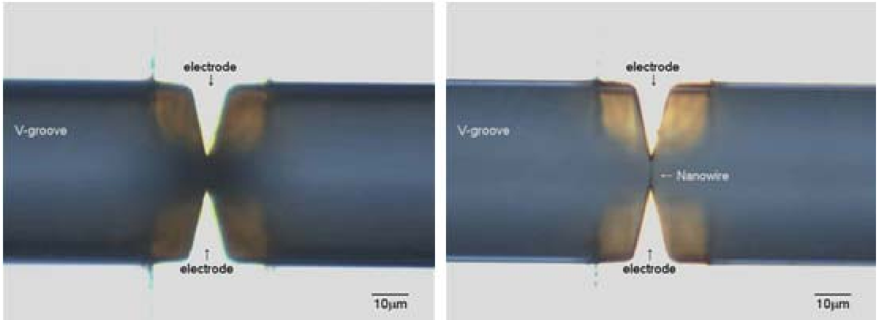


Figure 2. Microscope images of nanowire fabrication process, (a) attraction of CNT between electrodes with AC voltage; (b) nanowire synthesized between electrodes after removal of solutions.

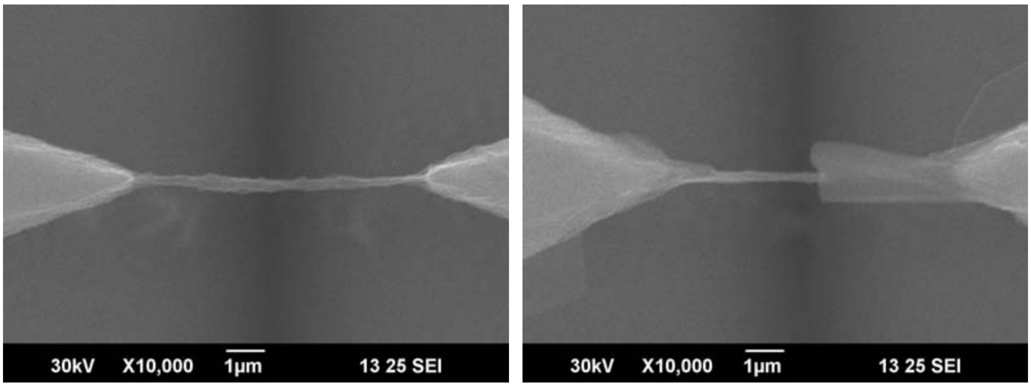


Figure 3. SEM image of (a) CNT-polypyrrole nanowire and (b) CNT-polyaniline nanowire.

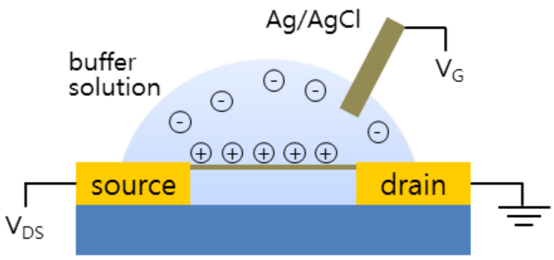


Figure 4. Schematic diagram of OECT measurement

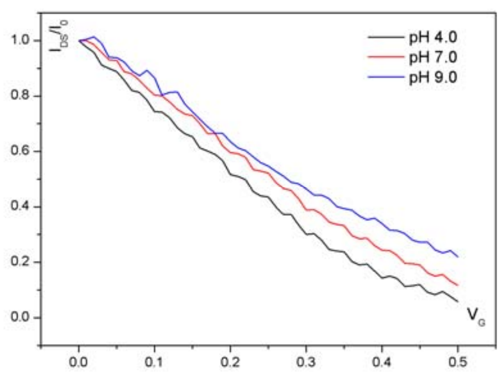


Figure 5. The graph of current ratio *vs.* gate voltage

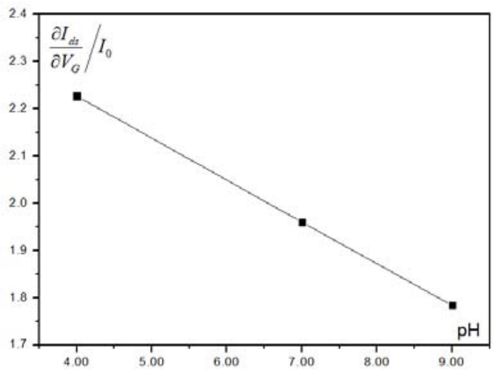


Figure 6. The graph of slope of current ratio according to gate voltage *vs.* pH