Influence of Au Nanoparticles on NOMFET for Application of Cancer Stem Cell Bio-sensor

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Recently, organic devices have attracted attention for the application in memory and bio-sensor because of low cost and flexibility. The nanoparticle organic memory field-effect transistor (NOMFET) has been demonstrated as a bio-sensor which employs the affinity between nanoparticle and linker for connecting bio-marker. Thus, we investigated the possibility of NOMFET for the application of cancer stem cell bio-sensor. When NOMFET linked with bio-marker was stuck to a charged cancer stem cell, it makes a change in the threshold voltage and decreases the drain current of NOMFET.

NOMFET structure consists of three terminal electrodes of drain, source, and bottom gate. As shown in Fig. 1 (a) and (b), Au nanoparticles were embedded in the organic semiconductor (pentacene) layer between drain and source electrodes. Since the pentacene is a p-type organic semiconductor, the drain-source current flowed through the hole-channel. So, the hole-channel is generated in the pentacene on the silicon oxide by biasing a negative gate voltage.

In our experiment, NOMFET were fabricated by eight sequences. At first, we prepared a highly doped silicon wafer grown by thermal oxidation. And photoresist (PR) film was formed by spin-coating process and soft-baked at 125 ^{o}C for 10 min. PR film was patterned by UV-exposure with Cr-mask and developed by using AZ-500. Ti and Au were deposited with a thickness of 5 and 200 nm by thermal evaporation, respectively. Source and drain electrode were defined by PR lift-off method. In order to form Au nanocrystals, Au layer was deposited by thermal evaporation and annealed at 700 ^{o}C for 2 hr. Pentacene was deposited on the OTS-treated SiO_2 substrate by thermal evaporation. As a reference device, organic field effect transistor (OFET) was fabricated by using the same process as that of NOMFET. I-V characteristics such as I_{ds}-V_{gs} and I_{ds}-V_{ds} were measured by using a 4155C semiconductor parameter analyzer. Before the I-V sweep, the bias conditions of program (the charging of hole in the Au nanoparticles) and erase (the discharging of hole in the Au nanoparticles) were V_g = -50 V for 20 sec and V_g = 50 V for 20 sec, respectively.

Figure 2 shows top-view of SEM images for Au nanoparticles formed on SiO_2 substrate by annealing process (700 ^{o}C, 2hr). Fig. 2 (a) shows the average size of 30 nm of Au nanoparticles after annealed with Au thickness of 5 nm by thermal evaporation. Also, Fig. 2 (b), (c), and (d) show Au nanoparticles was increased in the average size from 88 to 566 nm with increasing in the thickness of Au layer from 10 to 20 nm. From the image analysis, it was confirmed that the density of Au nanoparticles for 5, 10, 15, and 20 nm is 8.58×10^{10}, 7.99×10^{9}, 1.22×10^{9}, 7.58×10^{7} cm^{-2}, respectively, as shown in Fig. 2(a), (b), (c), and (d). On the average, the larger Au layer thickness has lower nanoparticle density.

Figure 3(a) and (b) show I-V characteristics of OFET, and Fig. 3(c) and (d) are for NOMFET. Fig. 3 (a) and (b) show threshold voltage shift (ΔV_{th}) is around -2 V and the drain current is almost same after program and erase at the OFET. Otherwise, Fig. 3 (c) and (d) show that NOMFET has larger threshold voltage shift (~ -11 V) than OFET after program and erase. And the drain current after erase was two times larger than the drain current after program in the Au nanoparticles. As a result, the threshold voltage to generate the hole-channel in the pentacene of NOMFET was larger than that of OFET, resulting from screening of the drain current due to Au nanoparticles.

In our presentation, we report the effect of Au nanoparticles in the pentacene of the NOMFET on electrical properties by characterizing samples by using SEM and TEM. In particular, we present the effect of Au nanoparticles size and density on shifting of threshold voltage and changing of drain current. In addition, we discuss the feasibility of cancer stem cell bio-sensor depending on the size and density of Au nanoparticles.

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Reference

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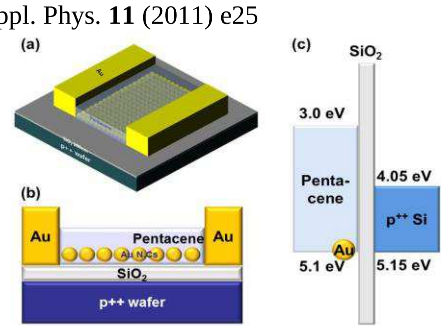

Fig. 1. NOMFET embedded with Au nanoparticles: (a) NOMFET structure, (b) cross-sectional structure and (c) energy band diagram

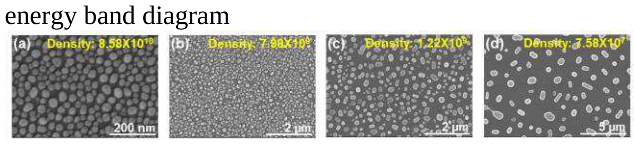

Fig. 2. Top-view SEM images of Au nanoparticles which is deposited thickness; (a) Au 5 nm : 200k, (b) Au 10 nm : 20k, (c) Au 15nm : 20k and (d) Au 20 nm : 10k

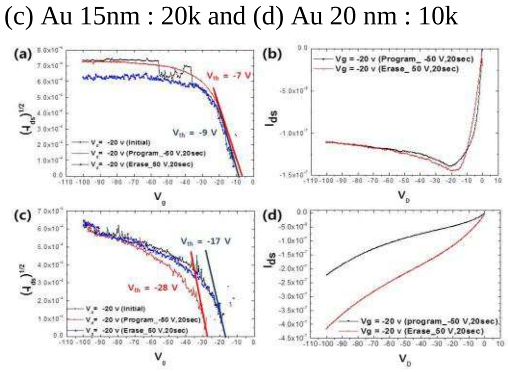

Fig. 3. I-V characteristics of OFET : (a) V_g vs. $(-I_{ds})^{1/2}$, (b) V_d vs. I_{ds}, I-V characteristics of NOMFET embedded with an average 30 nm Au nanoparticles : (c) V_g vs. $(-I_{ds})^{1/2}$, and (d) V_d vs. I_{ds}