Evaluation of ZnO:Ga nanoparticle-based thin-film-transistors

(D)Islam Md Maruful[1], Toshiyuki Yoshida[2,] and Yasuhisa Fujita[2]
[1]Interdisciplinary Graduate School of Science and Engineering, Shimane University, Matsue 690-8504, Japan
[2]Graduate School of Natural Science and Technology, Shimane University, Matsue 690-8504, Japan
*s199801@matsu.shimane-u.ac.jp

Zinc oxide, a third-generation semiconductor material with a wide and direct band gap, has received considerable attention due to its excellent optical and electrical properties. The band gap of 3.37eV and a relatively higher exciton binding energy of 60meV **[1]**. Recently, both n-channel and p-channel back-gate TFTs on Si/SiO_2 substrates were demonstrated by using laboratory synthesized ZnO-nanoparticles (NPs) with a physical spray coating method **[2]**, But the sheet resistance of conductive layer was too high which degraded the performances of TFT. In our previous study, the dramatic improvements of current transportation ability of ZnO-NP based Schottky-gate TFTs by using a unique thermal diffusion type Ga-doping process **[3]** was presented. This study represents the comparison of ZnO MESFET and MISFET properties with a low resistive n-channel layer.

ZnO-NPs were synthesized using an arc-discharge-mediated gas evaporation process with a chamber pressure of 610 Torr and an arc current of 20 A **[4]**. Diffusion type Ga-doping into ZnO-NPs was carried out according to ref. **[5]**, i.e. mixing ZnO-NPs with Ga_2O_3-NPs and thermally treated in open-air at 800° C for 60 min. Particles were dispersed in ultrapure water by ultrasonic homogenization and centrifugation processes, which can remove residual Ga_2O_3-NPs. Obtained dispersions (median size of 240 nm) were sprayed onto quartz and Si (covered with 100 nm SiO_2) substrates with 5 and 10 s intervals for ~13 and 22 min using a wide-used air-brash (**Fig. 1**) with hotplate temperature 500 and 270° C for MESFET and MISFET fabrication process, respectively. For both FET operations, 0.4 x 0.4 mm^2 Al electrodes (ohmic source and drain) with a distance of 450 μm were deposited. A 30nm gold electrode was used as a MES-top-gate. **Figs. 2(a)** and **2(b)** show the cross-sectional illustrations of ZnO MISFET and MESFET, respectively.

Previous analyses indicate that the resistance value falls from the order of MΩ/sq to sub-kΩ/sq by thermal treatment with Ga_2O_3 NPs and Ga incorporated into ZnO-NPs with substituting for Zn; i.e. Ga-doping was achieved effectively **[5]**. **Fig.3** shows the variations of transconductance (g_m) and ON/OFF current ratio for MES- and MIS-gate-type TFTs. The gate voltage was applied 0 V to -10 V and 0 V to 10 V with 2 V step to measure the I_D-V_D characteristics. The MIS-gate-type TFTs on Si/SiO_2 substrates showed an improved transconductance (g_m=1.9μS) compared with MES-gate-type TFTs on quartz substrates (g_m=0.6μS) . The value of I_{OFF}/I_{ON} ratio @V_D=10 V was 0.05 in MIS-gate-type, which is one order of magnitude smaller than the value of 0.17 in MES-gate-type. Details should be shown in the presentation. Thus the effect of our unique Ga-doping for ZnO-NPs was clearly observed.

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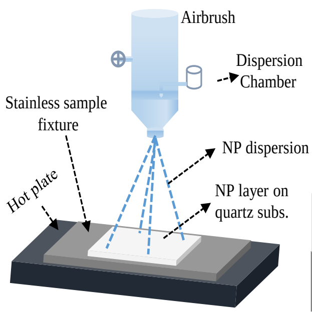

Fig.1. Schematic illustration of spray coating method

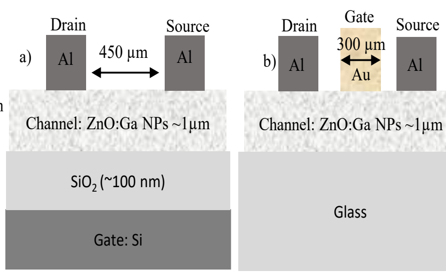

Fig.2. Cross sectional view of (a) MISFET and, (b) MESFET.

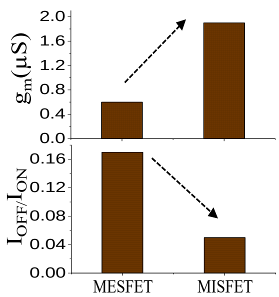

Fig.3. Calculated transconductance and OFF/ON current ratio.