1. Introduction

Amorphous oxide semiconductor materials have attracted much attention as key components of TFTs for flexible electronics [1]. The advantages of such materials include flexibility and transparency which are compatible with plastic substrates, and higher mobilities than those of amorphous-Si and organic semiconductor TFT materials.

In this paper, the operation of an amorphous oxide semiconductor TFT was analyzed by the two-dimensional numerical simulator ATLAS to verify the applicability of standard drift-diffusion models to an amorphous oxide semiconductor material.

2. The Device Structure and Models

An amorphous oxide semiconductor TFT fabricated and reported by Nomura et al. [2] was simulated and resultant ID-VD and ID- VG curves were compared with measured data.

The device structure reported is shown in Figure 1. Top gate structure was adopted. Amorphous In-Ga-ZnO (a-IGZO) channel layer was fabricated on a polyethylene terephthalate (PET) sheet. A high-k dielectric Y2O3 material for gate insulator and transparent indium-tin oxide (ITO) material for the source, drain and gate electrodes were deposited. The channel length and width are 50 µm and 200 µm respectively.

In order to grasp the fundamentals needed to describe a-IGZO TFT electrical behavior, models which are as simple as possible were selected and their parameters were calibrated as follows:

For all the ITO electrodes, Schottky contact model with work function of 4.6 eV were chosen. For the a-IGZO material, an acceptor type density of states model with no doping, constant electron mobility model of 8.0 cm²/(Vsec), and band-to-band tunneling model were assumed.

Figure 2 shows the energy distribution of acceptor type density of states used. Unlike amorphous-Si or many organic materials, slope of tail state is quite gentle and peak density of states is located not at band edges but around mid-gap.

3. Results and Discussion

The output characteristics are shown in Figure 3. The simulation results (blue lines) are in fairly good agreement with the measured data (red lines). Since the mobility dependencies of a-IGZO material have not been fully investigated yet and remains mostly unknown, constant mobility model is used. The mobility modeling for a-IGZO material may improve simulation accuracy much further.

Figure 1. Cross section of the a-IGZO TFT.

Figure 2. Energy distribution of acceptor type density of states assumed.
The simulated transfer characteristic (blue line) for a drain-source voltage of 2V is shown in Figure 4 with measured curves (red line). The simulated on/off current ratio of about 1.0e6 and the subthreshold slope about 240 [mV/decade] are well agreed with measured data. For the gate reverse biased region, though it is stated in ref.[2] that drain current corresponded with gate current in measurements, gate current model is omitted as a matter of minor importance. That is thought to be the cause of the difference in drain off currents. But as such gate leakage current may cause the interface charge between a-IGZO and Y$_2$O$_3$ in this particular case, a sheet charge of 1e11 [1/cm$^2$] is assumed to simulate the ID-VG measurement curve.

Figure 5 shows electron concentration distribution in the channel layer with potential contour lines superimposed both in on state (upper picture) and off state (lower one). Channel pinch-off is clearly shown near the drain in on state, and channel electron is well depleted in off state and hole inversion layer about 1.0e17 [1/cm$^3$] which is also superimposed as contour lines comes out under gate. Depending on the donor type density of states which are not needed to be considered this time, there may be a possibility for complementary operation.

4. Conclusion
In this paper, it was shown that the electrical characteristics of an amorphous oxide semiconductor TFT can be simulated numerically by standard drift-diffusion models in ATLAS. A density of states model was used to characterize the a-IGZO material for trapped charges and generation/recombination in it.

The models of standard drift-diffusion with density of states have wide applicability not only for organic materials [3] but also for amorphous oxide semiconductors.

References