Amorphous In-Ga-Zn-O-based Metal-Semiconductor Field-Effect Transistors
by Schottky contact made of bottom Pt electrode

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Introduction
Amorphous oxide semiconductors (AOSs) thin-film transistor (TFT) is expected as an alternative to Si-based TFTs in next-generation flat-panel displays (FPDs) because AOS TFTs exhibit large field-effect mobilities over 10 cm²(Vs)⁻¹ [1]. In addition, AOSs have a significant advantage of a low-temperature process, which would lead to the flexible electronics technology. For producing practical AOS flexible devices, it is important to develop optoelectronic devices other than TFTs, and metal-AOS Schottky contacts can be used not only for oxide-based flexible electronic circuits integrated with AOS TFTs but for such applications as metal-semiconductor field-effect transistors (MESFET) and photodetectors.

In this study, we firstly report the good and stable Schottky contacts made of amorphous In-Ga-Zn-O (a-IGZO) and Pt electrodes, and secondly introduce a-IGZO-based MESFET originating from the a-IGZO/Pt Schottky junction.

Experimental
The a-IGZO layers were deposited by pulsed laser deposition (PLD) at RT and the Pt electrodes were formed by electron-beam evaporation. ITO was used for the ohmic contacts. Highly-resistive a-IGZO films should be used to make good Schottky contacts, and some devices are subjected to a post-annealed process below 200°C. The device characteristics were examined by current density-voltage (J-V) and capacitance-voltage (C-V) measurements at RT in an ambient atmosphere in dark using a semiconductor parameter analyzer (Agilent, 4294A), respectively.

Results and Discussion
Fig. 1 shows J-V characteristics of the two different Pt/IGZO Schottky device structure before and after annealing process. We obtained the good and stable rectifying effects even for the as-fabricated devices by simply changing the device structure from the top Pt structure to the bottom Pt structure as showed inset of Fig. 1(a, b). These different electrical results of top and bottom Pt structure may be due to a strong Fermi level pinning or tunneling contact formation in the top Pt/a-IGZO interface because surfaces of oxide semiconductor as well as a-IGZO are very sensitive and easily reduced by depositing metal electrode. However, further studies need to be undertaken to investigate the lack of significant rectifying contact properties. It was found that Schottky contacts optimally faricated (open triangles in fig. 1(b)) have an ideality factor n ~ 1.1 and a barrier height \( \varphi_b \sim 0.9 \) eV from J-V curves analyzed using the thermionic emission model as follow eq. (1, 2).

\[
J = J_0 \exp(\frac{qV}{nk_BT}) \\
J_0 = A^*T^n \exp(-\varphi_b/k_BT)
\]

Fig. 1. J-V characteristics of the (a) top contact Pt/IGZO and (b) bottom contact Pt/IGZO Schottky device structures before and after annealing process.
Fig. 2. Temperature dependent (a) J-V characteristics and (b) ln(J0/T^2) (Richardson plot) and ideality factors n (c) each of effective barrier heights \( \phi_{b, eff} \) extracted eq. (3) for Pt/a-IGZO device.

Fig. 2(a) shows the temperature dependence of J-V curves for the Pt/a-IGZO Schottky junction (having \( \phi_b \sim 0.9 \) eV and n~1.1 at RT) measured between 157 and 298 K. First, we try to estimate an effective barrier height \( \phi_{b, eff} \) from the slope of Richardson plot expressed eq. (2) by fitting a part of dashed-box in Fig. 2(a). However, the obtained plot (as shown fig. 2(b)) shows not enough linearity at 200K on the boundary and the extracted ideality factor values for each temperature were also not constant and increase to 1.9 with decrease of temperature. These results indicate the \( \phi_{b, eff} \) values has a distribution as changing temperature which is unexplained a simple Schottky barrier model. Therefore, we applied the barrier potential fluctuation model [2]. Under the these distribution of barrier potentials, the \( \phi_{b, eff} \) determined by J-V characteristics becomes smaller by decreasing temperature as expressed by eq. (3) because current preferentially flows over lower barrier paths at lower temperatures,

\[
\phi_{b, eff} = \phi_{b, m} - q\sigma_s^2 / 2k_B T \quad (3)
\]

Fig. 2(c) shows the \( \phi_{b, eff} \) obtained from the J-V curves as a function of temperature, and we found that it follows well the barrier potential fluctuation model. This analysis provides net electron affinity \( \chi_s \) of a-IGZO of 4.2 eV at the mean barrier height \( \phi_{b, m} \) value of approximately 1.2 eV having the standard deviation \( \sigma_s \) of 0.13 eV.

Finally, we examined the performance of a-IGZO based MESFET made of Pt Schottky contact.

Fig. 3. (a) Transfer characteristics and gate currents \( I_G \) (black dashed line) and (b) Output characteristic for a-IGZO based MESFET made of Pt Schottky contact.

References

Publication
[paper]

[presentation]