Quantitative analysis of organic anti-ambipolar field-effect transistors

◦(M1) Junyi Zhu[1], Takehiko Mori[1]

Tokyo Institute of Technology, Department of Materials Science and Engineering [1]

E-mail: zhu.j.af@m.titech.ac.jp

In recent years, anti-ambipolar transistors (AATs) have received widespread interest due to the characteristic negative differential resistance (NDR) [1,2]. In this work, AATs are quantitatively analyzed based on a series circuit consisting of N- and P-type transistors.

AATs are constructed from P-type dibenzotetrathiafulvalene (DBTTF) and N-type cyclohexyl-naphthalenediimide (Cyh-NDI) transistors. The transfer characteristics (Fig. 1(a)) are well represented by $I_D = (\mu_e CW/2L)(V_G - V_{th}^e)^2$ and $I_D = (\mu_h CW/2L)(V_G - V_D - V_{th}^h)^2$, from which the (P-/N-type) carrier mobilities and threshold voltages are extracted to be 0.028/0.0194 $cm^2 V^{-1} s^{-1}$ and −8 /42 V, respectively. To attain the same I_D in a series of P- and N-type transistors, the observed results are well reproduced by the simulation (Fig. 1(b)). As shown in Fig. 1(c), the output characteristics follow $I_D = (\mu_h CW/2L)(V_G - V_D - V_{th}^h)^2$ when $V_D < \left(1 + \sqrt{\mu_e/\mu_h}\right)(V_G - V_{th}^e) + V_{th}^e - V_{th}^h$, and constant above this. By using triethoxyperfluorodecylsilane as a SAM of the DBTTF device, V_{th}^h increases above 80 V; when $V_{th}^e < V_{th}^h$, a non-zero current appears in the $V_D < 0$ V region (Fig. 2(a)). The $V_D < 0$ V characteristics (Fig. 2(b)) are satisfactorily reproduced by the simulation (Fig. 2(c)).

[1] Y. Wakayama, *et al.*, Adv. Funct. Mater. **30**, 1903724 (2020).

[2] J. Shim, *et al.*, Nat. Commun. **7**, 13413 (2016).

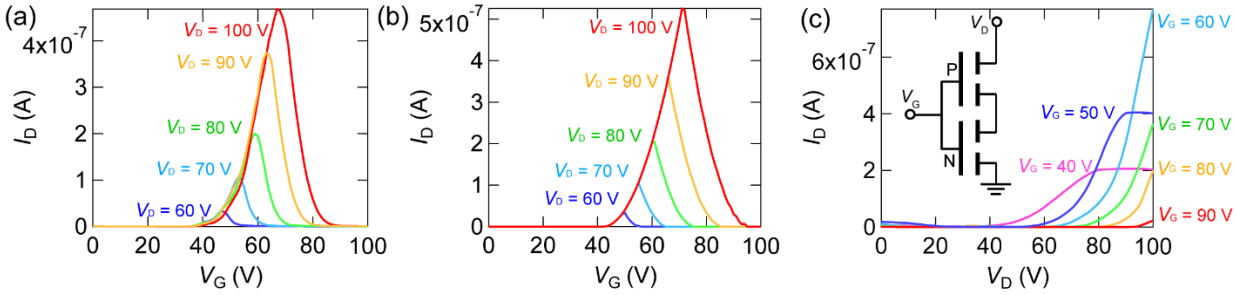

Fig. 1 (a) Observed, and (b) simulated transfer characteristics of an AAT where V_{th}^e = 42 V and V_{th}^h = −8 V. (c) Observed output characteristics of the AAT and the circuit diagram.

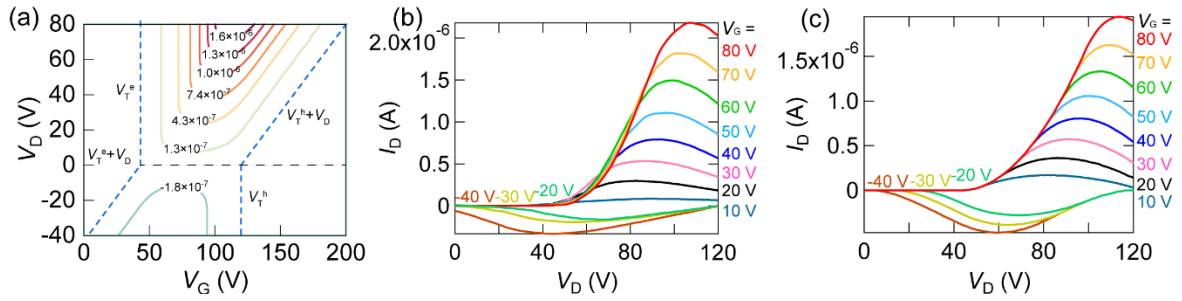

Fig. 2 (a) Contour map of I_D where V_{th}^e = 43 V and V_{th}^h = 120 V. (b) The corresponding observed, and (b) calculated transfer characteristics.