ALUMINIUM OXIDE PREPARED BY ATOMIC LAYER DEPOSITION IN ORGANIC THIN-FILM TRANSISTORS OPERATING AT 2 V: COMPARISON WITH UV-OZONE OXIDATION

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INTRODUCTION

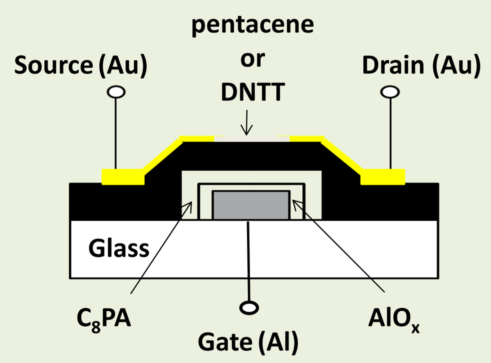
Large-area, roll-to-roll fabrication of thin-film circuits demands layer thickness uniformity over large areas. Previously, a 10-nm-thick dry bi-layer dielectric based on aluminium oxide (AlO_x) prepared by UV-ozone oxidation and n-octylphosphonic acid (C_8PA) monolayer prepared by vacuum evaporation has been developed for organic thin-film transistors (OTFTs) based on pentacene. Here we compare such OTFTs to similar transistors that incorporate ALD-AlO_x/C_8PA bi-layer. In addition, a 12.9-nm-thick ALD-AlO_x exposed to UV-ozone for 60 minutes was incorporated into OTFTs based on dinaphtho[2,3-*b*:2',3'-*f*]thieno[3,2-*b*]thiophene (DNTT).

AIMS

- Use atomic layer deposition (ALD) to grow thin layers of AlO_x for low-voltage OTFTs.
- Compare Al/ALD-AlO_x/C_8PA/pentacene/Au and Al/UV-ozone-AlO_x/C_8PA/pentacene/Au transistors and metal-insulator-metal (MIM) structures.
- Fabricate Al/ALD-AlO_x/DNTT/Au and Al/ALD-AlO_x/C_8PA/DNTT/Au OTFTs and compare them with pentacene OTFTs.

EXPERIMENT

- Two devices incorporated thin ALD-AlO_x (12.9 nm) and two used thicker (36.8 nm) ALD-AlO_x. ALD performed from H_2O and TMA at 160°C.
- Within each pairing, one sample underwent a 2-minute UV-ozone clean prior to C_8PA assembly and/or pentacene evaporation. All other transistor layers were identical to UV-ozone-AlO_x (9 nm) OTFTs. W = 1000 µm and L = 30, 50, 70 and 90 µm.
- In the DNTT OTFTs the ALD-AlO_x (12.9 nm) layer was exposed to UV-ozone for 60 minutes prior to C_8PA self-assembly. Source/drain and gate contacts are similar to pentacene transistors.



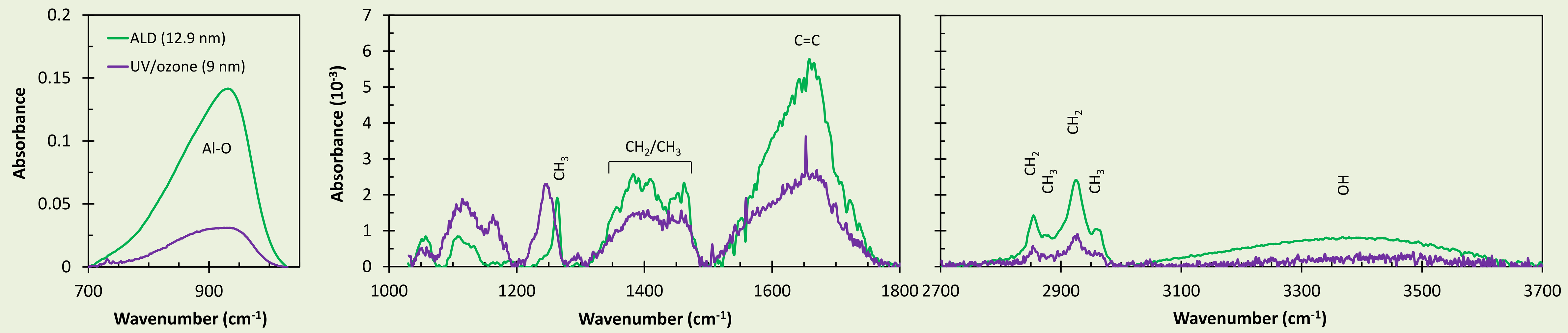
Linear regime ($|V_{DS}| < |V_{GS}-V_t|$):

$$I_D = \mu C \frac{W}{L}\left(V_{GS}-V_t\right)V_{DS} \qquad \mu_{lin} = \frac{\partial I_D}{\partial V_{GS}} \cdot \frac{1}{C V_{DS}\frac{W}{L}}$$

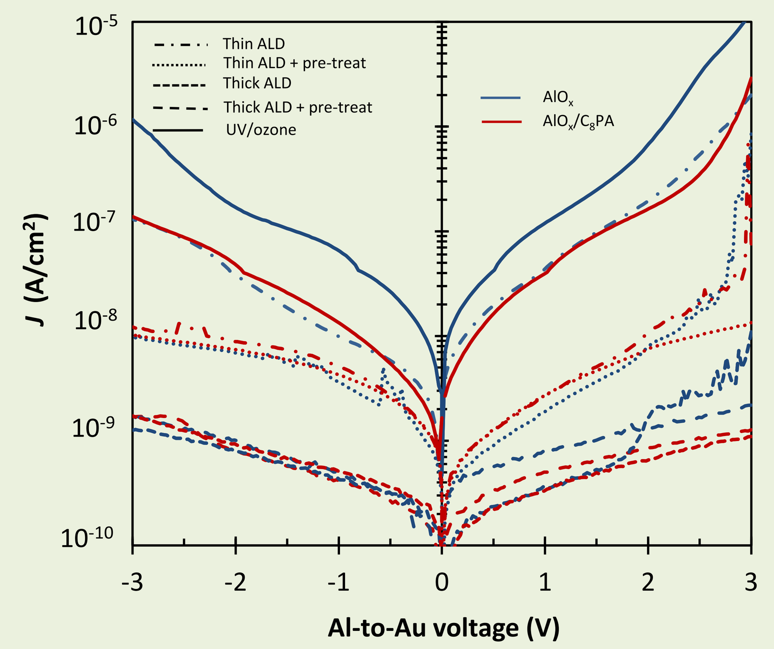
Saturation regime ($|V_{DS}| > |V_{GS}-V_t|$):

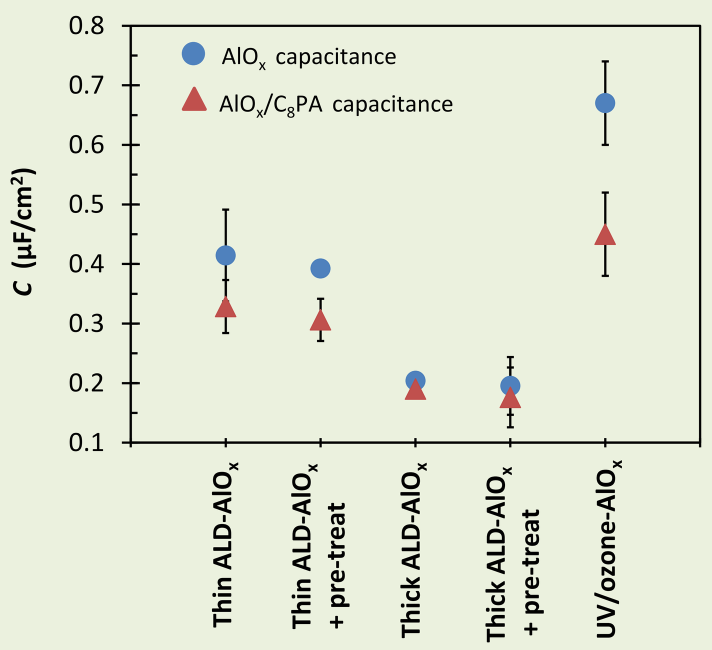
$$I_D = \mu C \frac{W}{2L}\left(V_{GS}-V_t\right)^2 \qquad \mu_{sat} = \left(\frac{\partial \sqrt{I_D}}{\partial V_{GS}}\right)^2 \cdot \frac{1}{C\frac{W}{2L}}$$

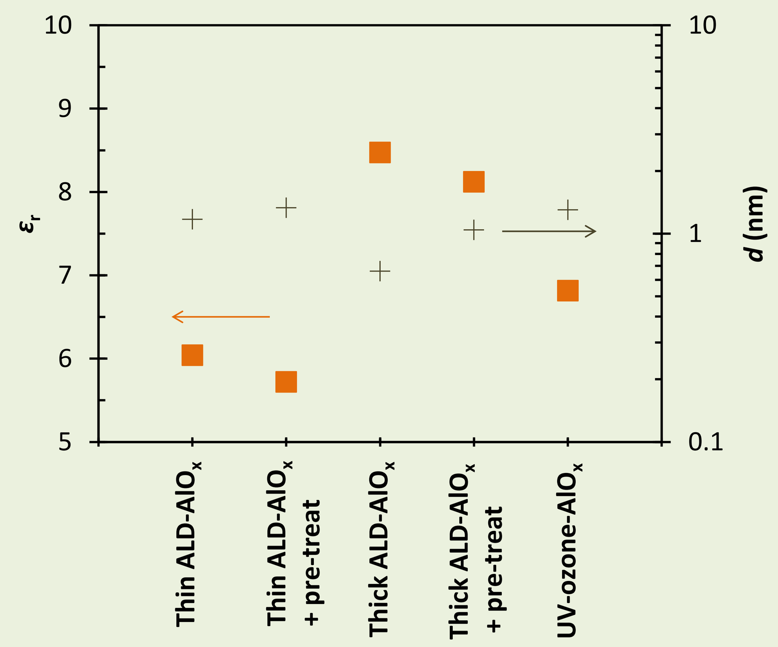
FTIR



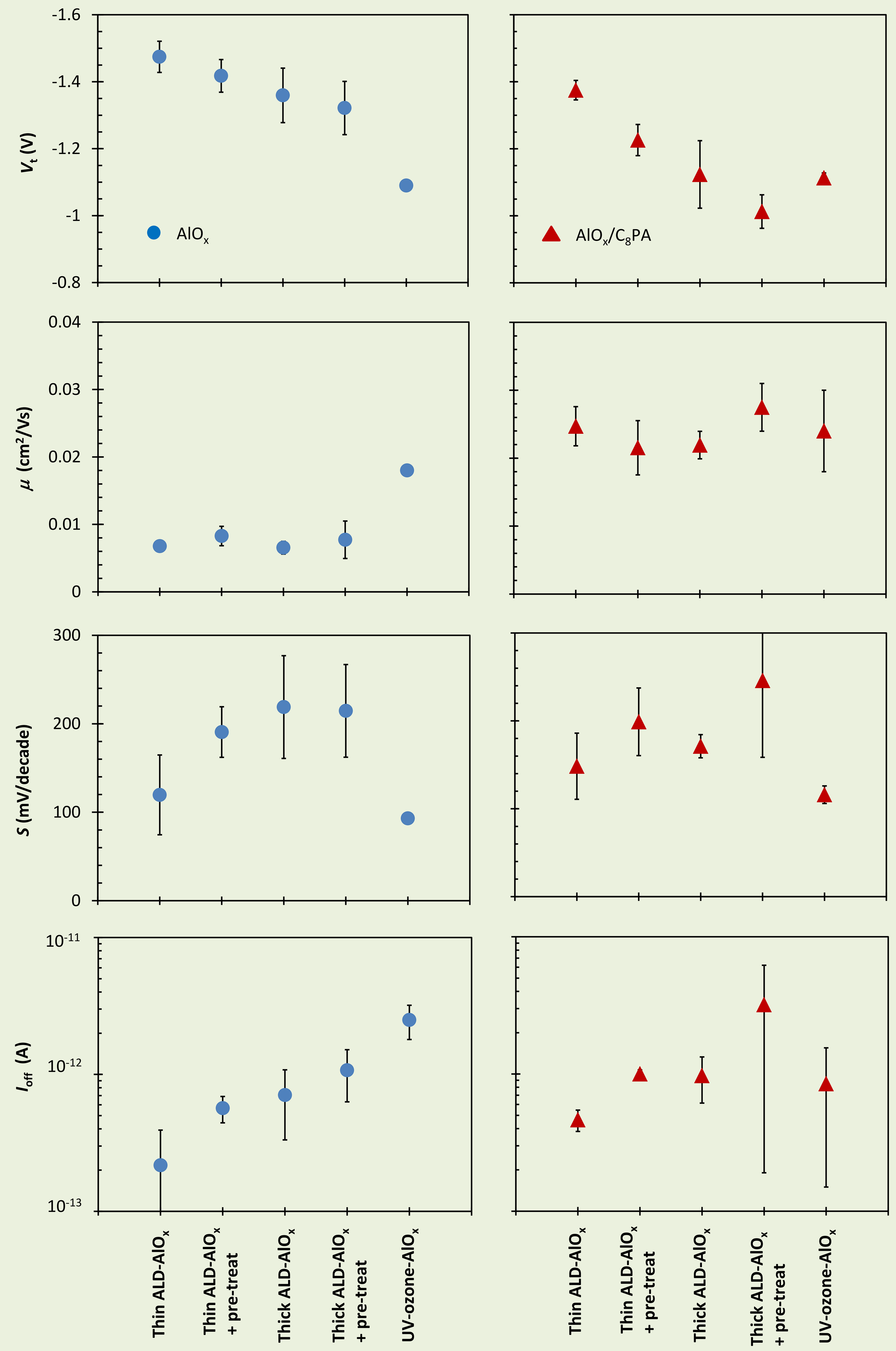
RESULTS: MIM STRUCTURES



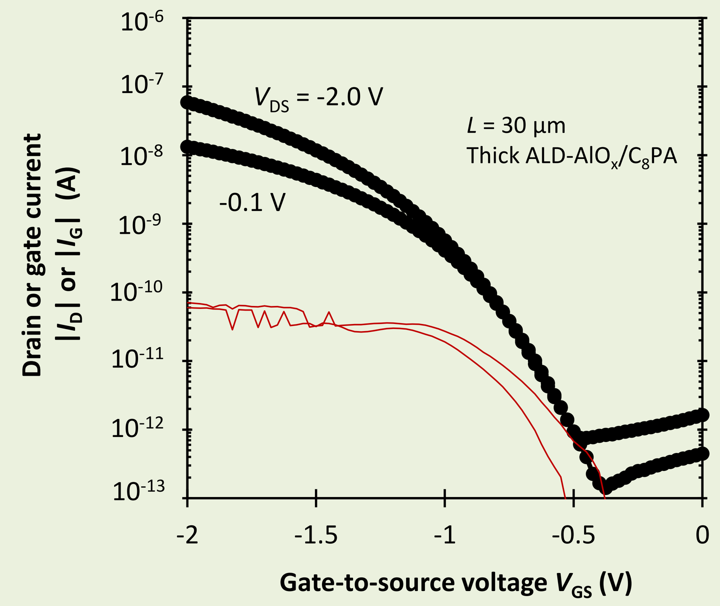




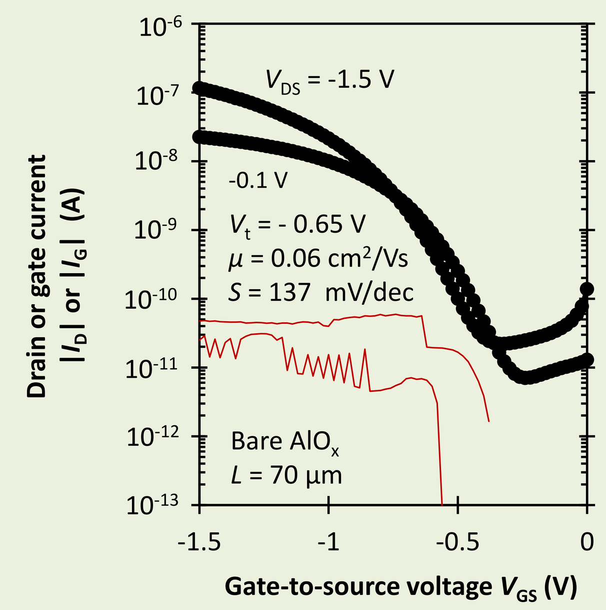
RESULTS: PENTACENE TRANSISTORS

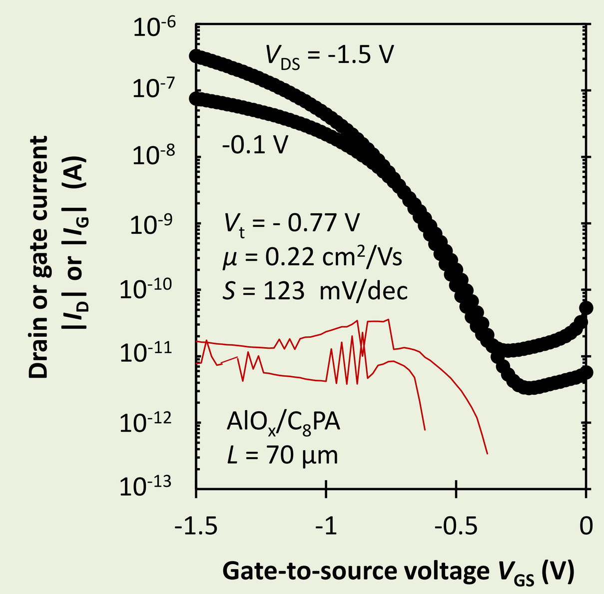


PENTACENE TRANSISTORS



DNTT TRANSISTORS





CONCLUSIONS

- Leakage current density and capacitance are lower for ALD-AlO_x; primarily as a result of the thicker layer.
- C_8PA self-assembly is not affected by the AlO_x layer or by its treatment.
- UV-ozone-AlO_x leads to the lowest threshold voltage. Other parameters are comparable to OTFTs with ALD-AlO_x.
- DNTT OTFTs show greatly improved transistor performance over pentacene devices; DNTT offers lower threshold voltage and substantially higher mobility.

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