

High operational stability of n-type organic transistors based on Naphthalene Bisimide

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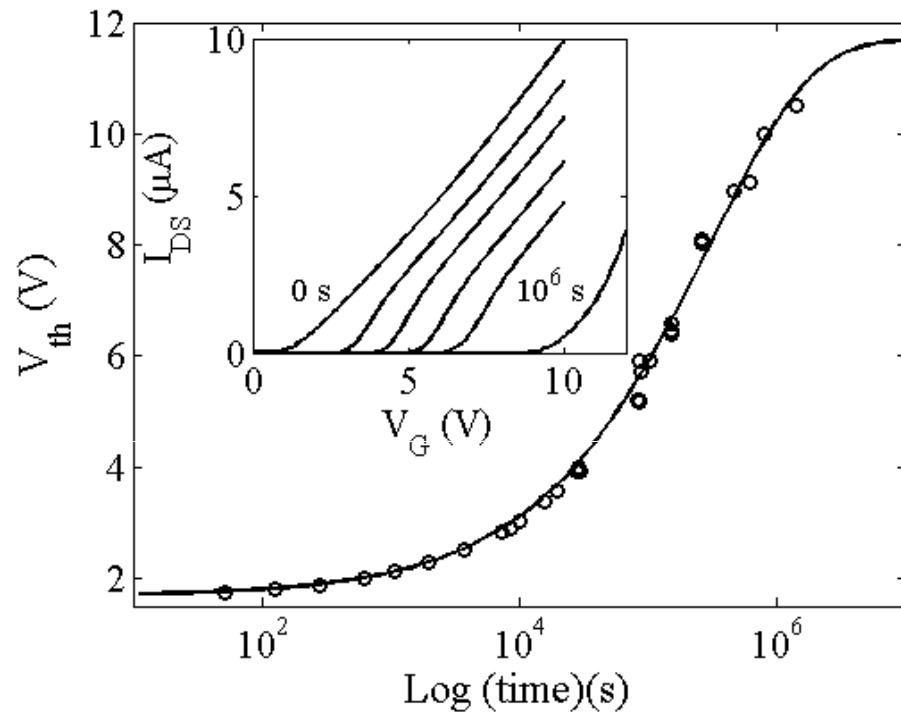


Outline

- **TFT operational stability (a review)**
figure of merit and benchmarking TFTs
(the need for a standard)
- **N-type OFETs based on Naphthalene Bisimide**
Drain-source and gate-bias stress
Trapping in the dielectric
Contact effects
- **Conclusions**

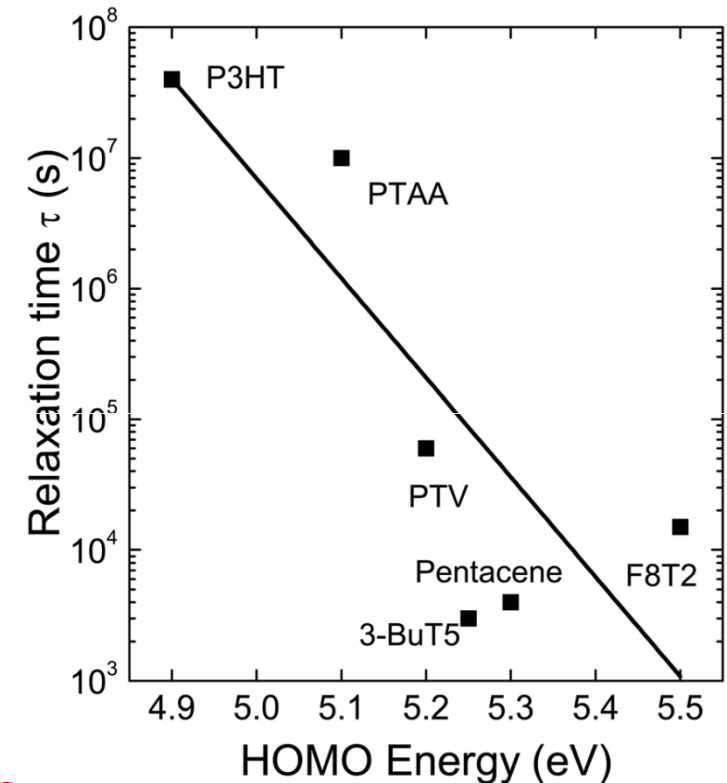


Gate-bias stress / (figure of merit)



$$V_T(t) = \Delta V_T \exp[-(t/\tau)^\beta] + V_{T0}$$

τ is a figure of merit that measures stability



A. Sharma et al.
Appl. Phys. Lett. 99, 103302 (2011)



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Benchmarking TFTs

Semiconductor		τ @RT (s)	β	E_a (eV)
Dielectric /Processing				
GIZO annealed @ 200 °C thermal SiO ₂ , measured in vacuum	Stress	3.0x10 ⁵	0.5	0.68
Organic semiconductor (in vacuum)		1x10 ⁷	0.44	0.6
Organic semiconductor (in air)		1x10 ⁴	0.5	
Amorphous silicon	Stress	8x10 ⁷		0.98
	Recover	5x10 ⁹		1.1
Micro-crystalline silicon		10 ¹²		1.07

Mathijssen Simon et al, "Advanced Materials **19**, 2785 (2007)

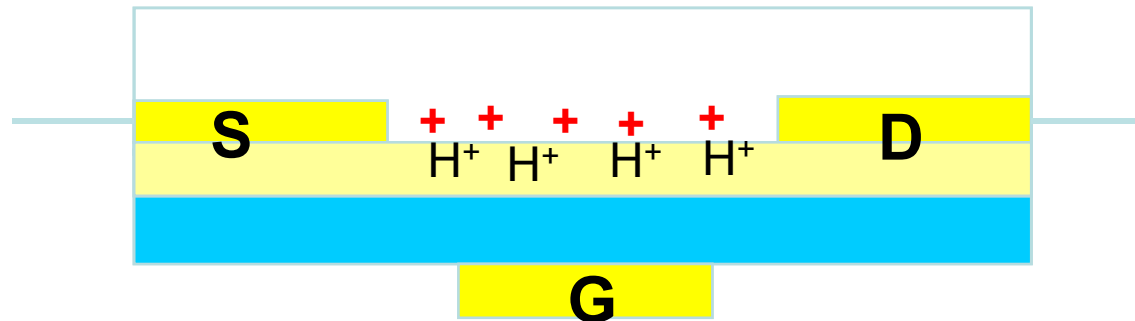
M. E. Lopes et al. Appl. Phys. Lett. **95**, 063502 (2009);

Chowdhury et al. J. Appl. Phys. 110, 114503 (2011)

The method is totally inadequate for an industry-standard benchmark.



Trapping of protons in the dielectric

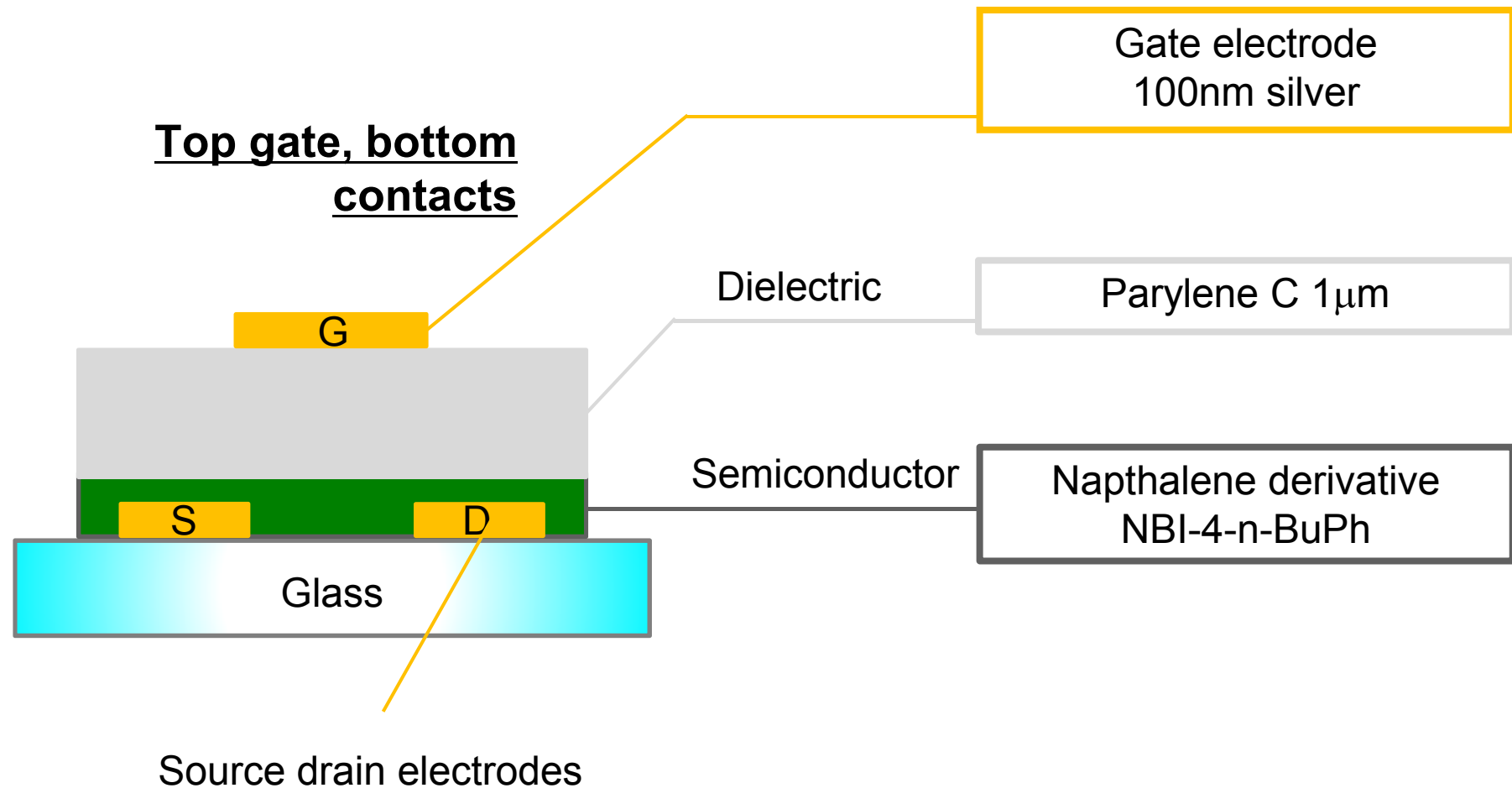


Production of protons .



A. Sharma et al. Appl. Phys. Lett. 99, 103302 (2011)

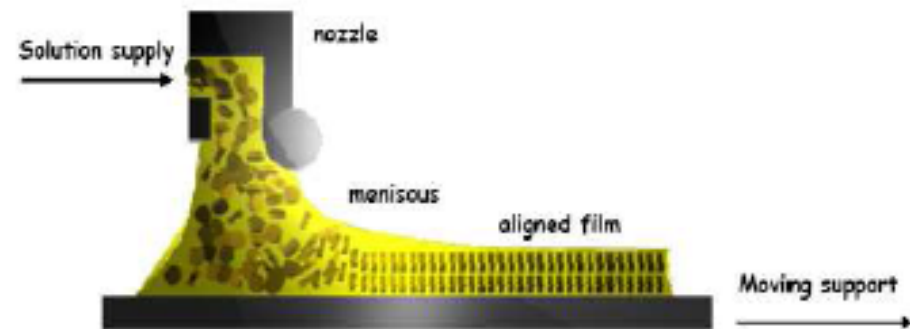
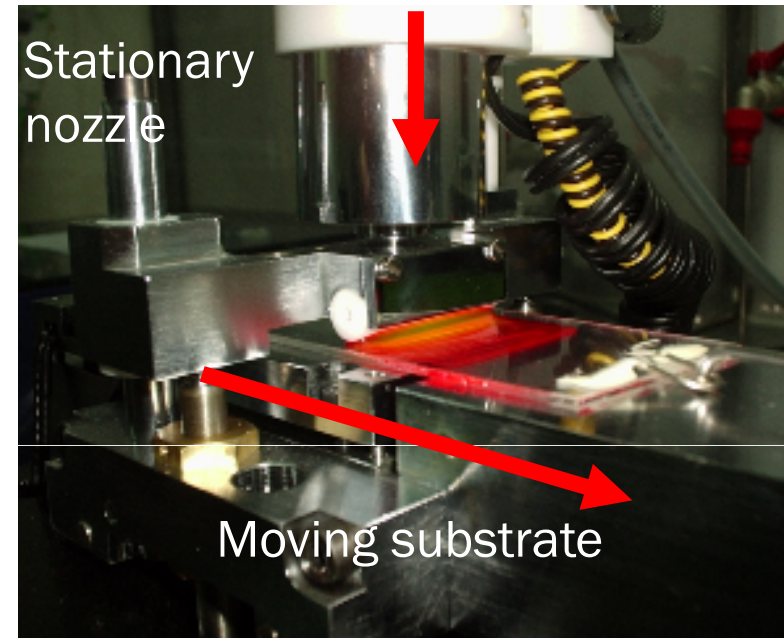
TFT structure



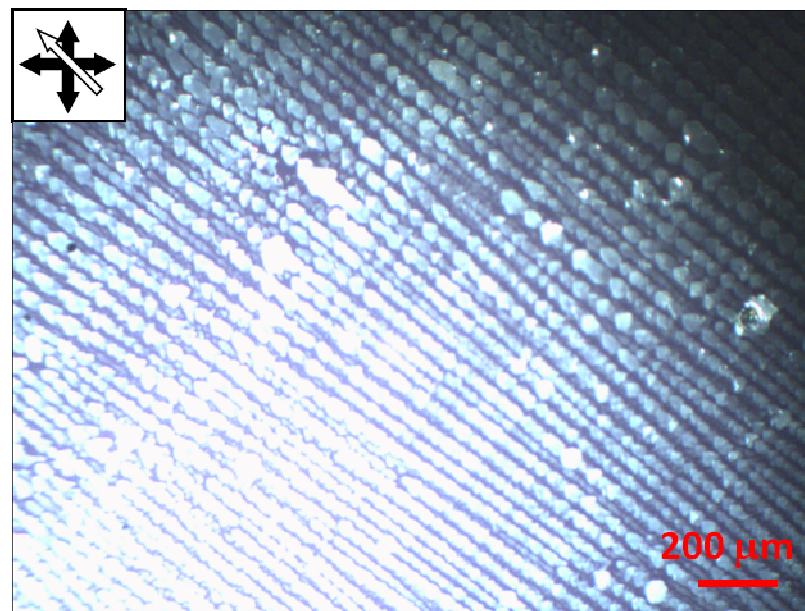
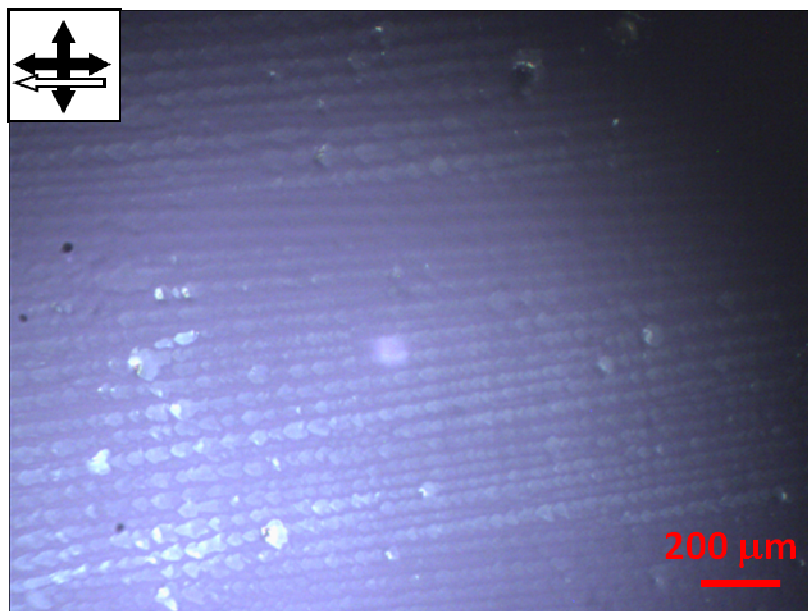
Zone-casting technique

The parameters affecting on the quality of the thin films:

- ✓ The temperature of the substrate and solution
- ✓ Solution supply rate and the substrate velocity
- ✓ The solution concentration
- ✓ The wettability of the substrate
- ✓ The distance between the flat nozzle and the moving substrate (meniscus)



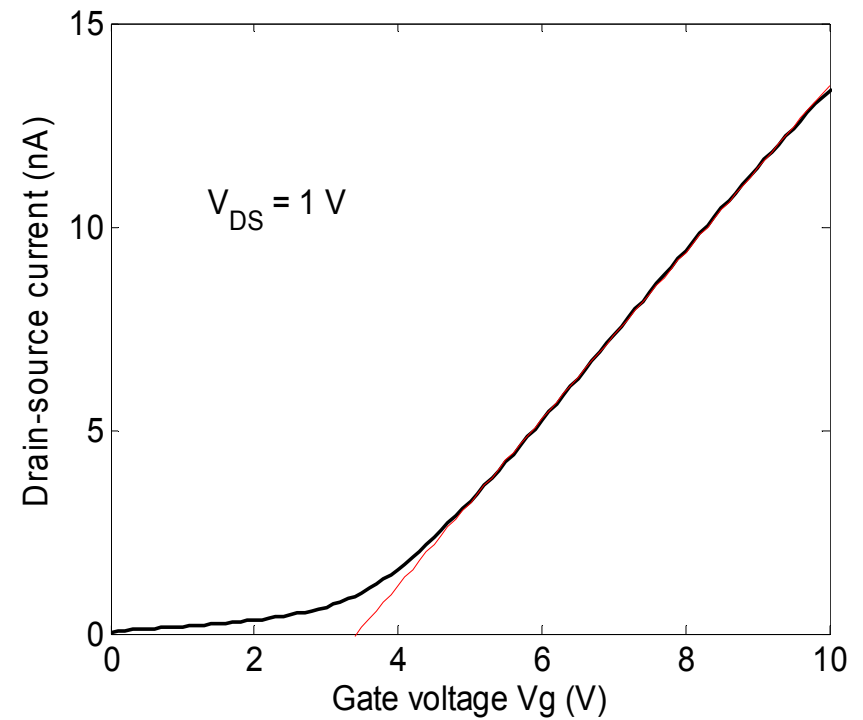
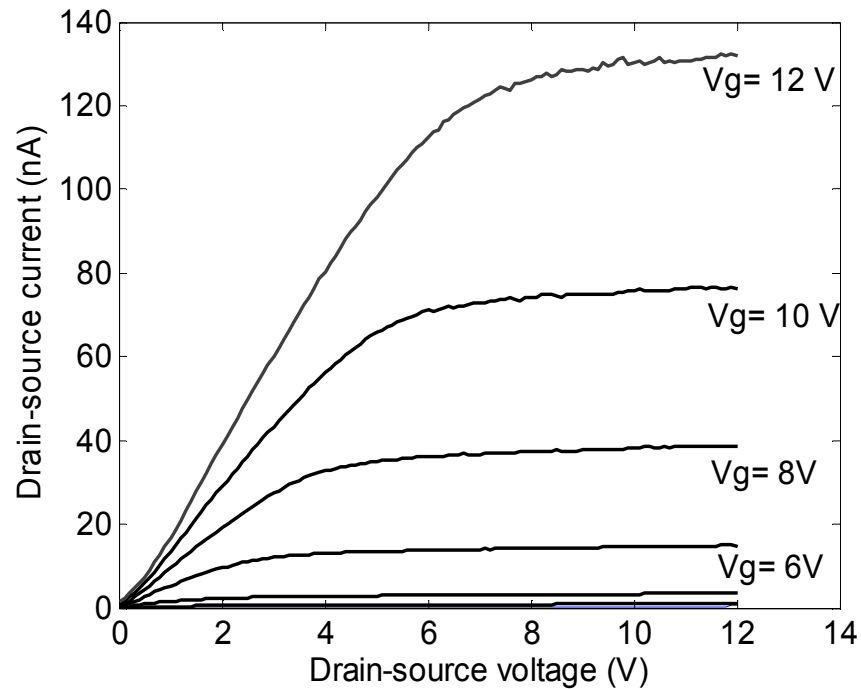
Thin oriented films



Polarized optical microscope images show optical birefringence of the polycrystalline film confirming unidirectional orientation of the crystals on large area

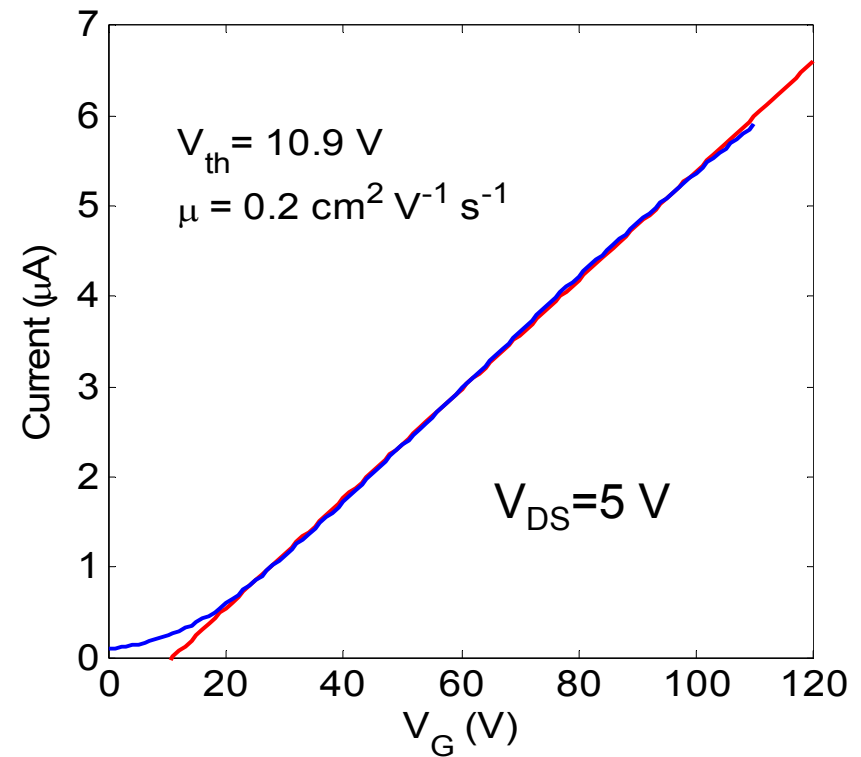
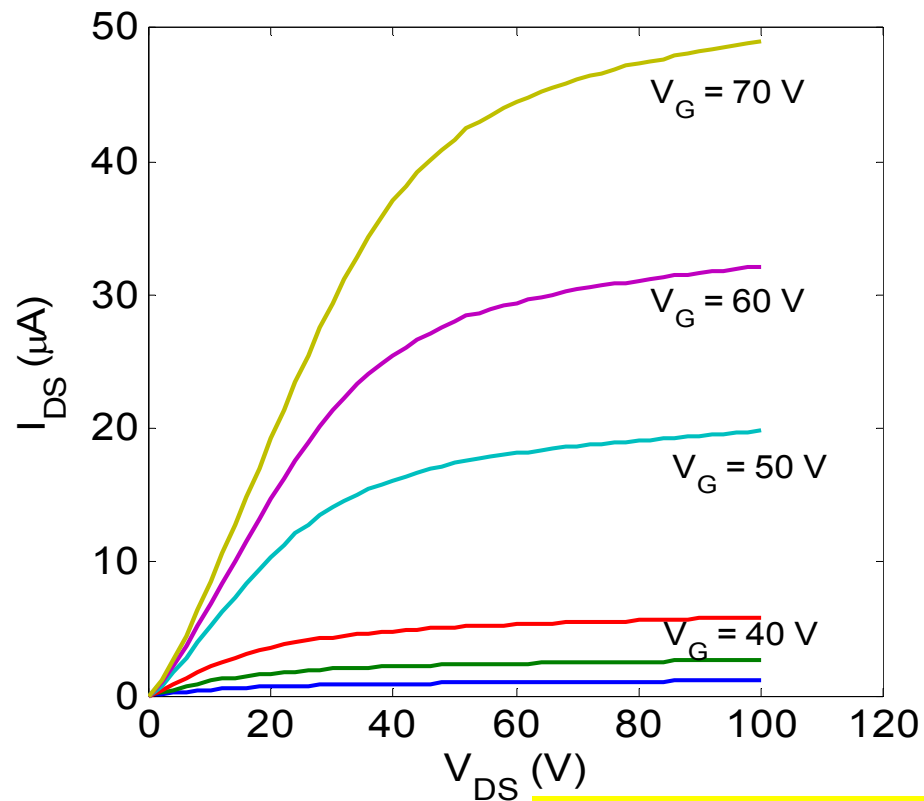
A. Tracz, et. al. *J. Am. Chem. Soc.*, **125**, 1682 (2003);
S. Kotarba, et al. *J. Appl. Phys.*, **108**, 014504 (2010);
T. Marszalek, et al. *Organic Electronics*, **13**, 121 (2012)

TFT Characteristics



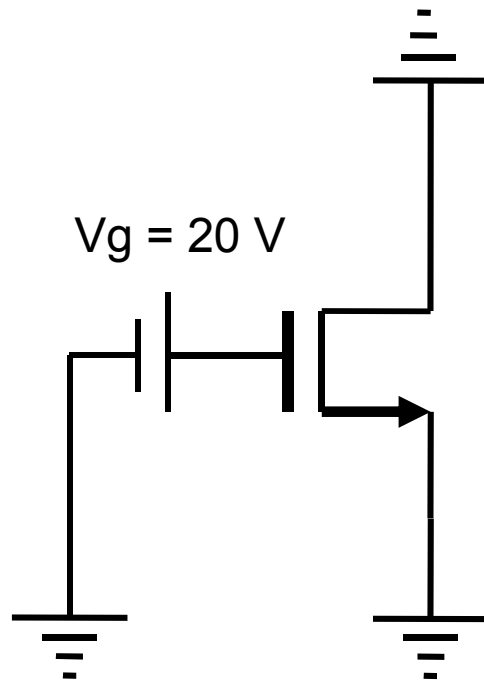
$$V_{th} = 3.6 V$$
$$\mu_{FET} (Lin) = 1 \times 10^{-2} (cm^2/Vs)$$

TFT Characteristics

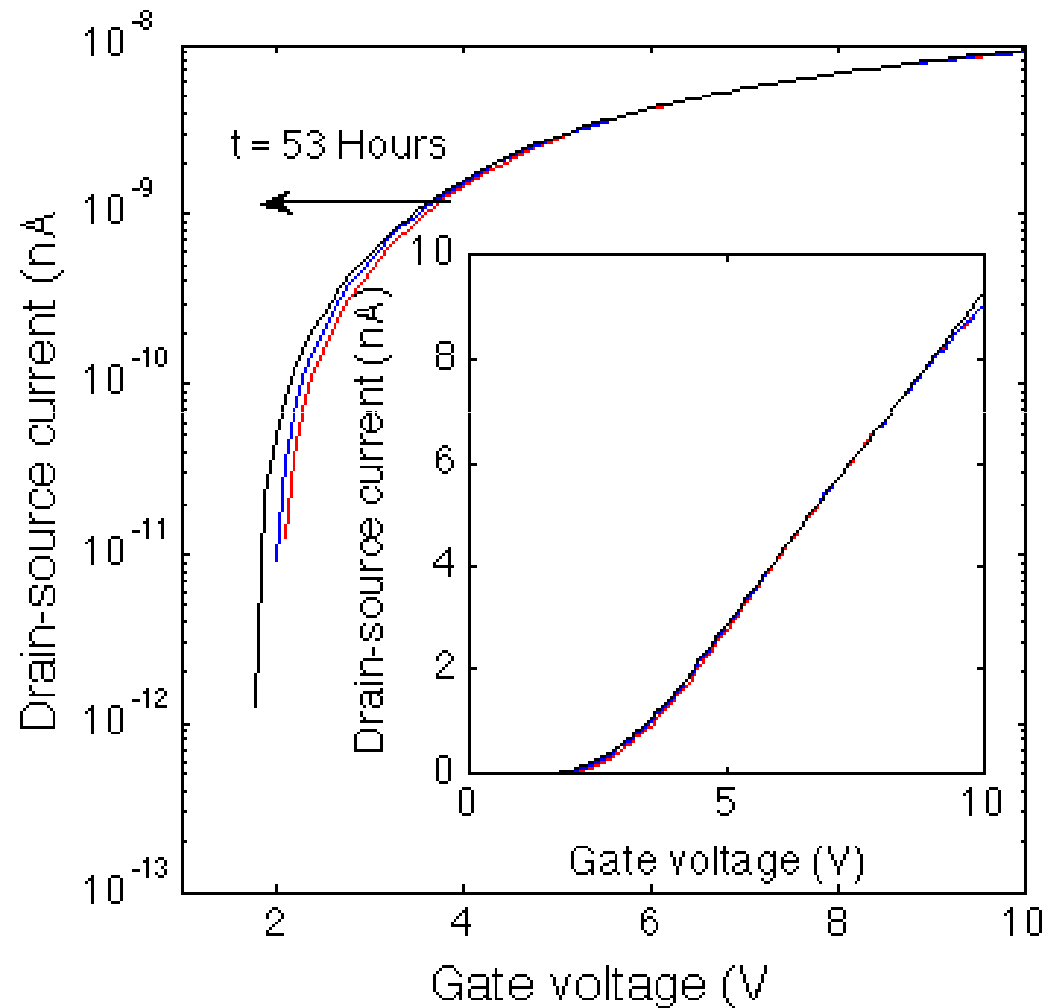


$V_{th} = 10.9 V$
 $\mu_{FET} \text{ (Lin)} = 0.2 \text{ (cm}^2/\text{Vs)}$

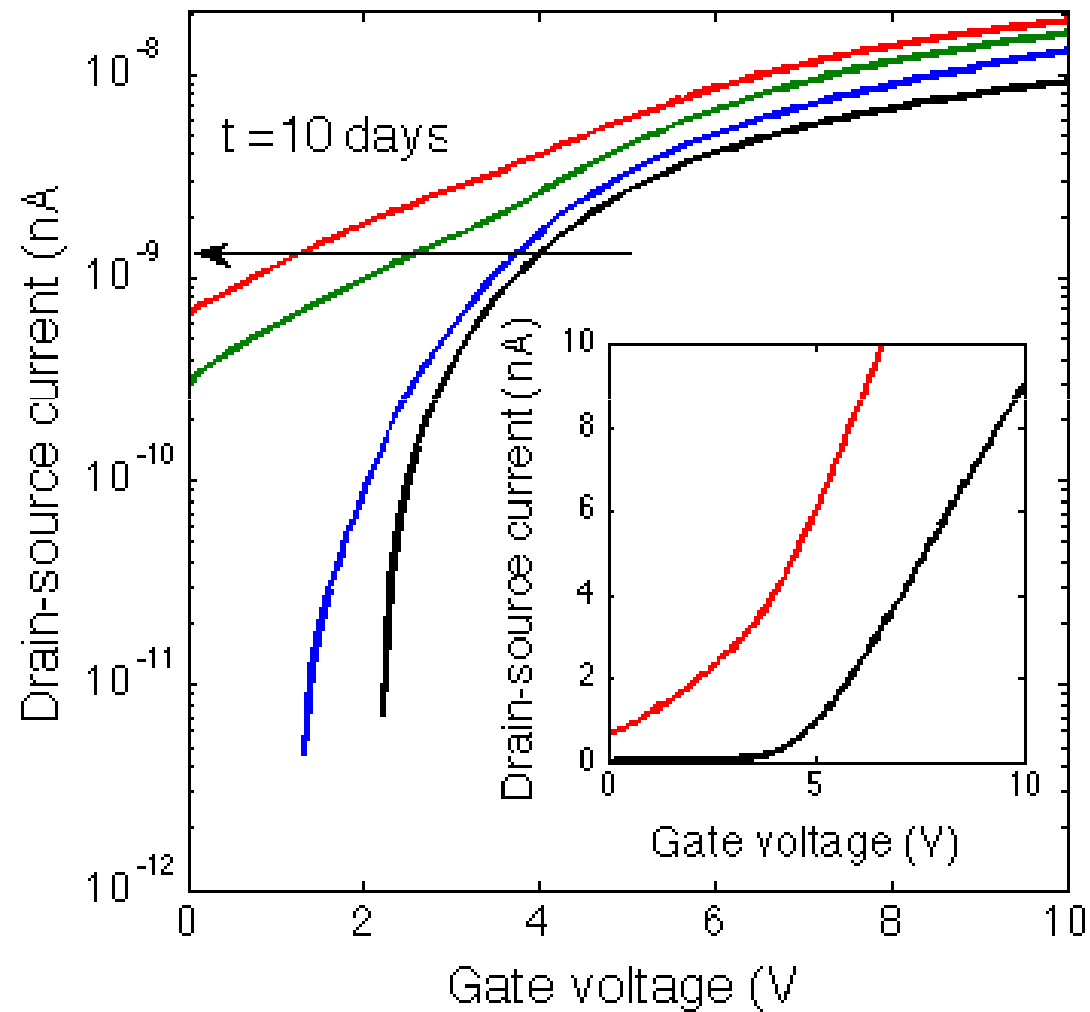
Gate-bias stress



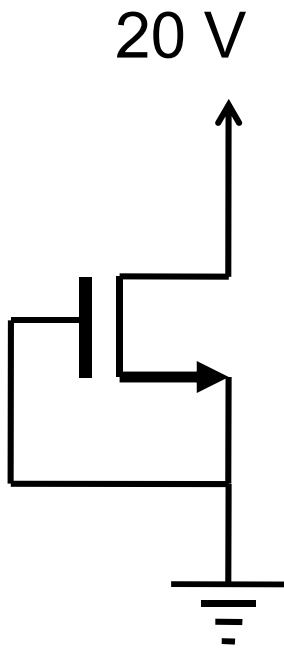
Highly stable against prolonged gate-bias stress (2.2 days)



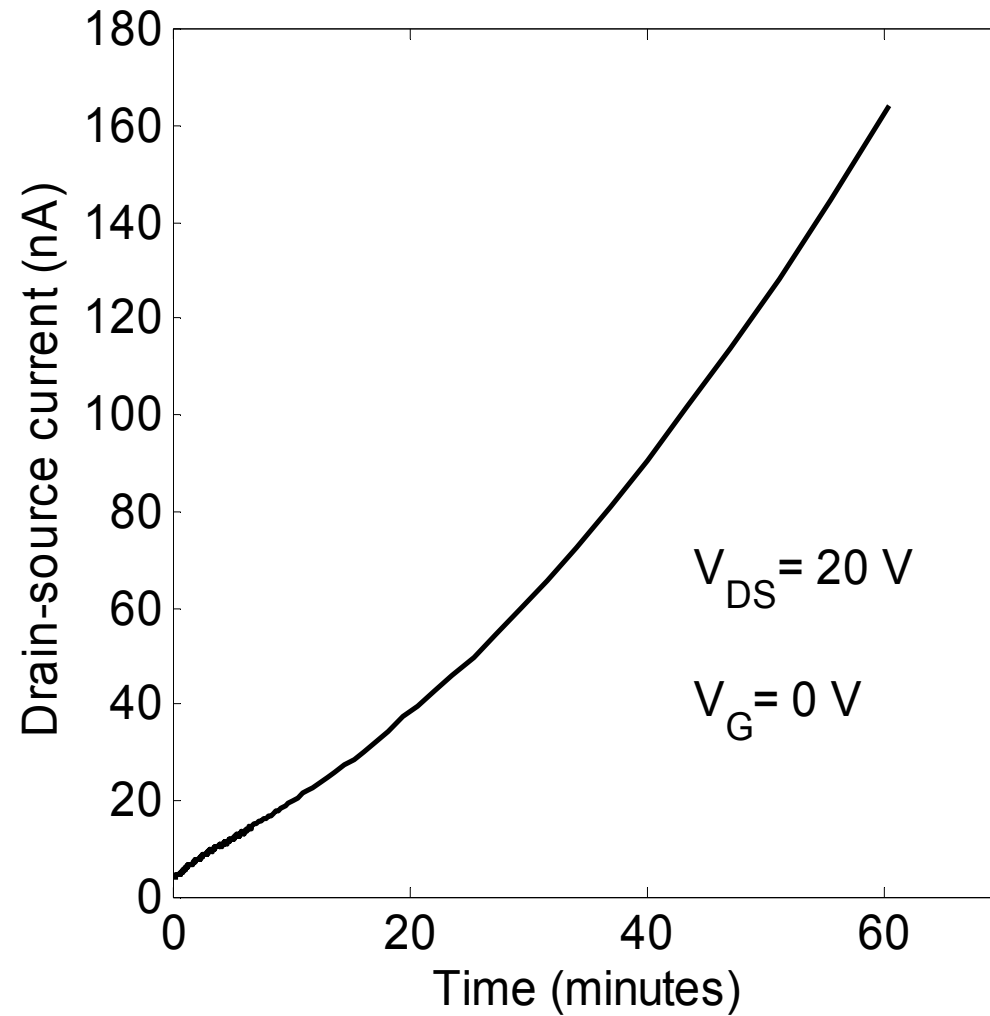
Gate-bias stress



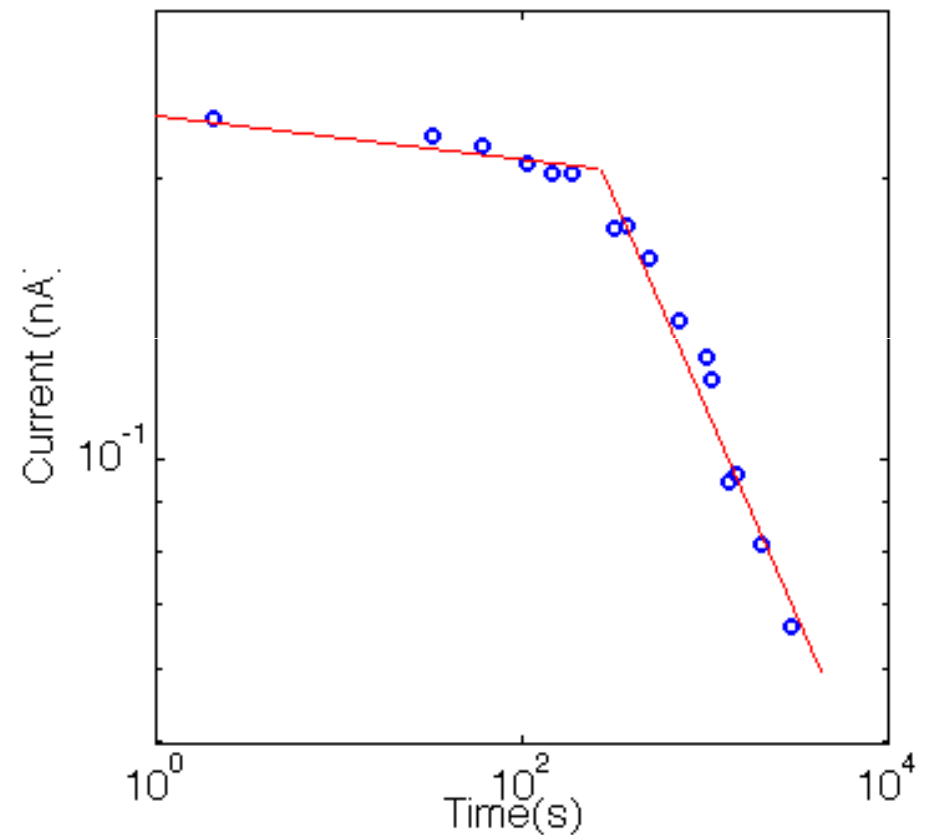
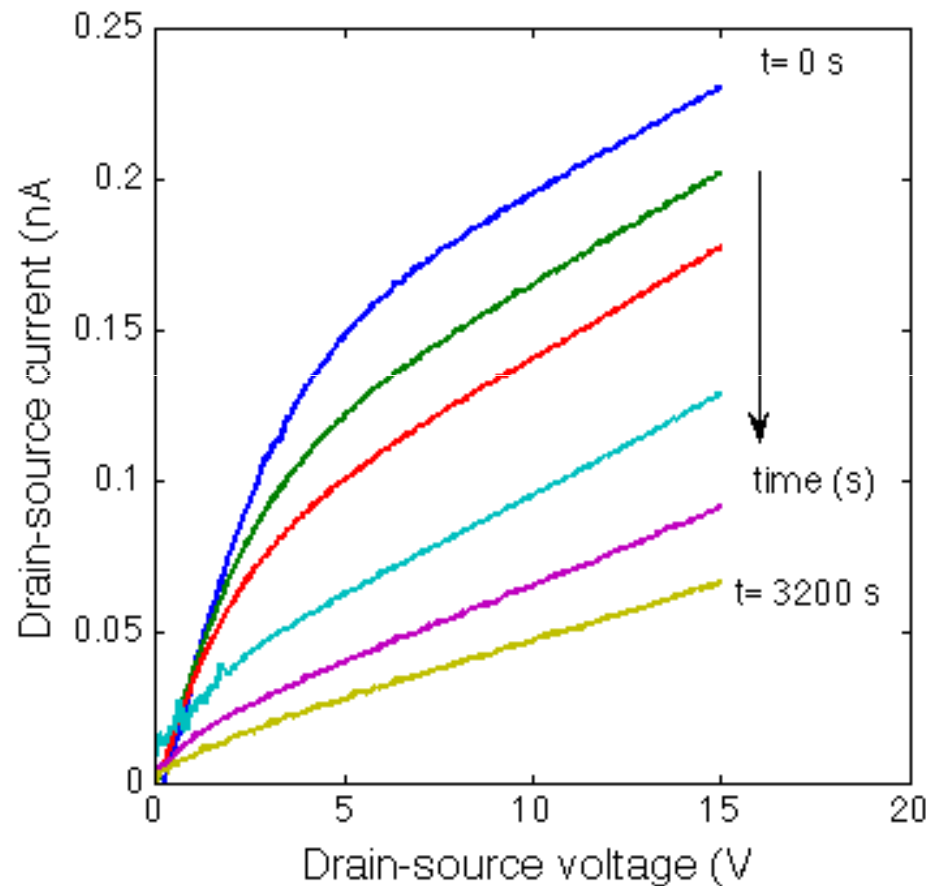
Drain-source bias stress



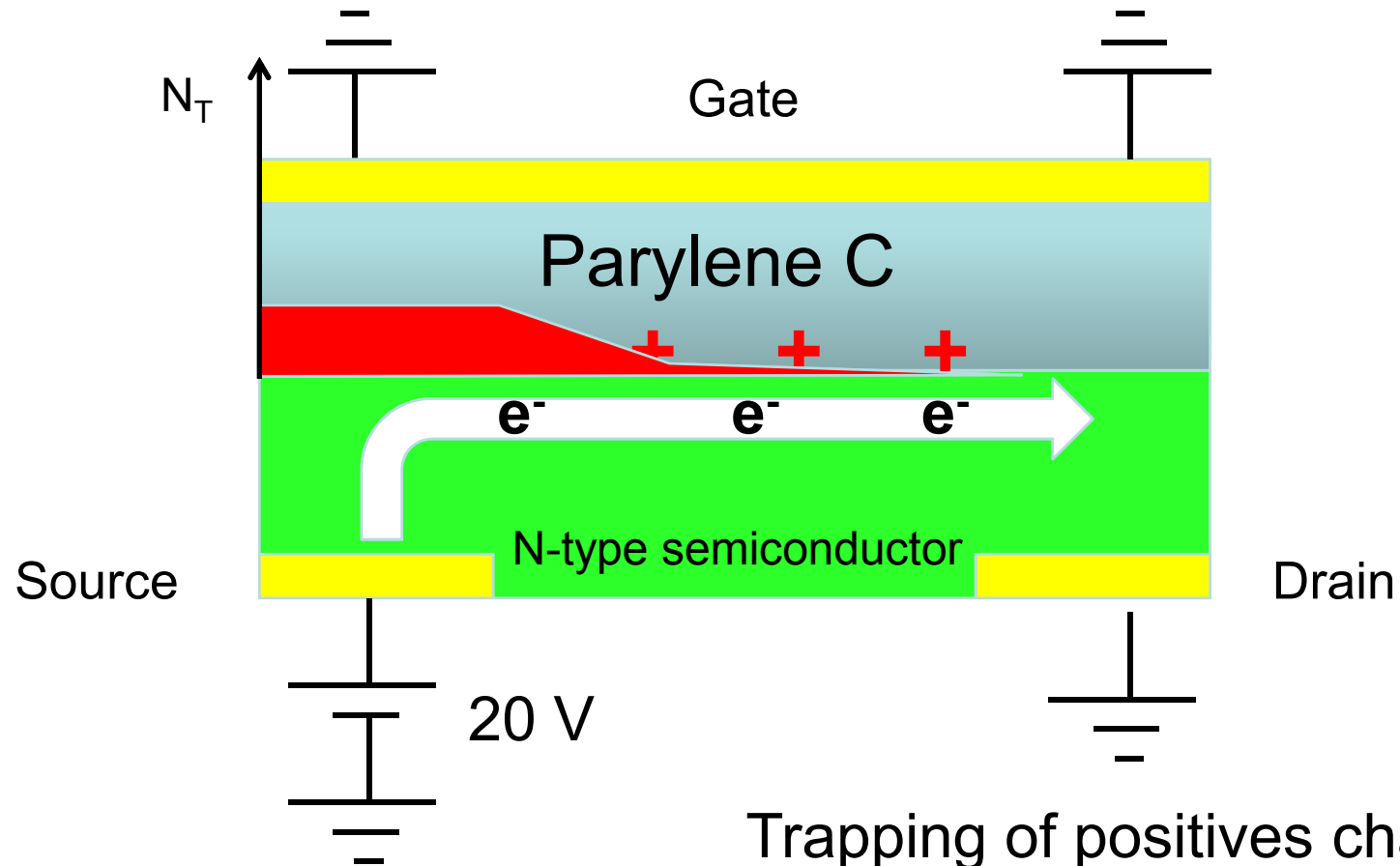
The off-current increases



Drain-source bias stress (recovering kinetics)

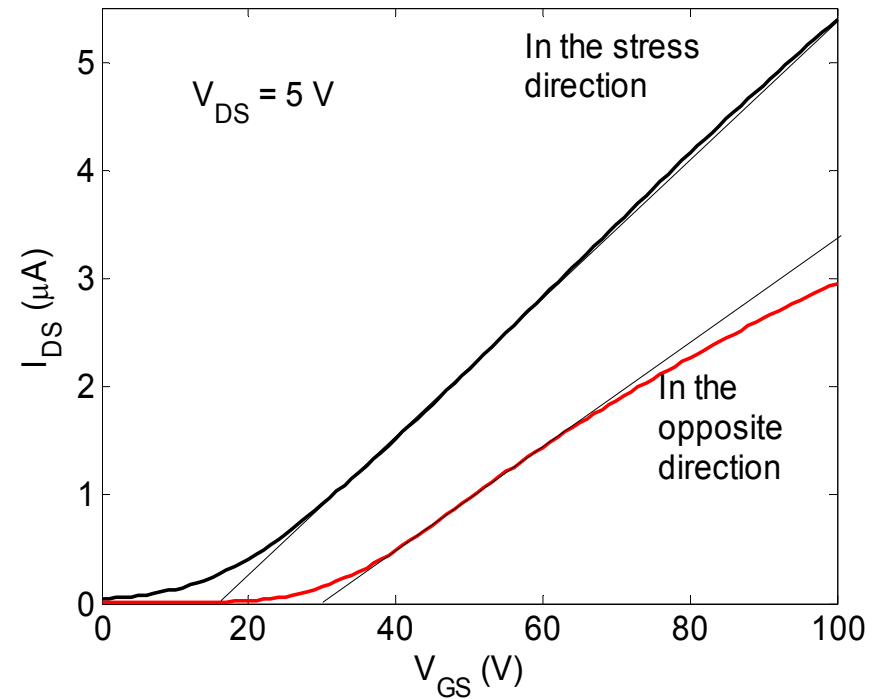
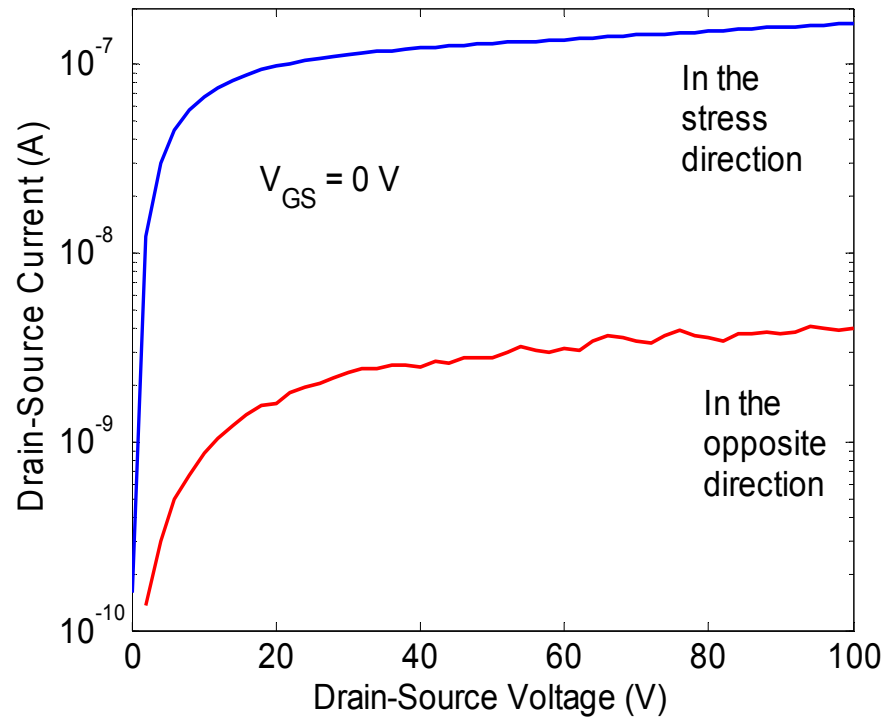


Carrier trapping



Trapping of positives charges
on the parylene C surface.

Non symmetric source and drain contacts



Conclusions

- The threshold voltage is stable after prolonged gate bias-stress
- Drain-source bias stress causes:
 - a metastable accumulation channel.
 - asymmetric source and drain contacts.
-
- Trapping of protons may have very deleterious effects in p-type TFTs but relative minor effects in the operational stability of n-type organic based TFTs

Acknowledgements

Financial support

FlexNet |

NoE FlexNet - Network of Excellence for building up Knowledge for improved Systems Integration for Flexible Organic and Large Area Electronics (FOLAE) and its exploitation (FLEXNET)

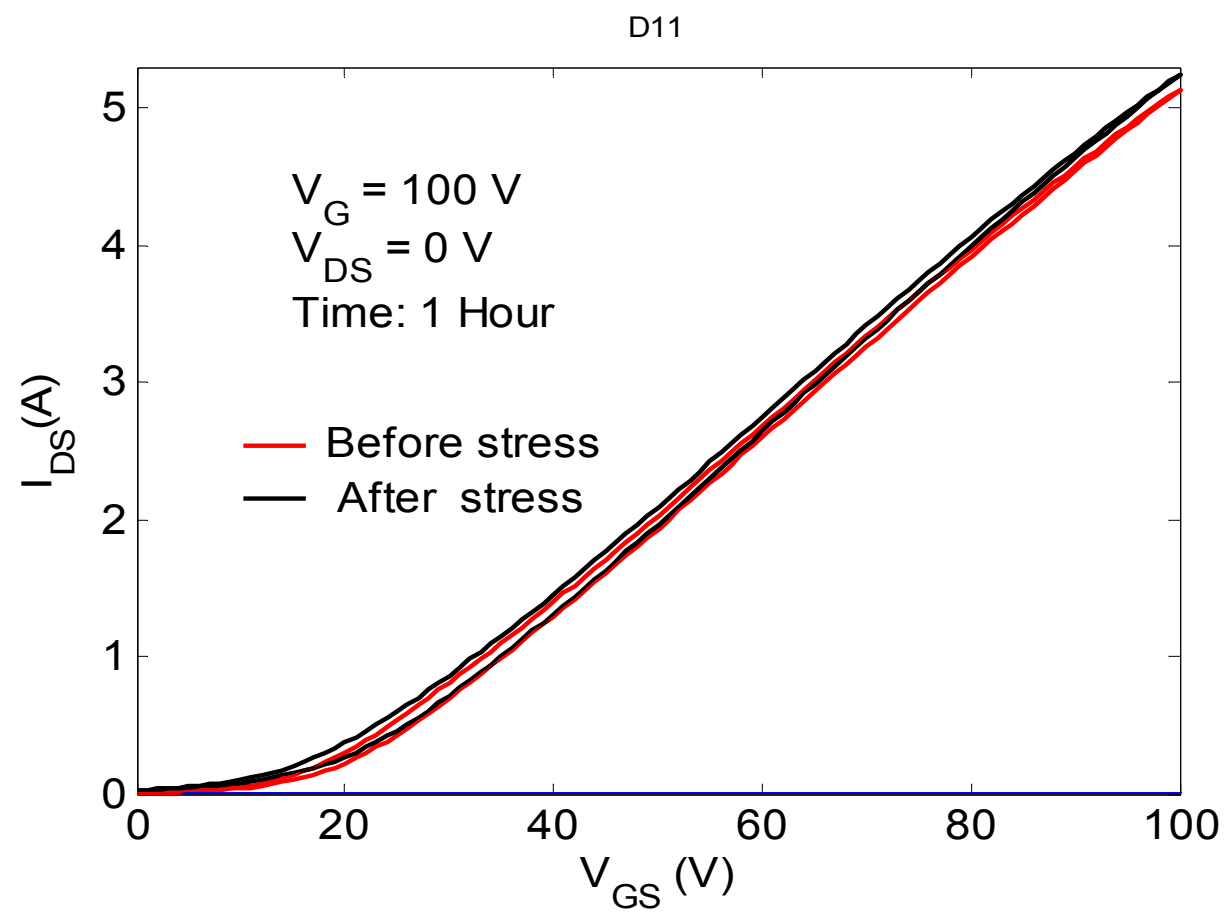


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Thank you for your attention

University of the Algarve
Faro, Portugal



Recovering of the TFT off-current

