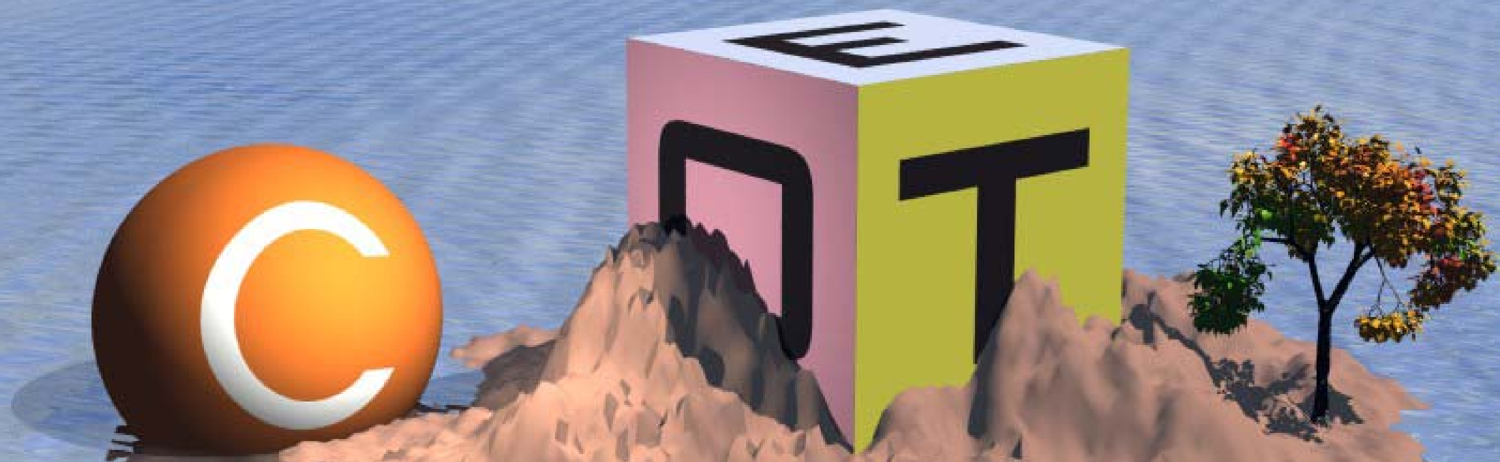
# Electrical Characterization of Organic Electronic Materials

3rd Workshop on Luminescent Conjugated Polymers

P. Stallinga, H.L. Gomes

OptoEl, CEOT, Universidade do Algarve

15 April 2005



# Overview

Light-emitting field-effect transistor. Optical and electrical are linked.

Current instability

Non-linear IV curves, transfer curves

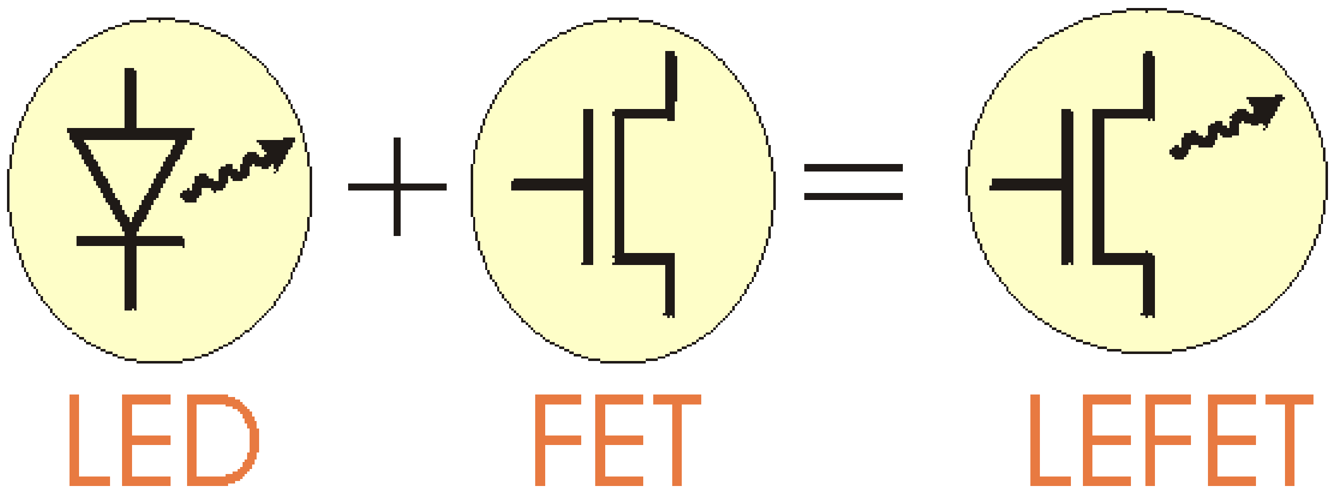
Stressing

Meyer-Neldel Rule

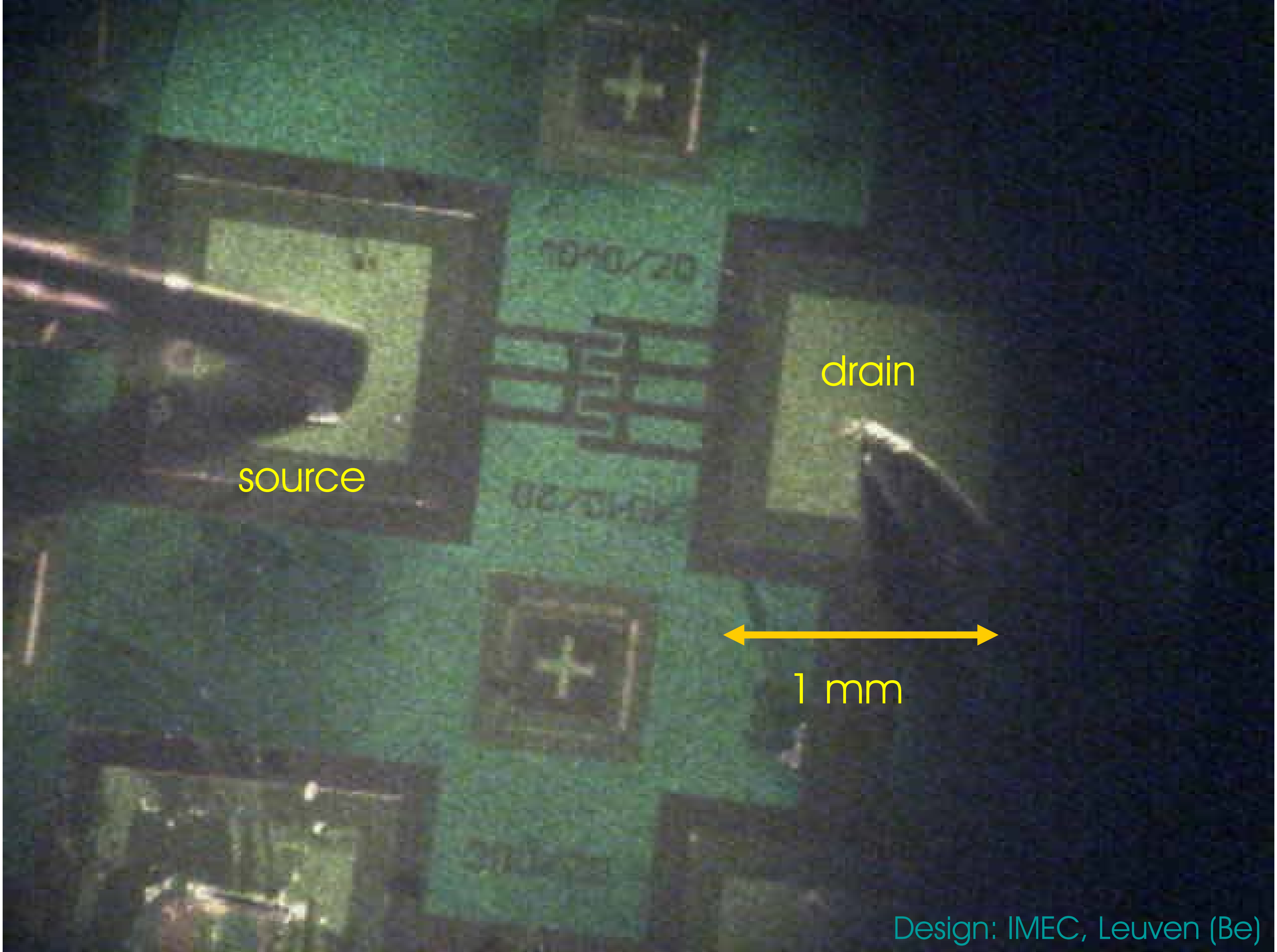
## Summary

Organic materials are governed by traps!

# Light-Emitting Field-Effect Transistor



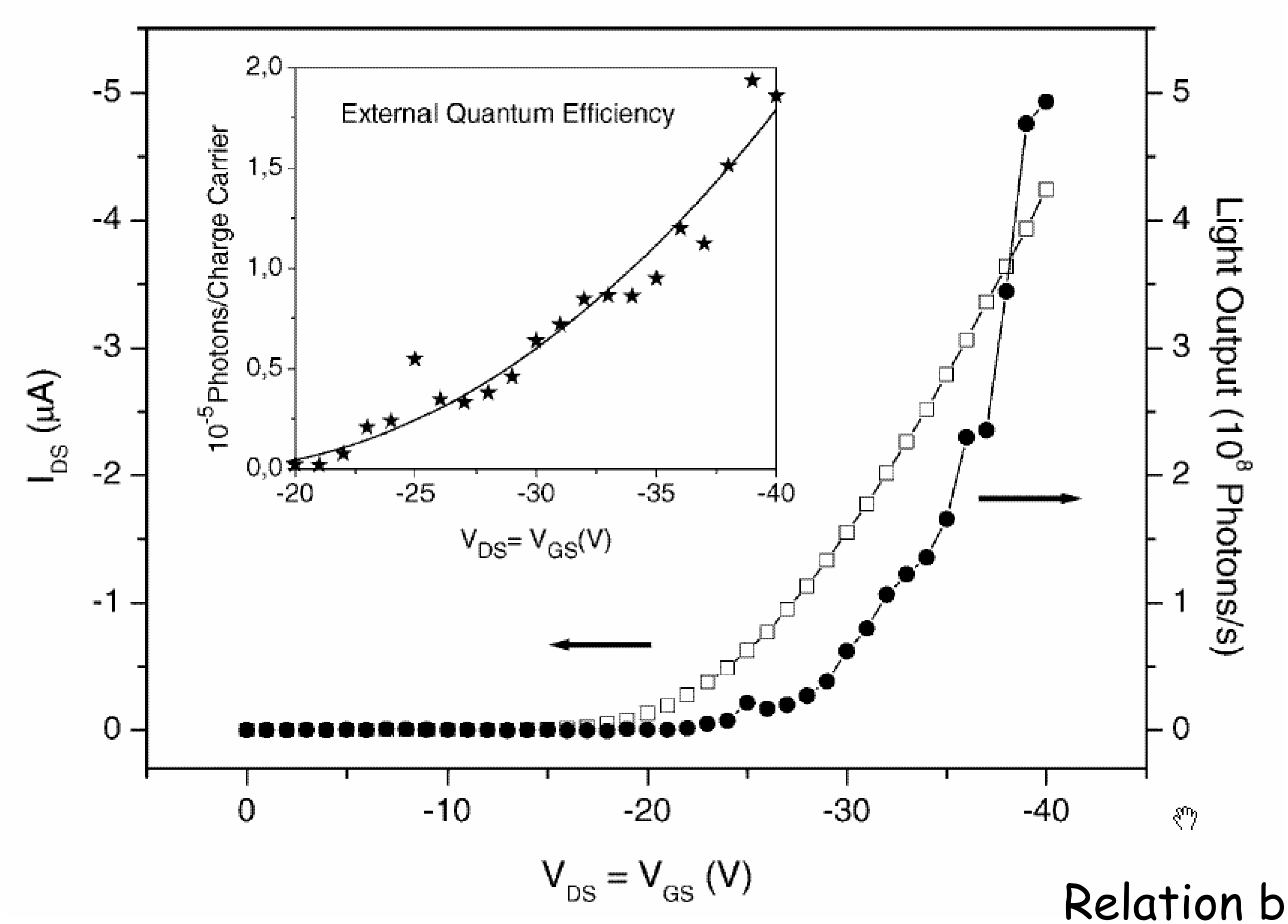

The advantages are obvious


drain
source
1 mm
Design: IMEC, Leuven (Be)

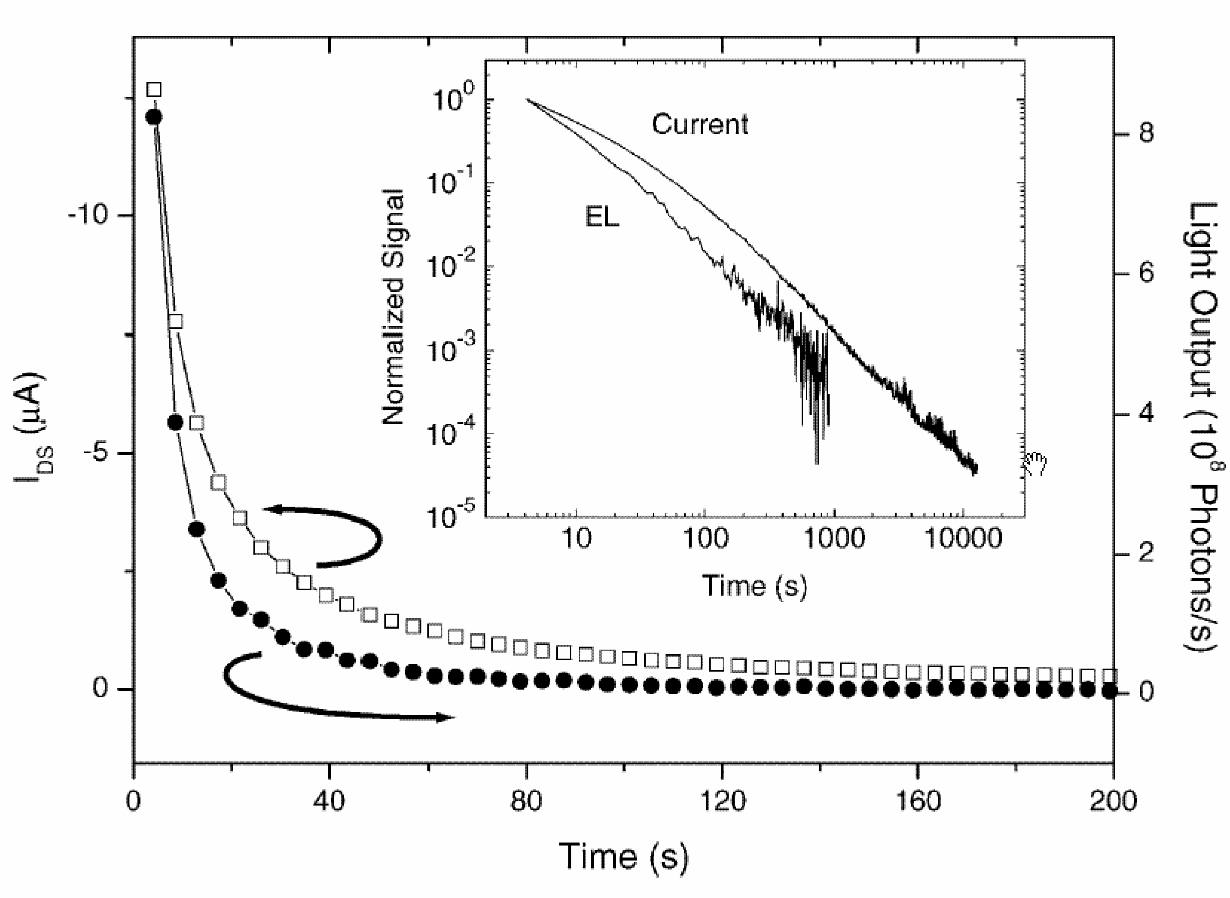
You are looking at the first picture taken showing light coming out of an FET … (Bologna, 2003)

C. Santato, M. Muccini, P. Stallinga, et al. Synth. Metals **146**, 329 (2004)

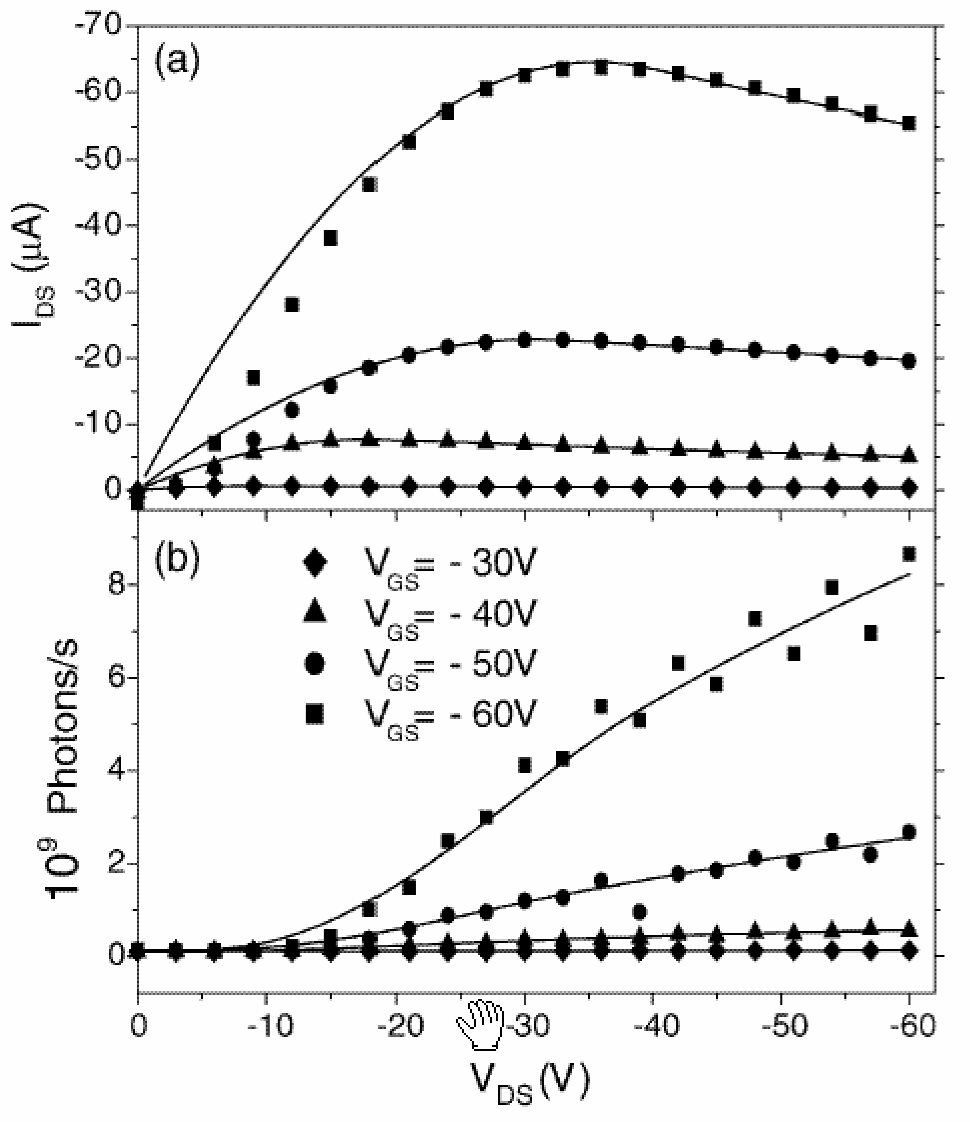
# Light-Emitting Field-Effect Transistor




Relation between current and light output



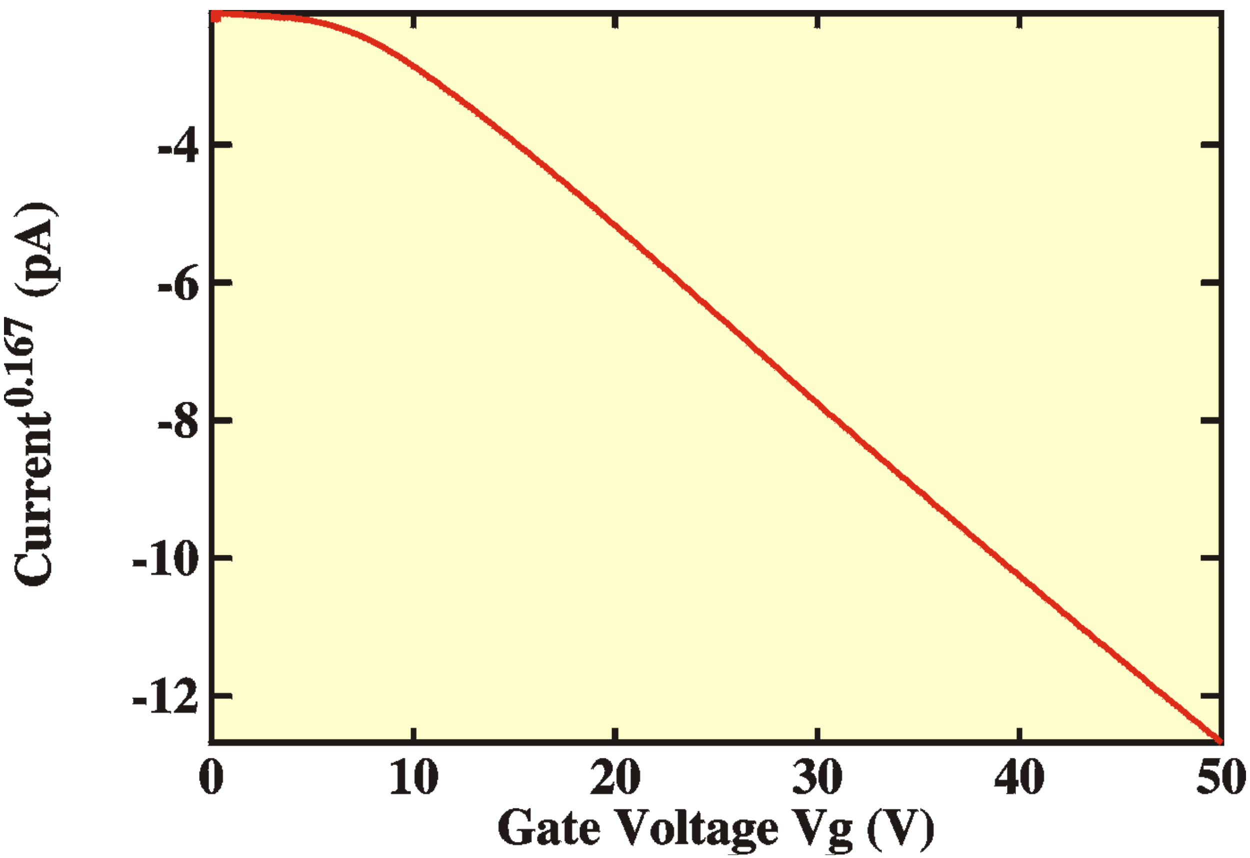

Ever-decreasing current and light output



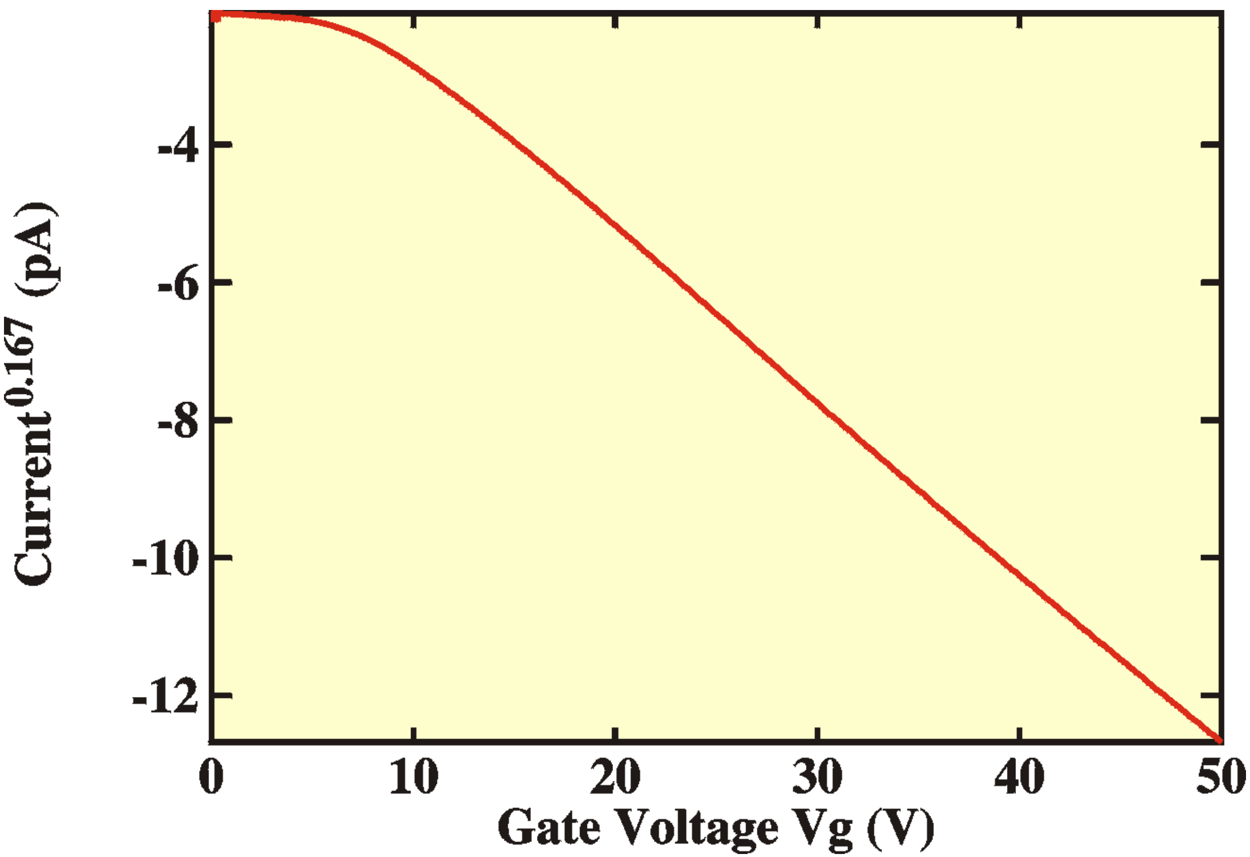

Non linearities in output curves

These seem to be general characteristics of organic electronic devices.
Let me show you some more ...

Non-linear Transfer curves observed

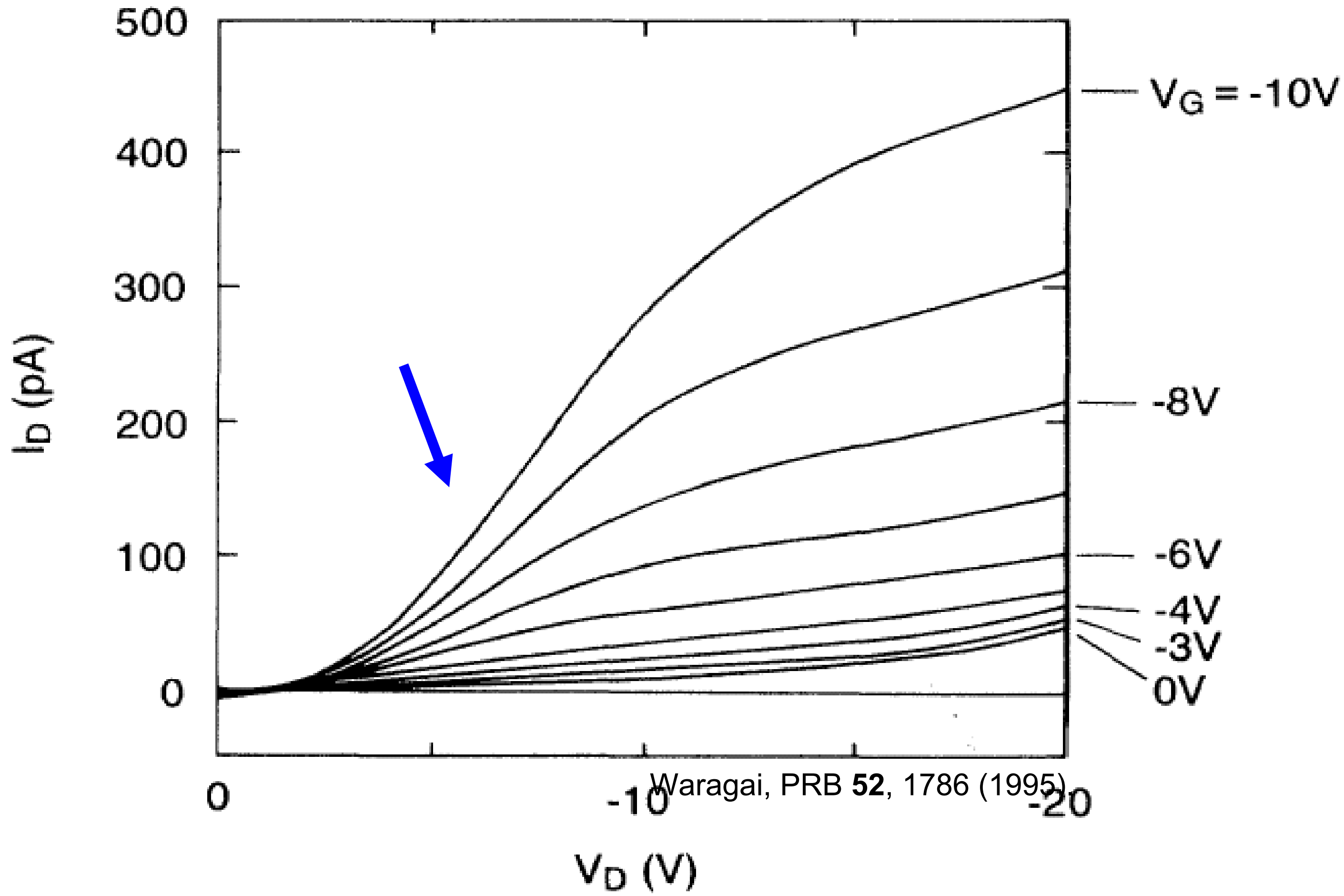


Non-linear Transfer curves observed



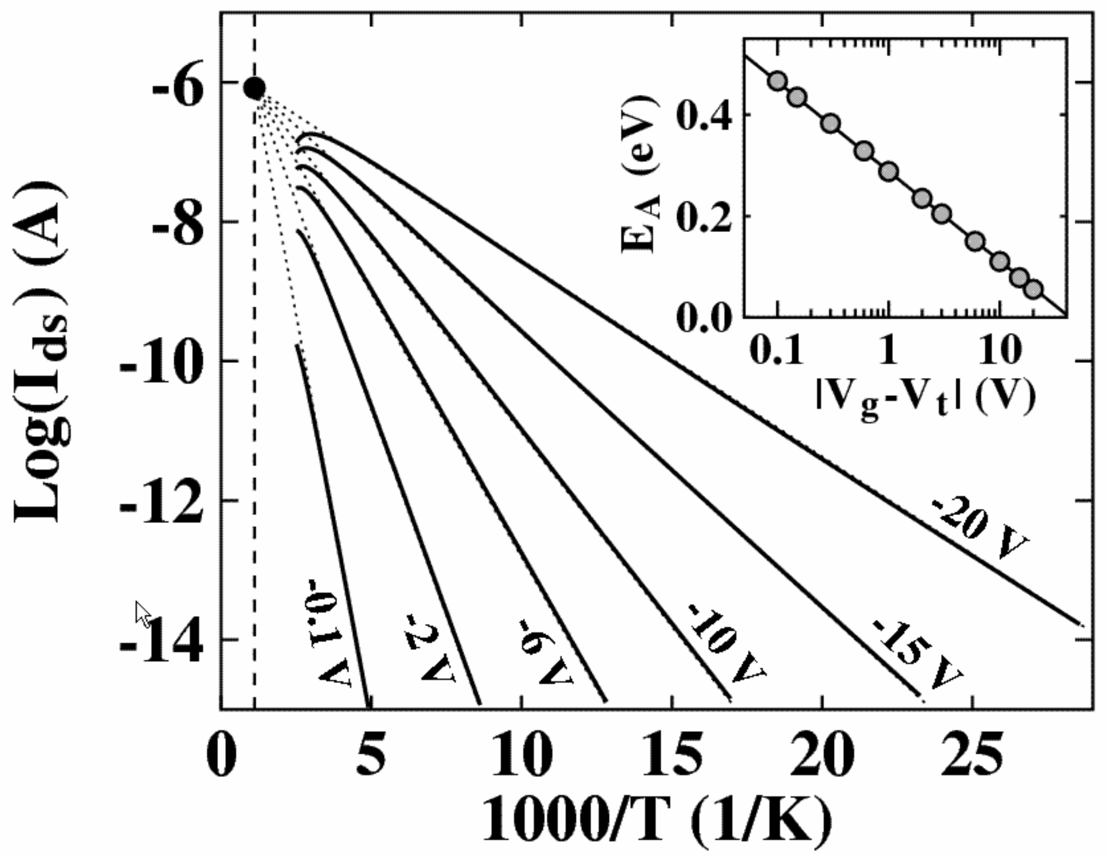

Non-linear Transfer curves explained by model of Shur and Hack for amorphous silicon. Traps!

Non-linear IV curves



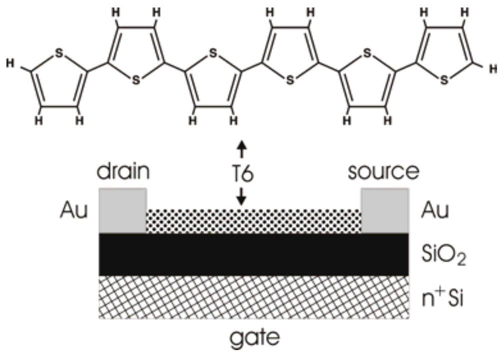

Explained by model of Poole and Frenkel. Traps!

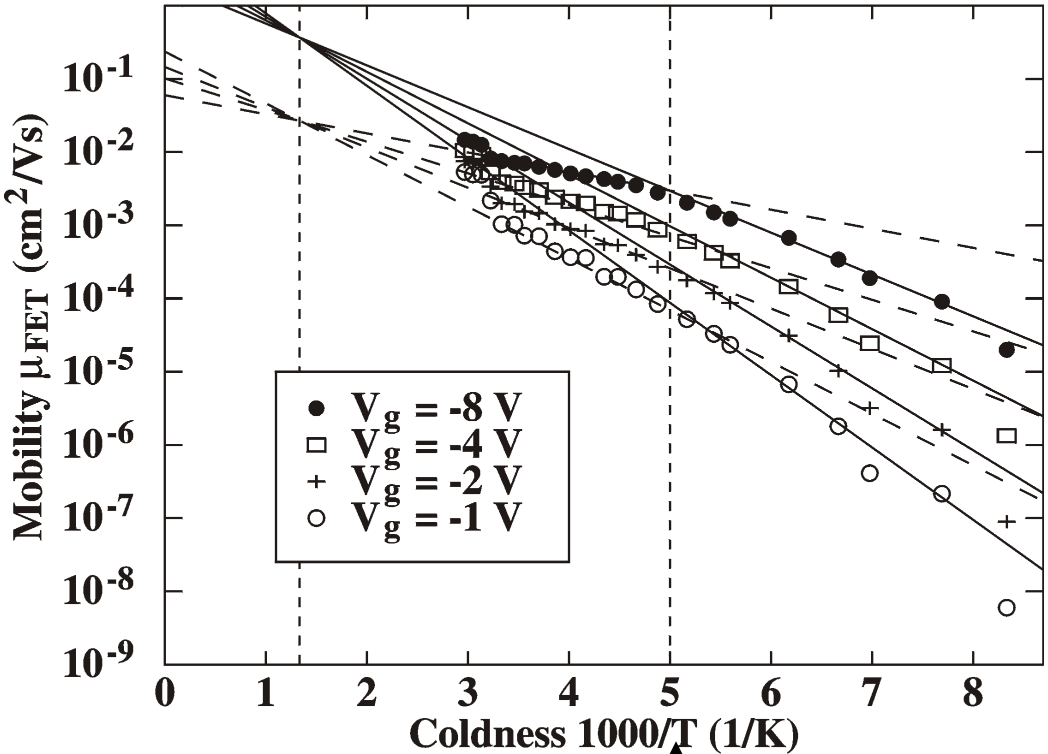
Meyer-Neldel Rule




Explained by Traps! (P. Stallinga, Org. Electr. 2005).

# Meyer-Neldel Rule in our T6 TFT

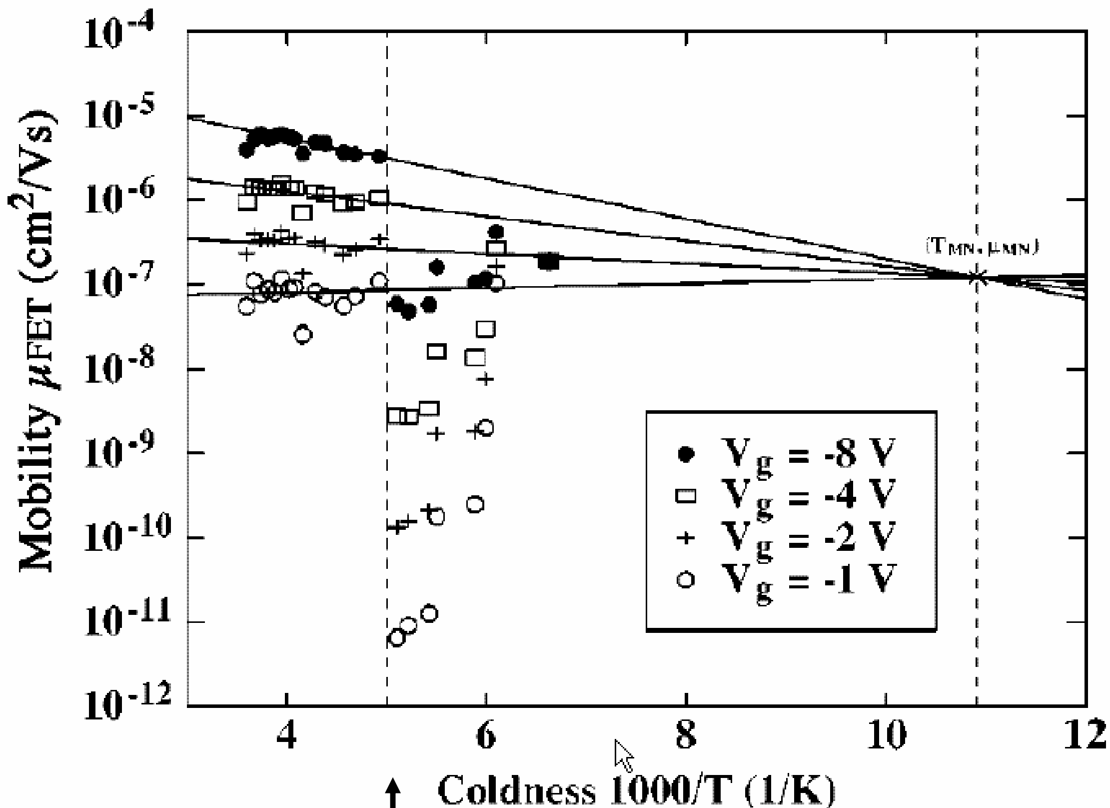



Phase transition at 200 K

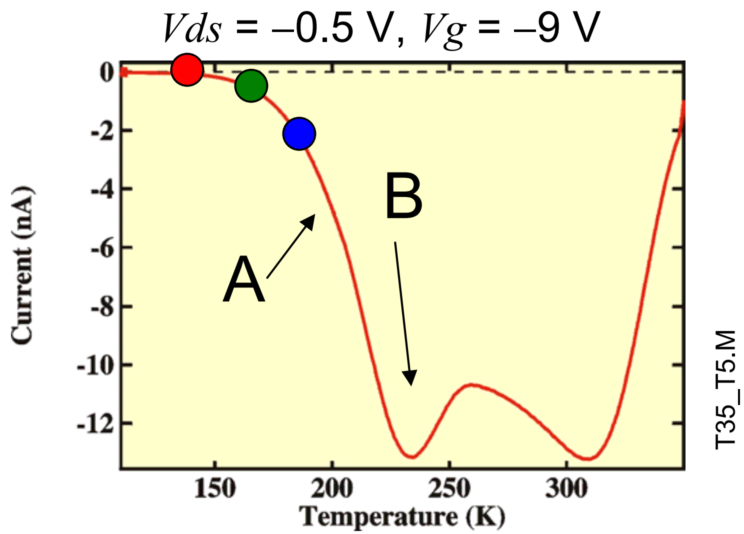
P. Stallinga *et al*., J. Appl. Phys. **96**, 5277 (2004)

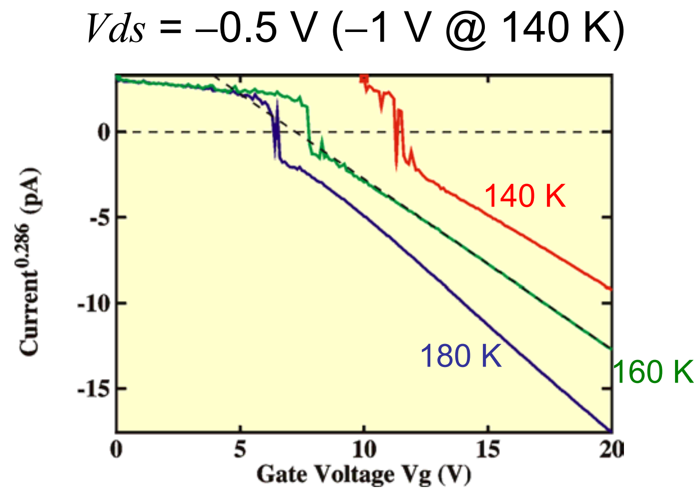
## Meyer-Neldel Rule




Phase transition at 200 K
Very clear at nano-FET

P. Stallinga *et al.*, J. Appl. Phys. **96**, 5277 (2004)




A: Poole-Frenkel: $\mu_{FET} = \exp(-E_A/kT)$

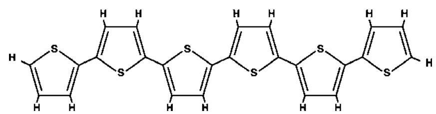
B: New traps start being filled. Decrease of current because threshold voltage $V_T$ increases. So-called "Stressing".

| Effect | Description | Explanation |
| --- | --- | --- |
| Transients | $I = \exp( -(t/\tau)^{\alpha} )$ | Traps. Kohlrausch (19th century) |
| Stressing | $V_T$ stretched exponential | Traps. Powell, $\alpha$-Si |
| Non-linear IV curves | $I = V_{DS} \exp(V_{DS})$ | Traps. Poole-Frenkel |
| Non-linear transfer curves | $I = \exp( V_G^{\gamma} )$ | Traps. Shur-Hack, $\alpha$-Si |
| Meyer-Neldel Rule | | Traps. Stallinga |

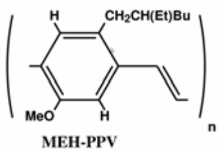
# Which materials are prone to these effects?

Most, but not all organic materials suffer from these effects.

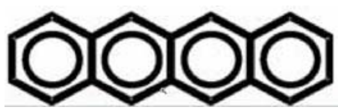
Examples:



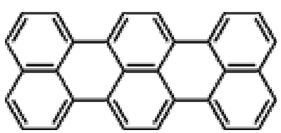

T6: strong.



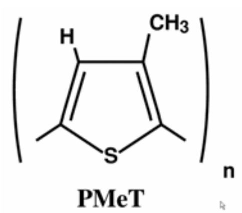

PPV: weak



Tetracene: strong



Terrylene: weak




PMeT: medium