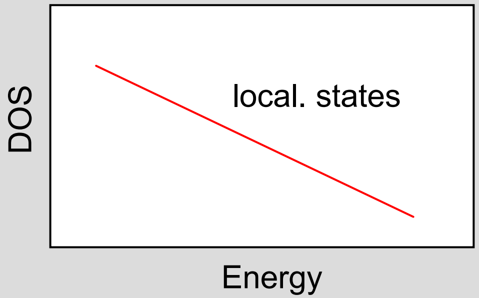
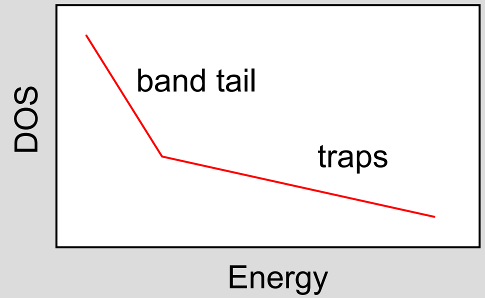
CRITELECTRICAL REMARKS

P. Stallinga, CEOT, UAlg

Hopping transport vs. traps

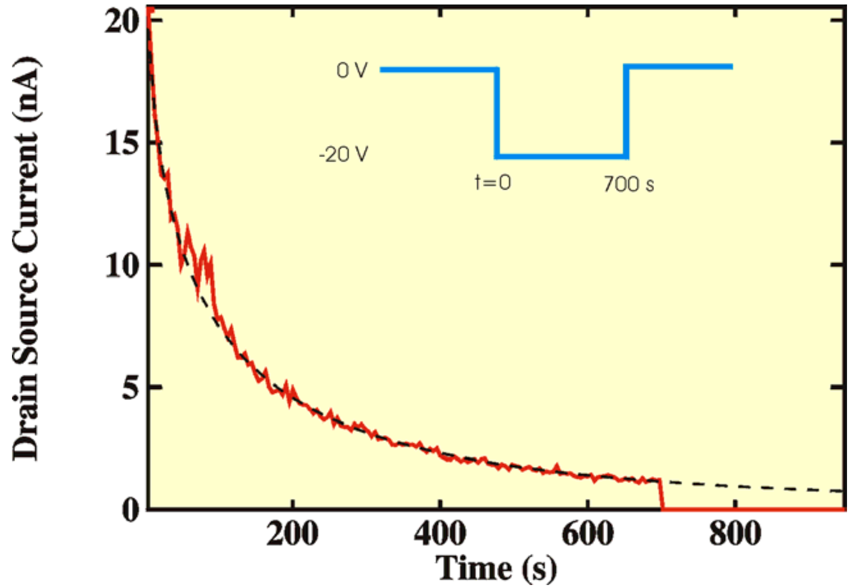
Hopping transport (Mott, Look, Bobbert, Vissenberg)		Band + traps (Shur, Pool-Frenkel, Stallinga)
		
ok	low μ	ok
no (<0.01 cm^2/Vs)*	high μ	ok (up to 100 cm^2/Vs)
ok	Vg dep.	ok
ok	Meyer-Neldel	ok
no **	Vds dep.	ok (P-F)
no ***	T dep.	ok (P-F)
no!	{ transients stressing }	ok

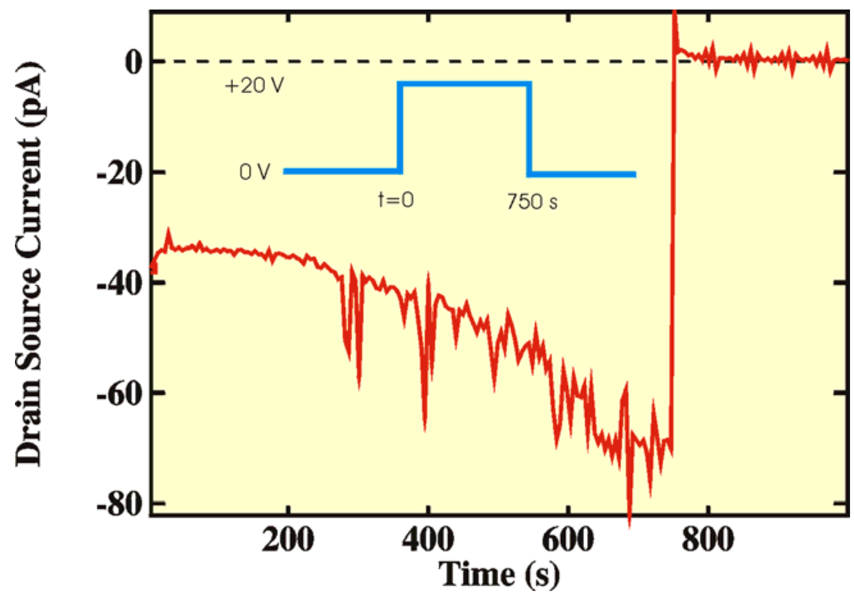
*: limited by $t\Delta E = h$. **: funny contact R needed. *** some cases ok

All FETs materials measured by us are explained by this traps model

Including tetracene (Bologna) and T6 (Bologna, Philips)

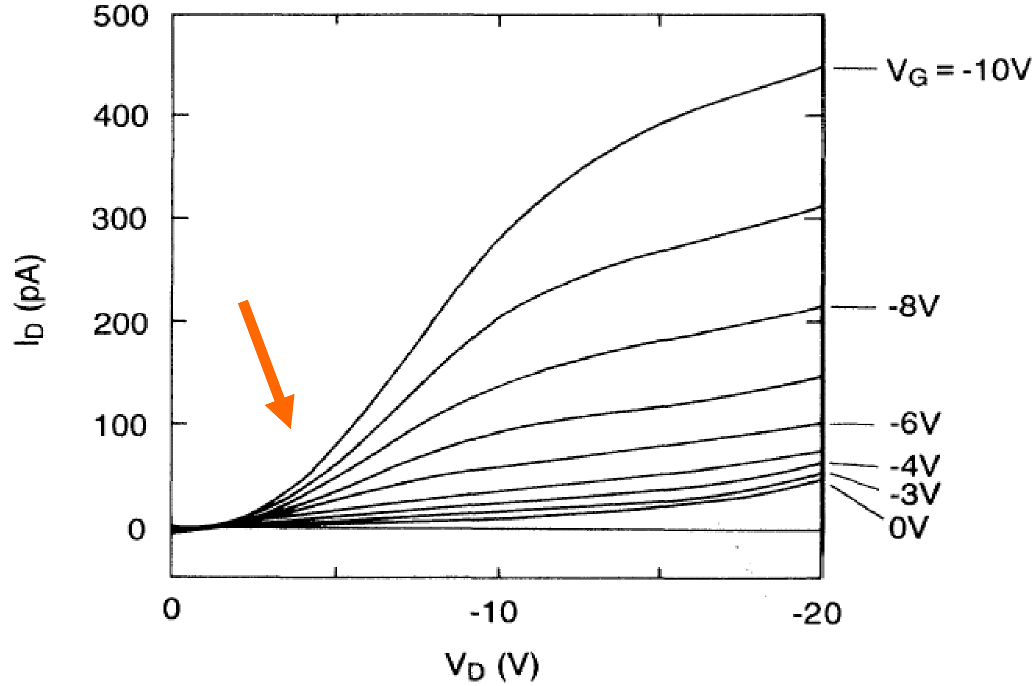
Bologna Visit 2003: Gate Voltaic Transients





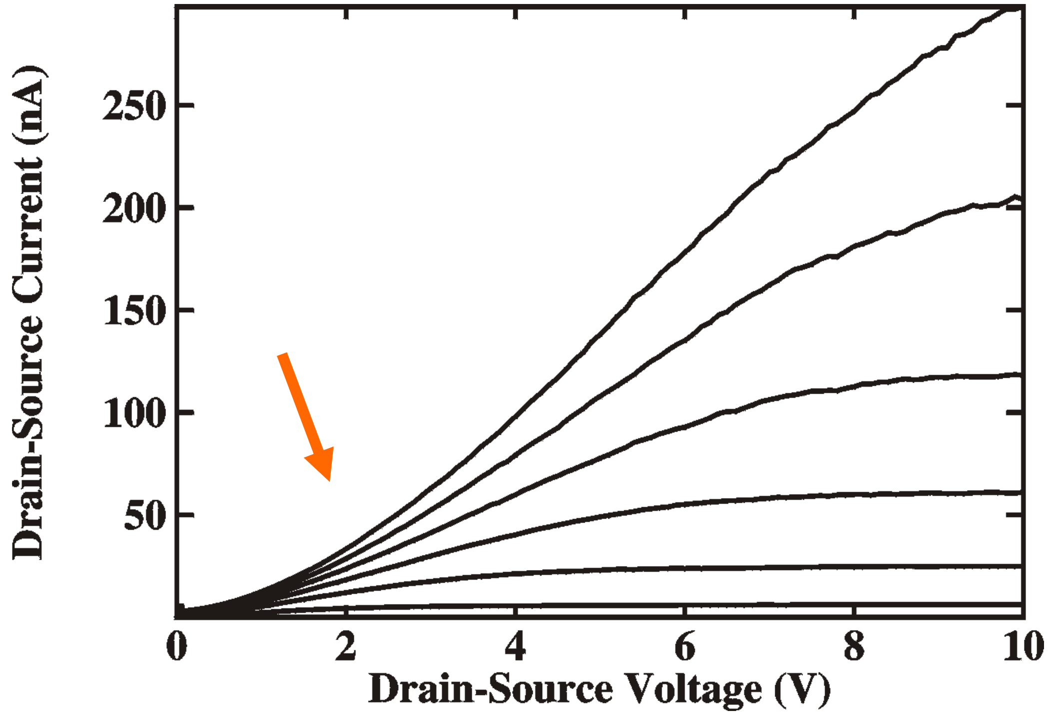
Assigned to traping of free carriers (2003)
2005: Still valid

Contact effects



To explain this non-linear behavior in IV curves (Ids-Vds), in literature, normally the magic words “Contact Effects” are used

Faro, DH4T



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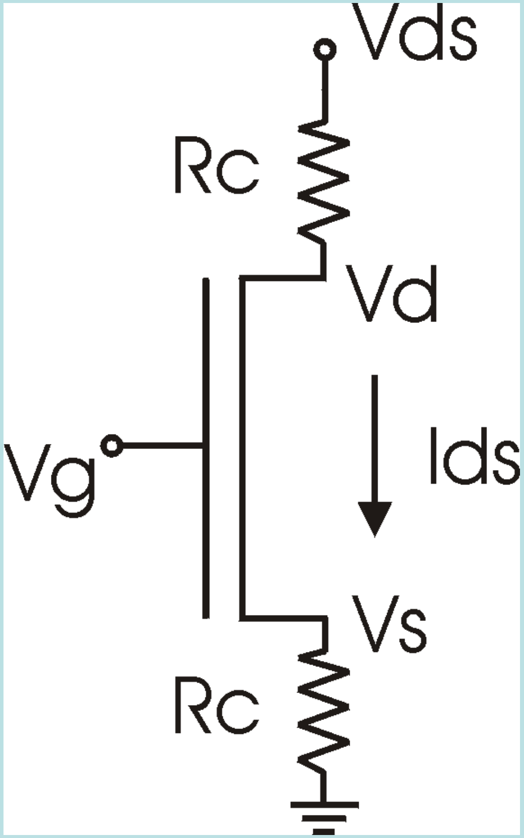
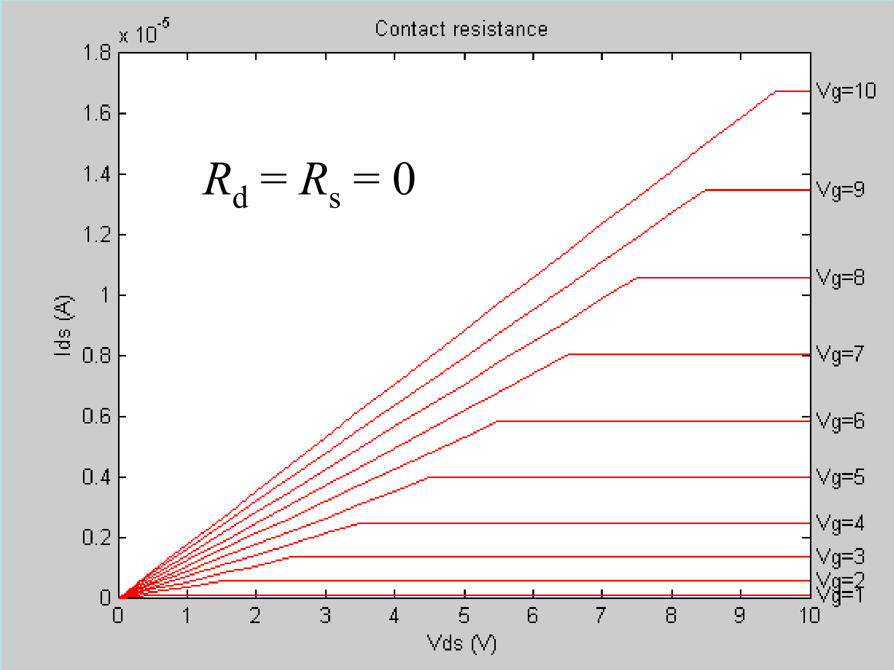
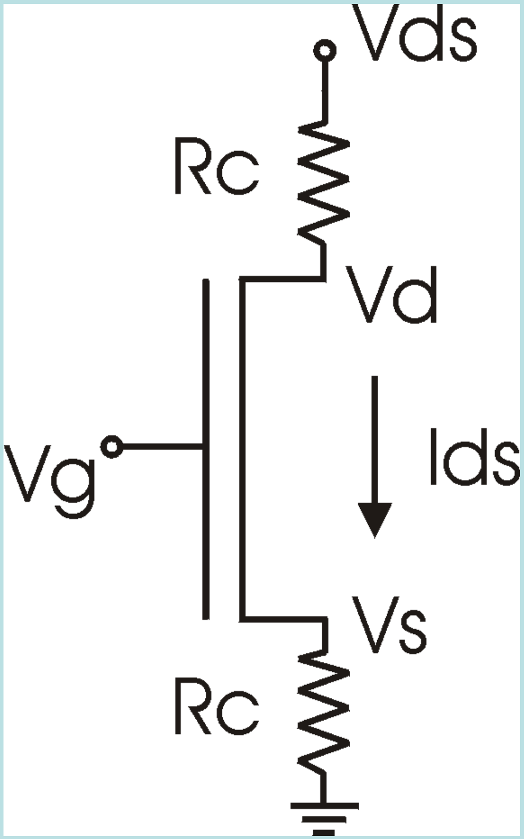
Contact Effects is correction factor, α = measured/theory



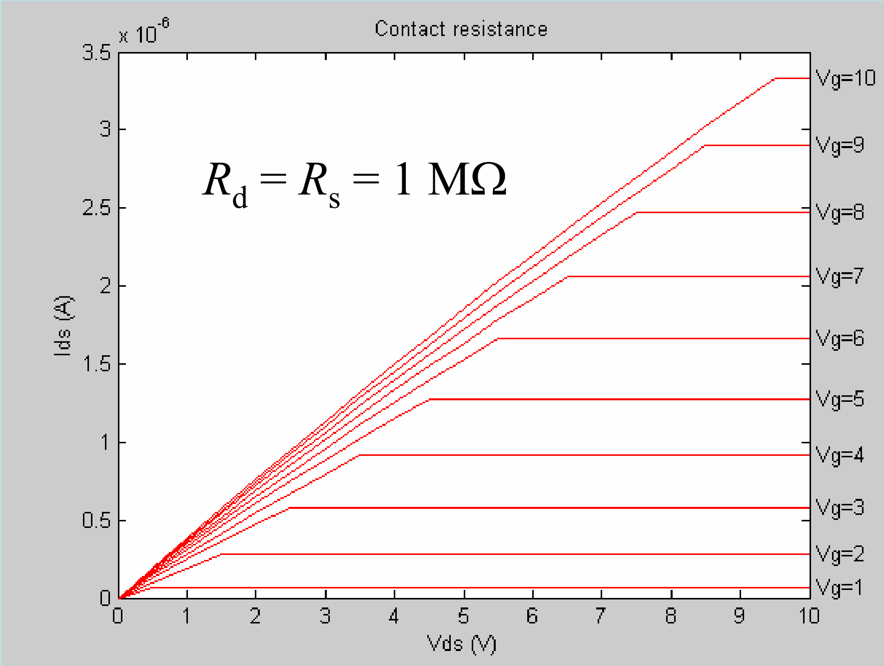
IV Curves:



poralyse/contactR2.m



IV Curves:
No effect on IV curves (shapes)!
(remember: an FET is a trans-resistor)



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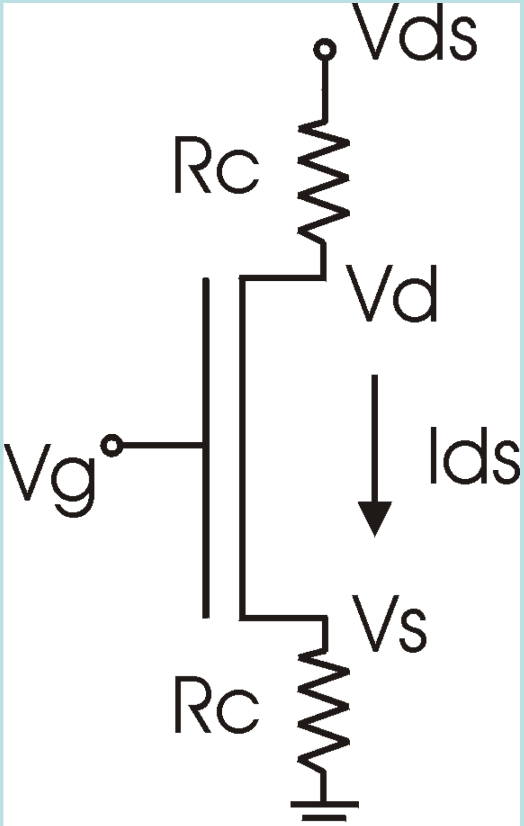

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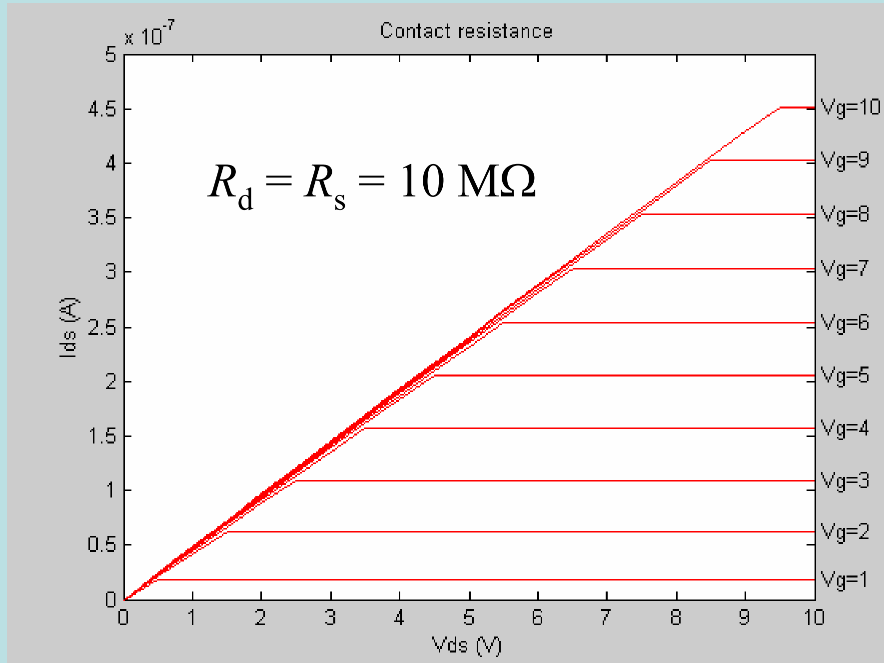

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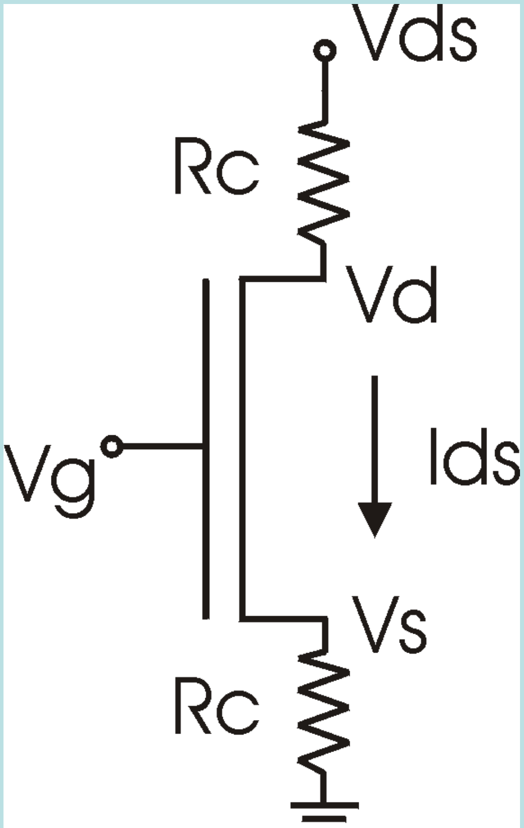
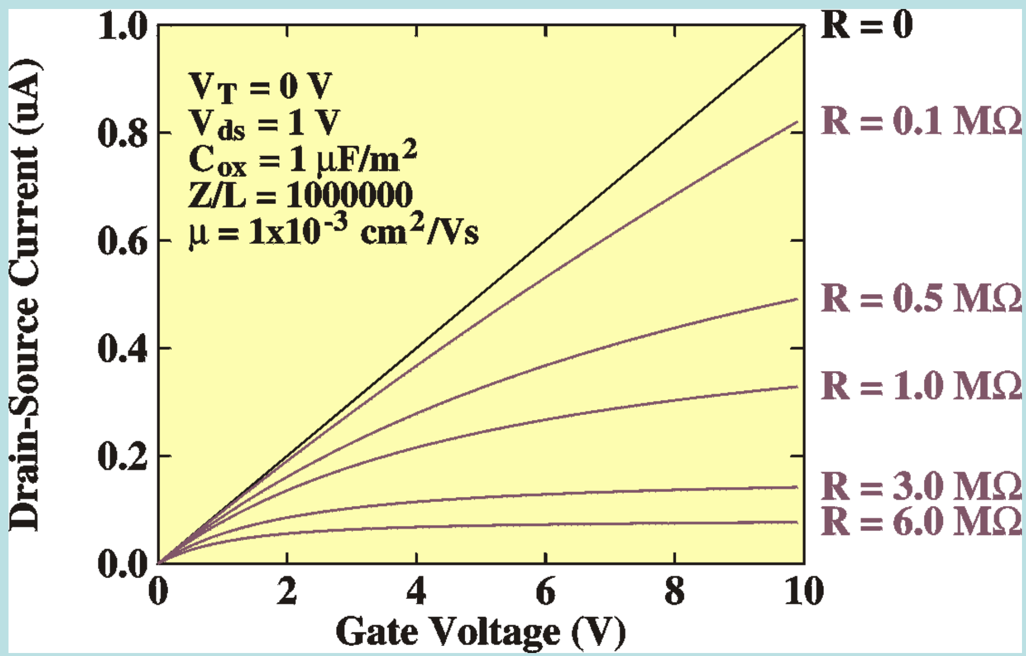


transfer Curves:

saturation



theory/fet/CONTACTR.PAS

IV Curves:
max current is reverse bias current
(always one diode is reverse)

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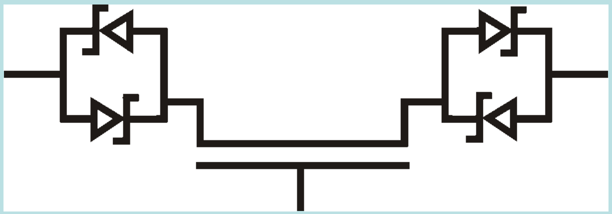


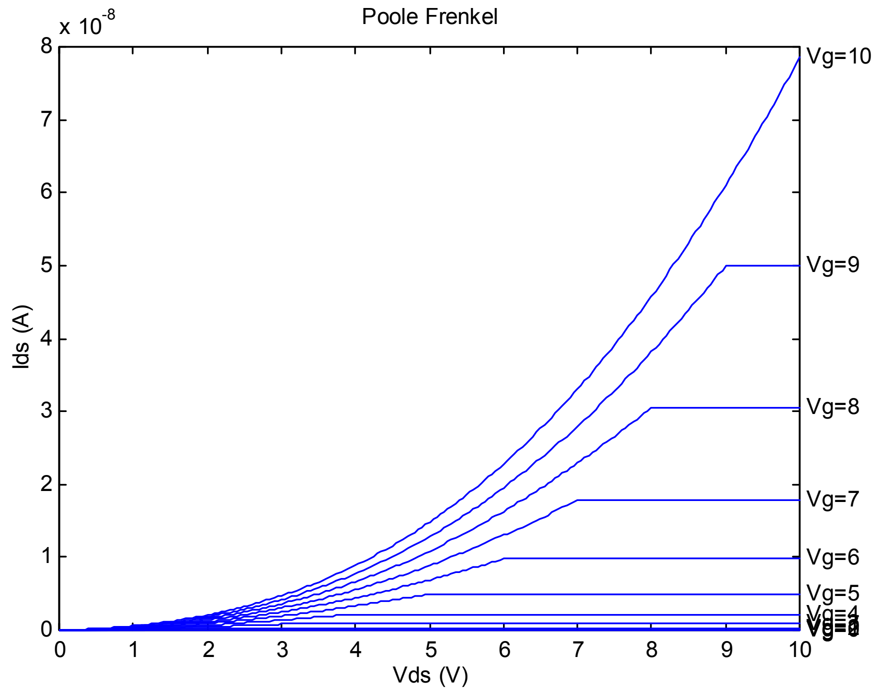
OK, but where is the physical
basis for this model

1: Simple model: field (and μ) constant in space

$$E = V_{ds}/L$$

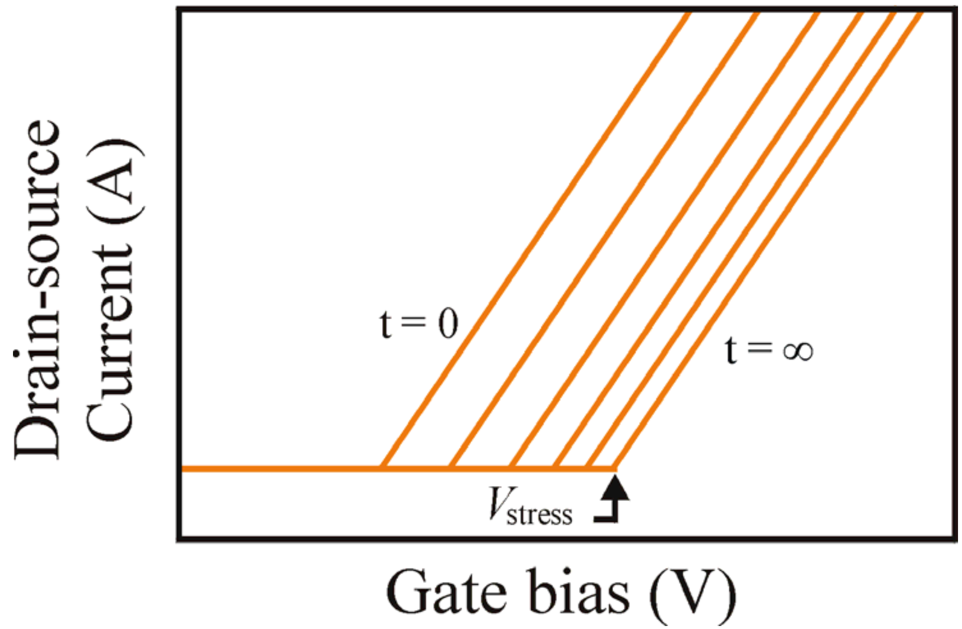
$$\mu = \mu_0 \exp(\gamma E^{1/2})$$

$$I_{ds} = a\, C_{ox}\,(V_G - V_T)\, \mu\, V_{ds}$$



waragai3.m

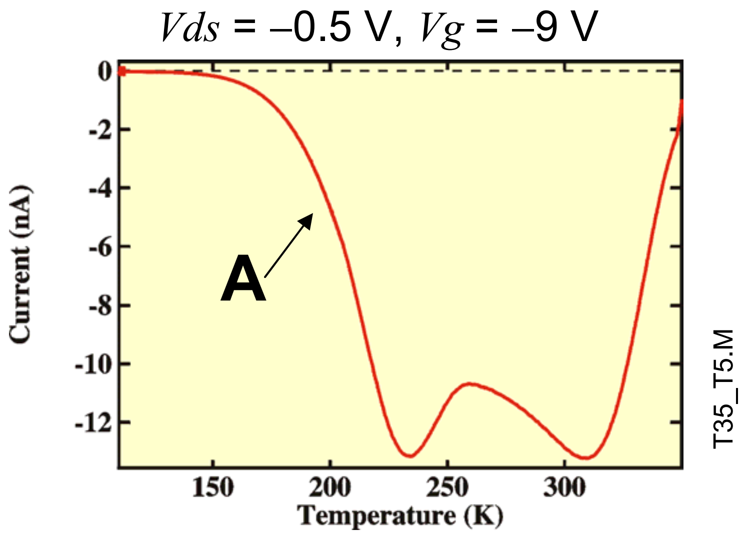
Stressing

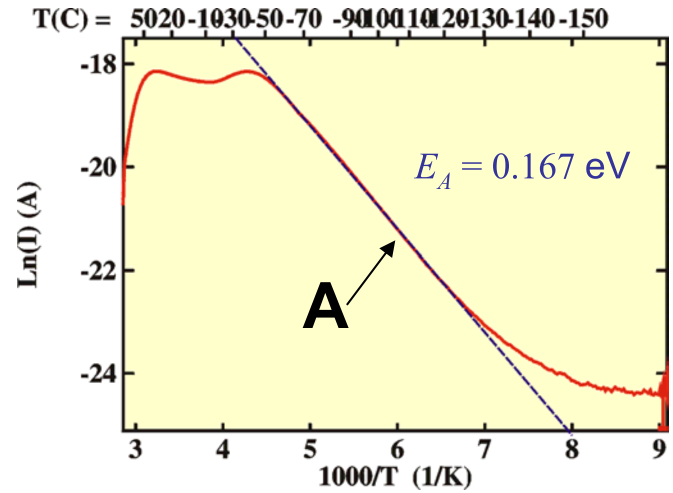


The fact that a threshold voltage exists in an accumulation-type FET proofs the existence of traps! Theoretically, the threshold voltage is zero (or >0, “Normally-on FET”).

Traps!

Temperature Scanned Current





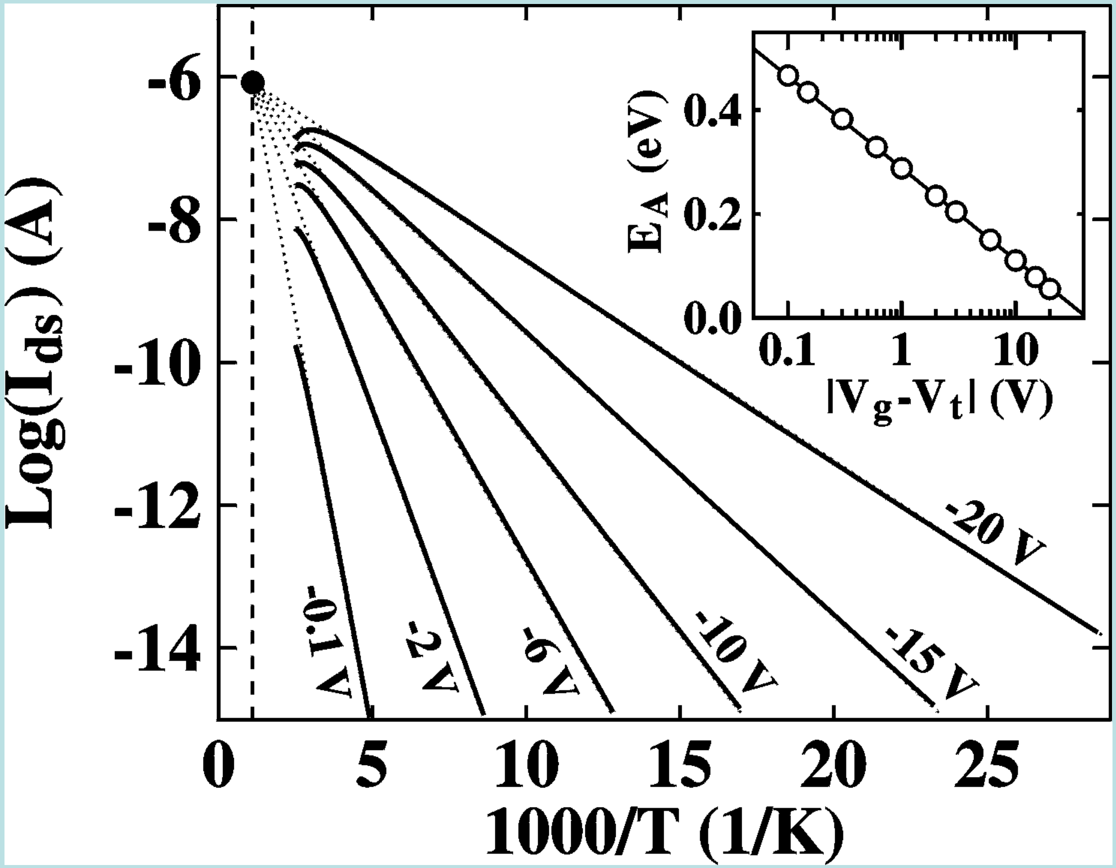
A:

Poole-Frenkel (traps): $\mu = \exp(-E_A/kT)$
(charges are emitted from traps)

Hopping: $\mu(T)$ = constant.

The final nail in the coffin of hopping conduction!

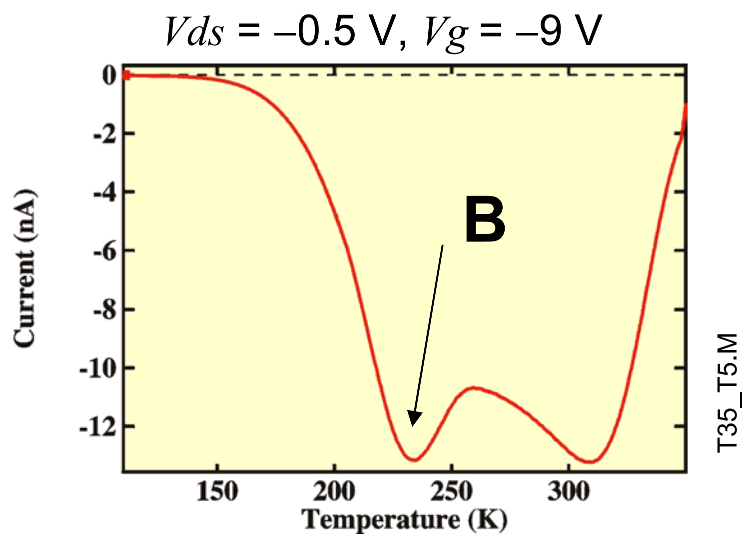
Meyer-Neldel Rule



Stallinga, Org.El. **6**, 137 (2005)

Careful with attributing a linear Arrhenius plot to a single level

Temperature Scanned Current

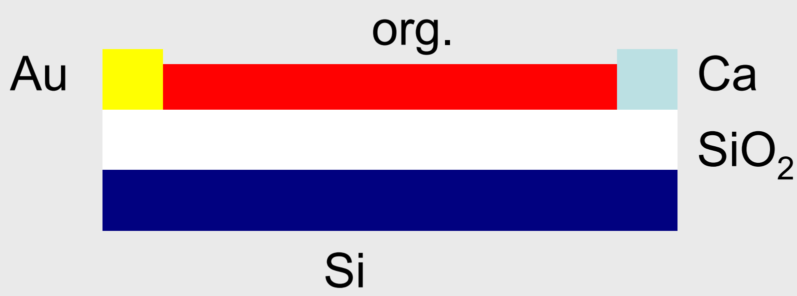


B:

New (abundant) traps formed. Charges retrapped

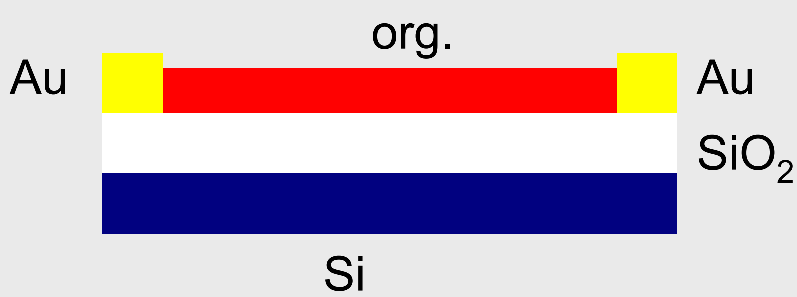
- crystallic deformation (“phase transition”) ?
- molecular deformation (“ring twist”) ?
- electronic deformation (“aromatic -> quinoid”) ?

The best: ambipolar materials, plus electrodes of different metal



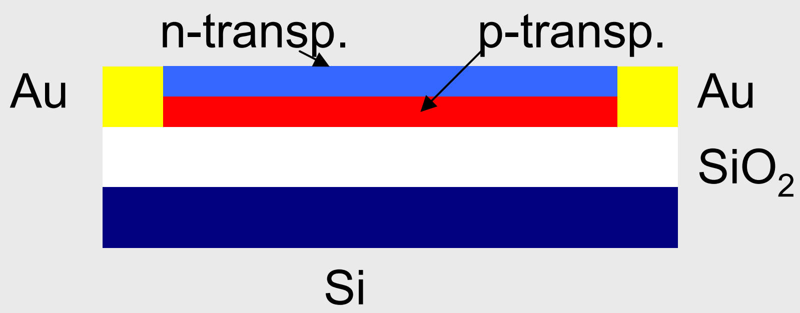
However, technologically difficult due to reactive low-work-function metal (Ca)

Ambipolar materials, plus equal electrodes



However, difficult electron injection (?)

Two different layers, n-type, p-type

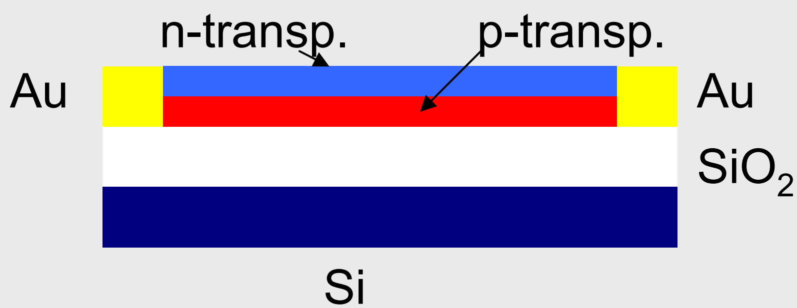


Still difficult to inject electrons (Au), or reactive (Ca)

and, doesn't work!

Ambipolar devices

Two different layers, n-type, p-type



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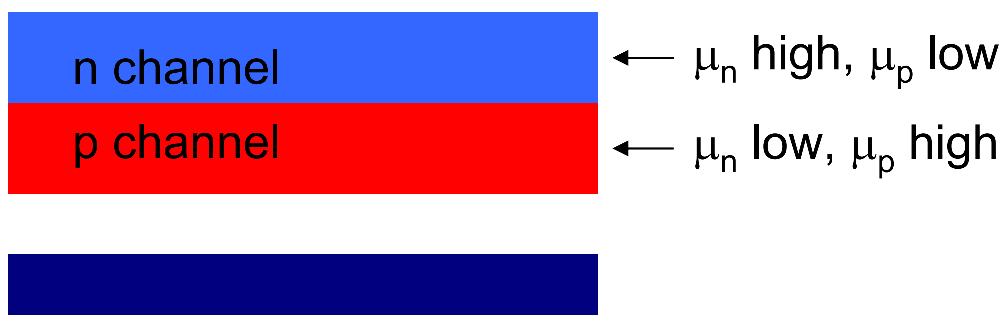

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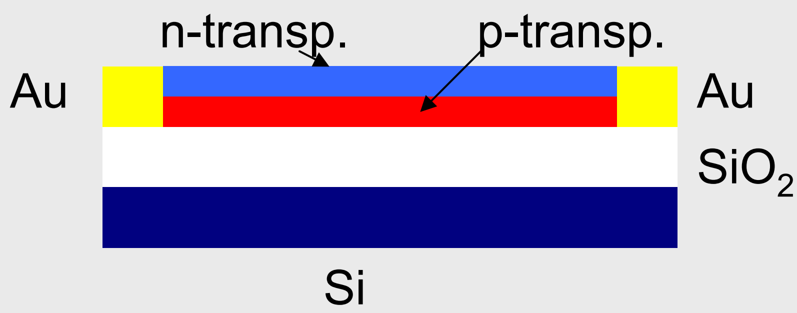
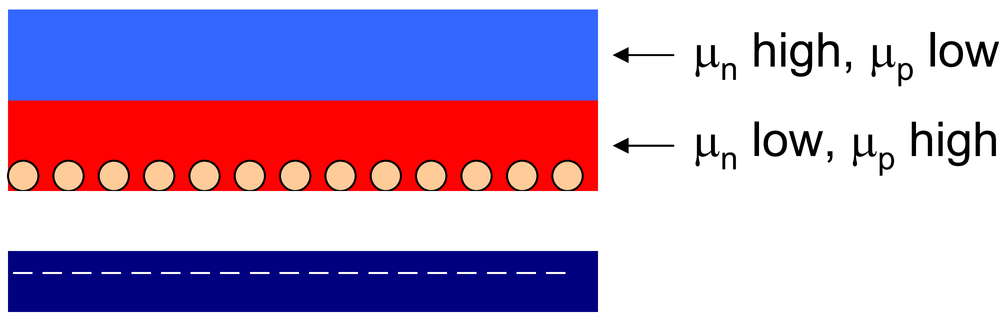


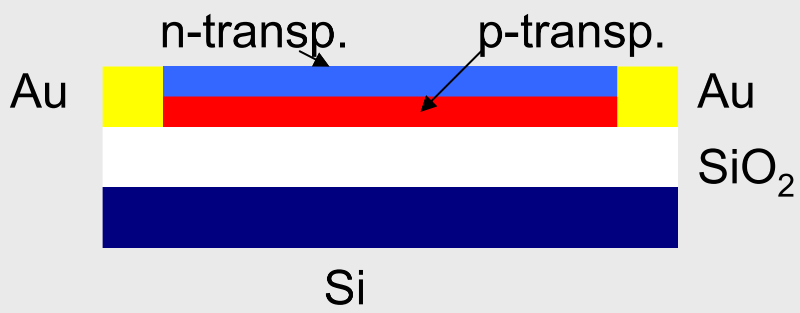
Still difficult to inject electrons (Au), or reactive (Ca)

and, doesn't work!

Negative gate bias:



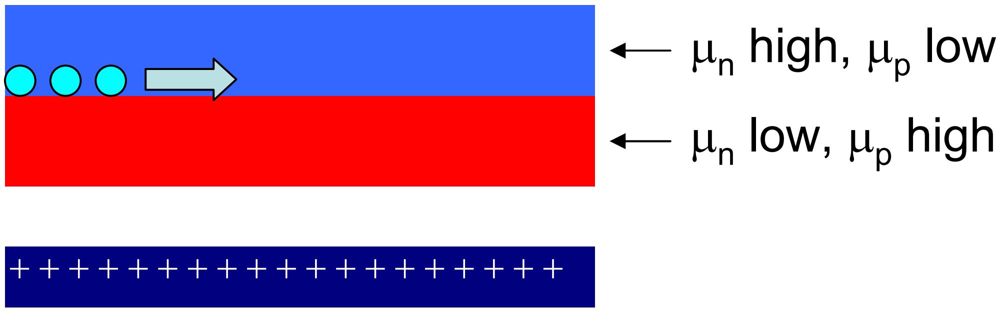
Two different layers, n-type, p-type



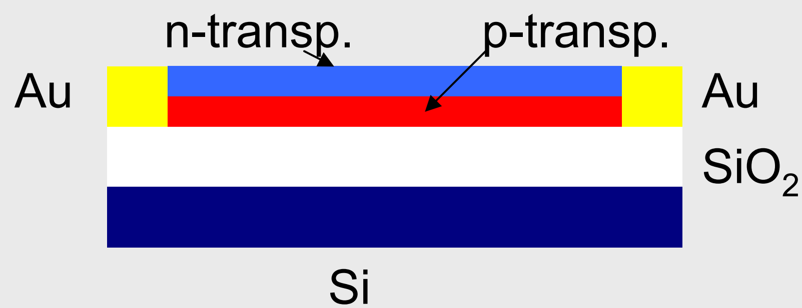
Still difficult to inject electrons (Au), or reactive (Ca)

and, doesn't work!

Positive gate bias:



Two different layers, n-type, p-type



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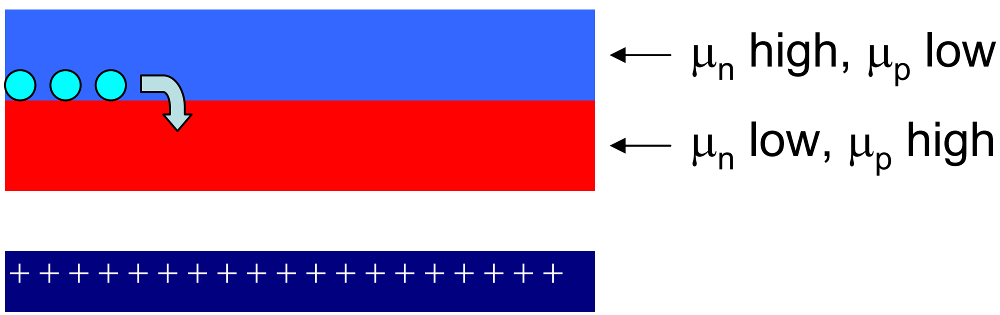
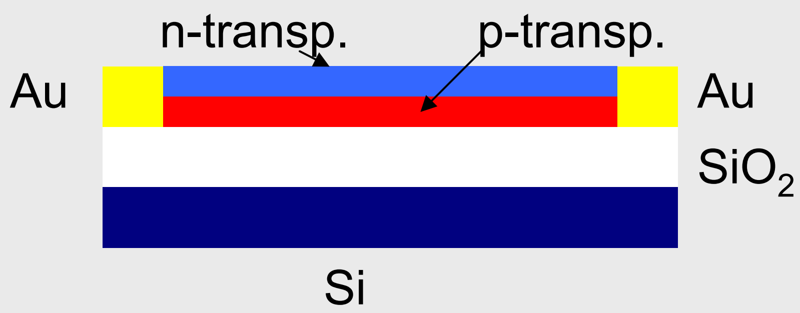


Ambipolar devices

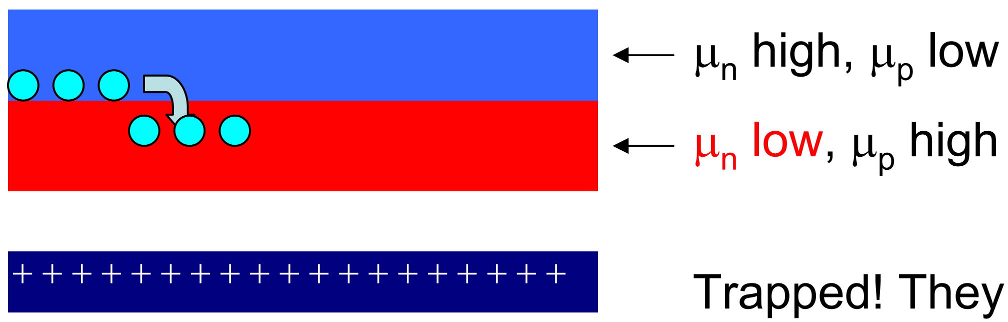
Two different layers, n-type, p-type



Still difficult to inject electrons (Au), or reactive (Ca)

and, doesn't work!

Positive gate bias:



Trapped! They don't make it very far!

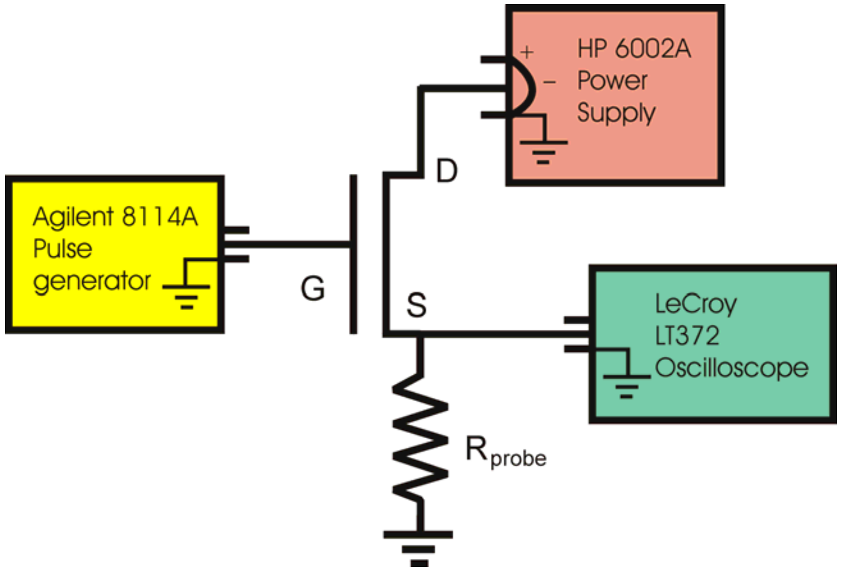
Two different layers, parallel n-type, p-type

Still difficult to inject electrons (Au), or reactive (Ca)

and, very difficult deposition technique.

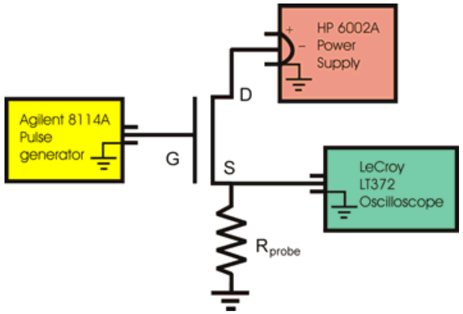
band bending at interface? 1 DEG?

For Pulse set-up no amplifiers can be used.



A probe resistance, R_{probe}, has to be used. Using an op-amp doesn't work

Pulse FET



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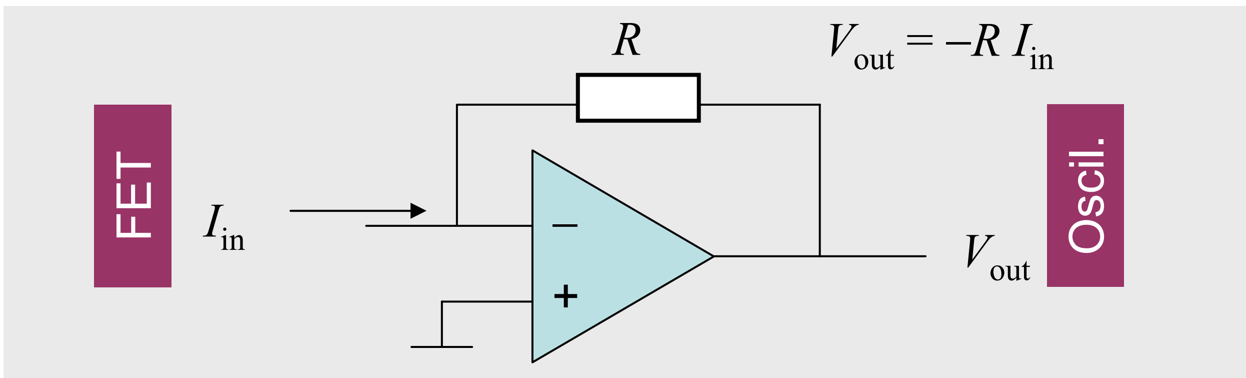

The cut-off frequency is 1 MHz →