Emerging Devices: RFETs and OPBTs

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Outline

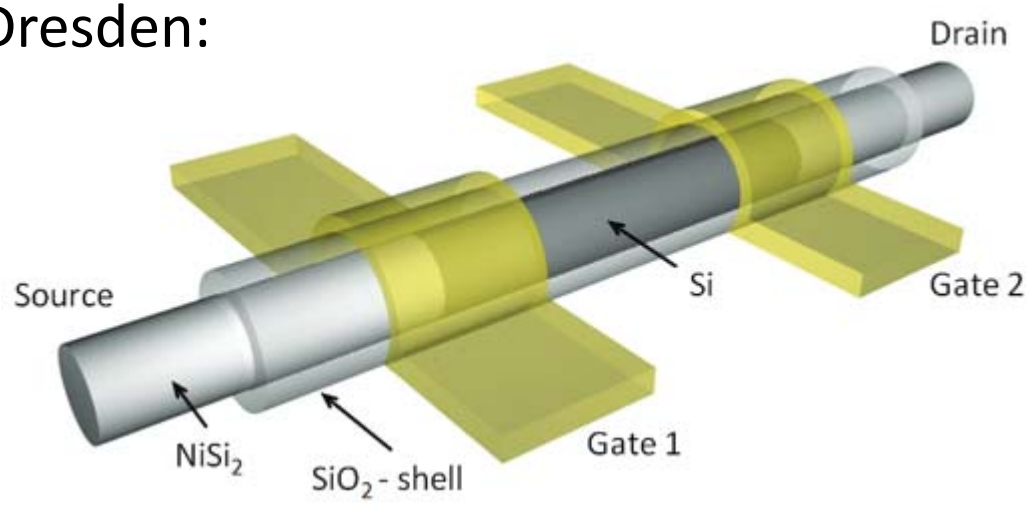
- **Reconfigurable FETs (RFETs)**
  - Fabricated SB Si NW Devices
  - Characteristics, and Simplified Design

- Organic Permeable Base Transistors **(OPBTs)**
  - Conventional Lateral OFETs
  - Vertical OFET, and **OPBTs**

- Conclusion

SB Si NW RFETs

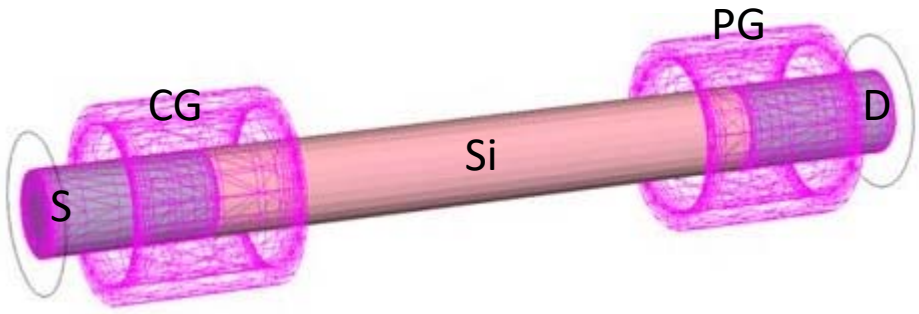
- Namlab, TU-Dresden:

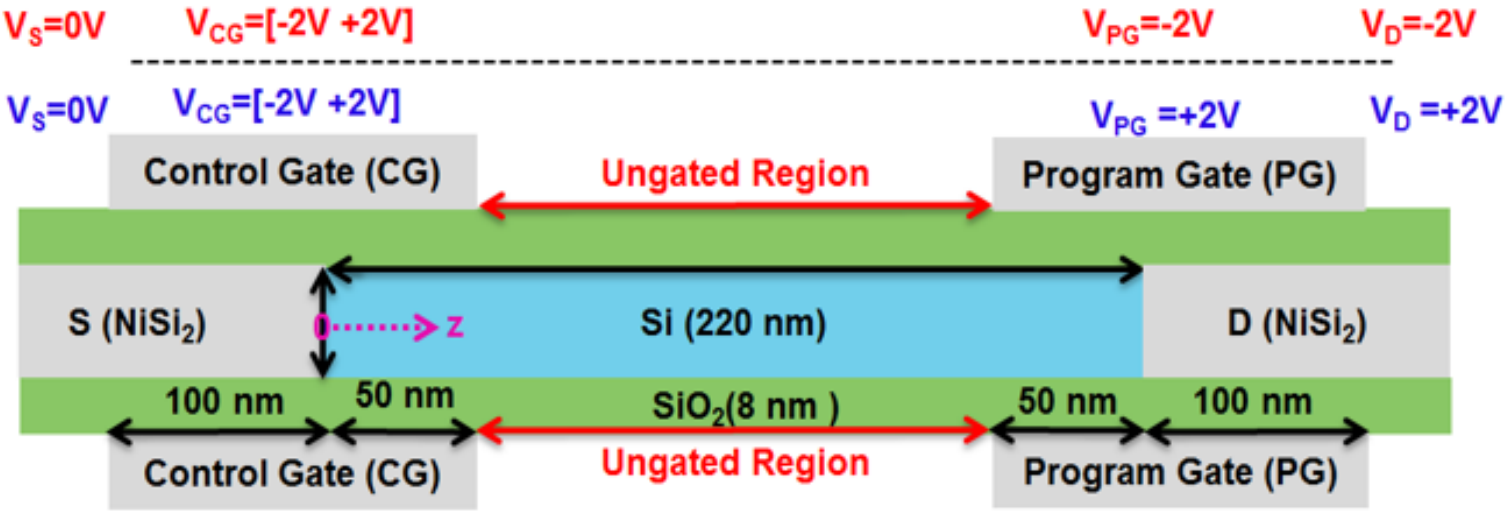


- ❑ Dynamically **switching** between n- and p-type **polarity**.
- ❑ Different logic **computations** use the **same hardware**.
- ❑ Number of **devices** can be reduced by **50%**.

[1] W. Weber *et al.,* "Reconfigurable nanowire electronics –A review", *Solid-State Electronics*

RFET structure and TCAD

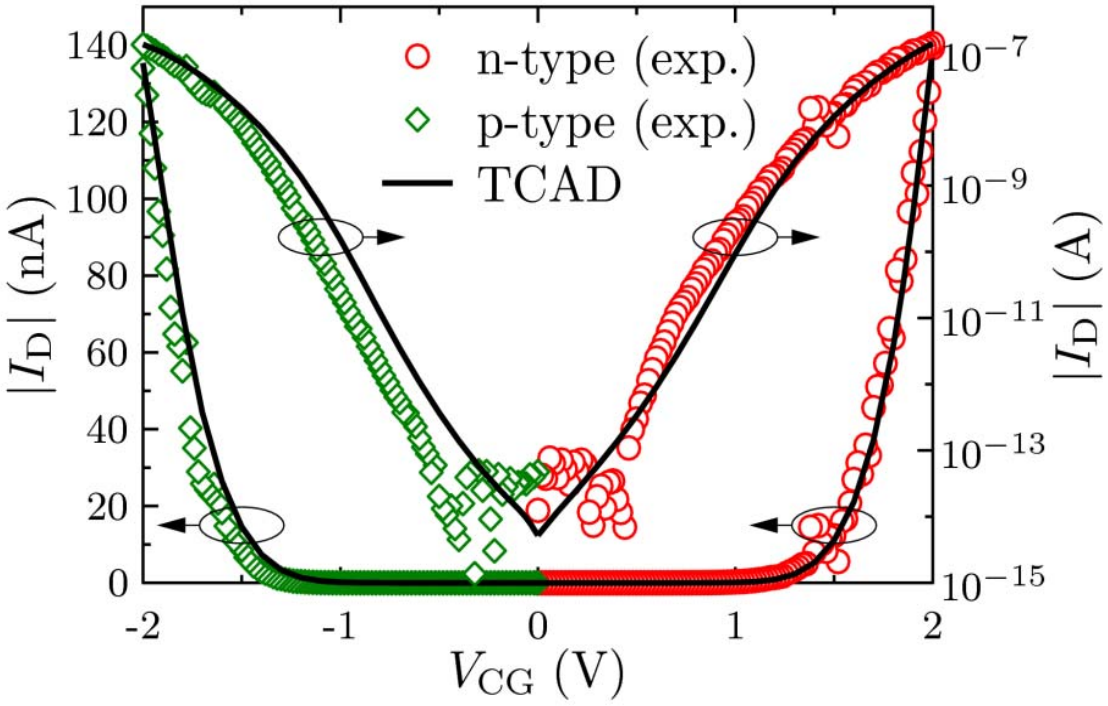




[1] G. Darbandy, *et al.*, "High-Performance Reconfigurable Si Nanowire Field-Effect Transistor Based on Simplified Device Design" IEEE TNT, Vo.15, No.2, 2016.

RFET Characteristics

- Modify effective mass, the band gap, and thus barrier height [1].



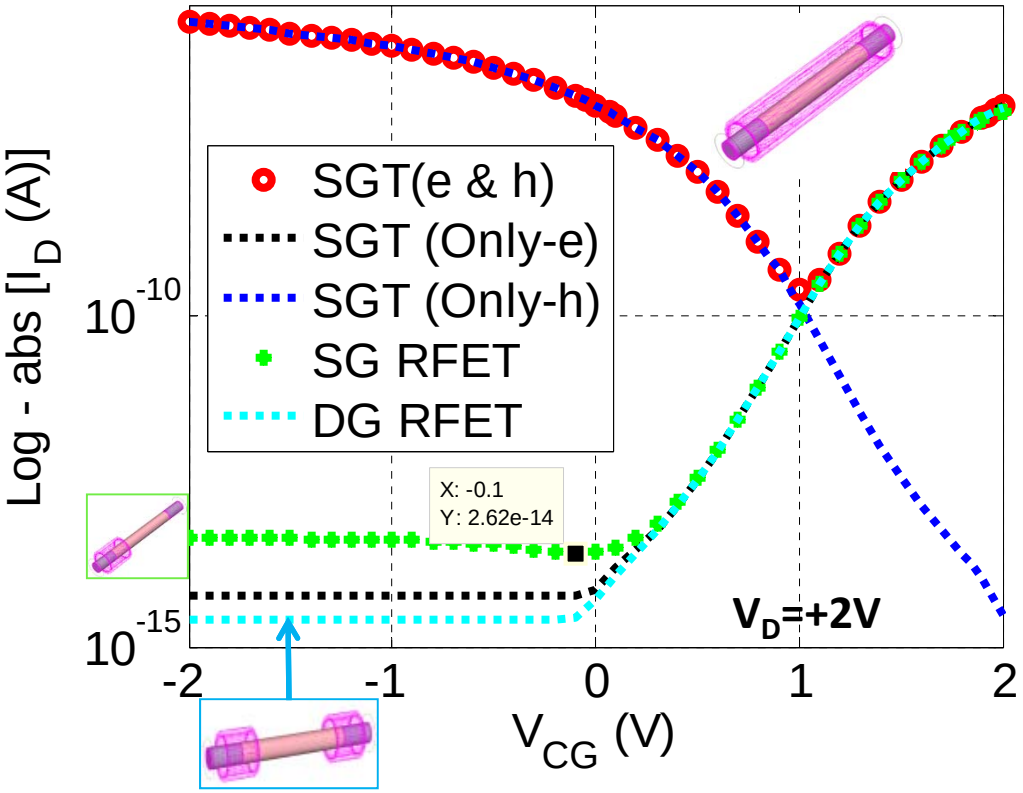
$$T_{n,p} \propto \frac{e^{-4}\sqrt{2m^*_{n,p}}\,\varphi^{1.5}_{n,p}}{3q\hbar E}$$

- ❑ **Symmetric** characteristics
- ❑ on/off > **1e7**
- ❑ **Dynamical** reconfigurable

[1] Heinzig, A. etal, "Dually Active Silicon Nanowire Transistors and Circuits with Equal Electron and Hole Transport" *Nano letters, ACS Publications,* **2013**, *13*, 4176-4181.

Theoretical limit of unipolar I-V

- Electron and hole contributions of an ambipolar SGT.



- **Ideal** unipolar (e**/h**) I-V can be **achieved** by DG/SG RFET.

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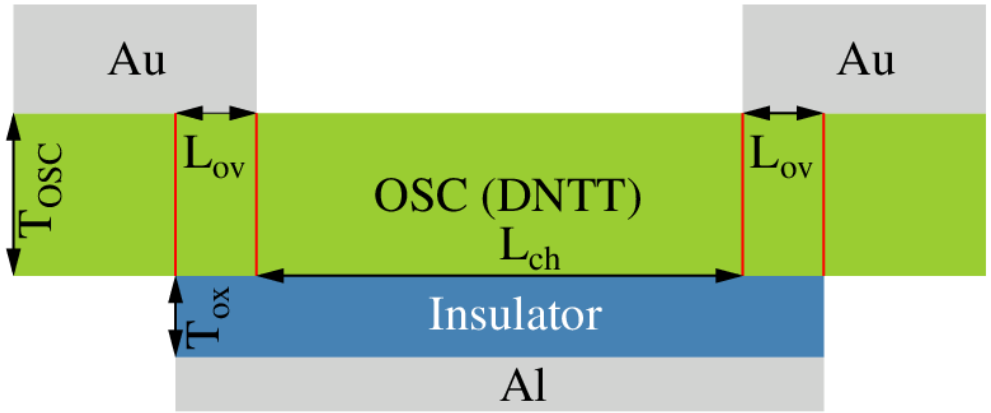
Lateral OFETs

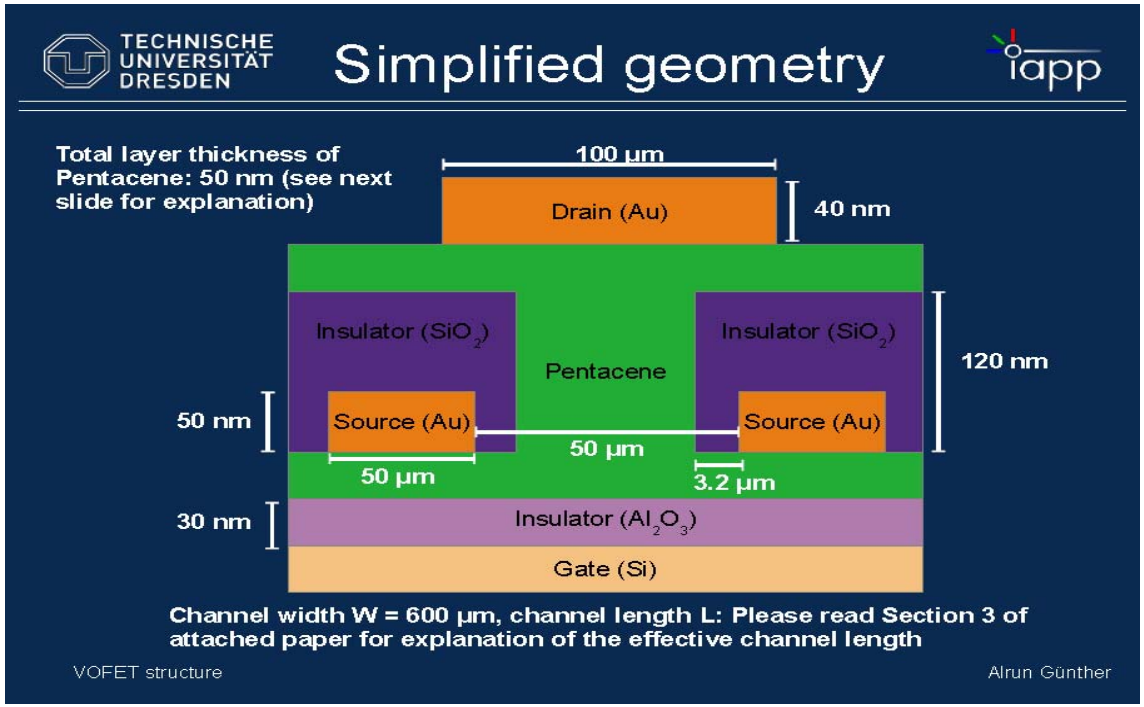


- Planar or staggered OTFTs.
- Impressive investigations.
- **Less** development of $\mathbf{f_T}$.
- Short L_{ch} is **NOT** feasible with low cost technology.

- ❑ An **alternative** to increase $\mathbf{f_T}$ mainly with short $\mathbf{L_{ch}}$.
- ❑ Different kind of **Vertical OFETs** are reported.

[1] H. Kleemnn *et al.*, "A Review of Vertical Organic Transistors", Adv. Funct. Mater. 2020.

Vertical OFETs

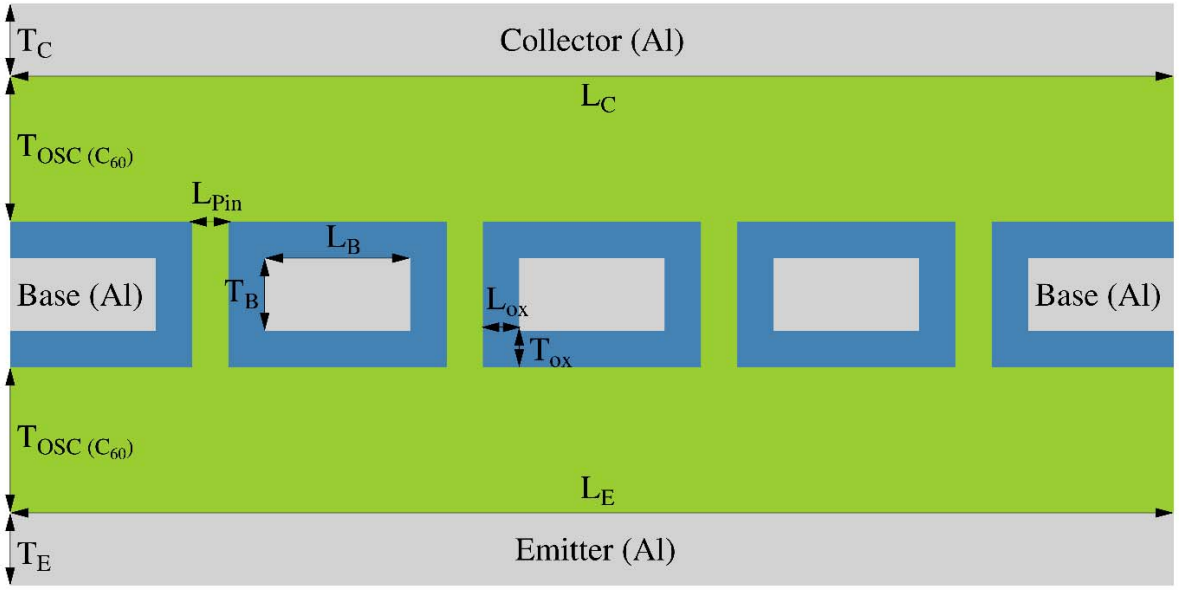


- The **current** flows **perpendicular** to the substrate.
- **Thickness** control down to 100**nm** with **low-cost**.

- ❑ An **issue** was/is combination of **lateral/vertical** L_{ch}.
- ❑ An **alternative** is **OPBTs**.

[1] H. Kleemann, *et al.,* "High-Performance Vertical Organic Transistors," *Small*, vol. 9, no. 21, pp. 3670–3677, 2013.

OPBTs



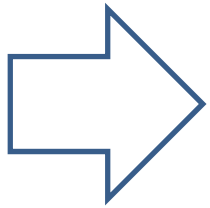
- Record-high f_T= **40 MHz** at μ_{Ver}=0.06 $cm^2\ V^{-1}\ s^{-1}$
- A large **room** for further DC / f_T improvements.

- Three parallel electrodes separated by two OSCs.
- Active length=T_{OSC} => controllable in **nm** range (**low cost**).
- **Stable**, **reliable** and **repeatable** characteristics are proved.

[1] F. Dollinger *et al*., Adv. Ele. Mat. 2019, [2] B. Kheradmand-Boroujeni *et al.,* Scientific Reports, 2018. [3] G. Darbandy *et al*., Adv. Ele. Mat. 2020.

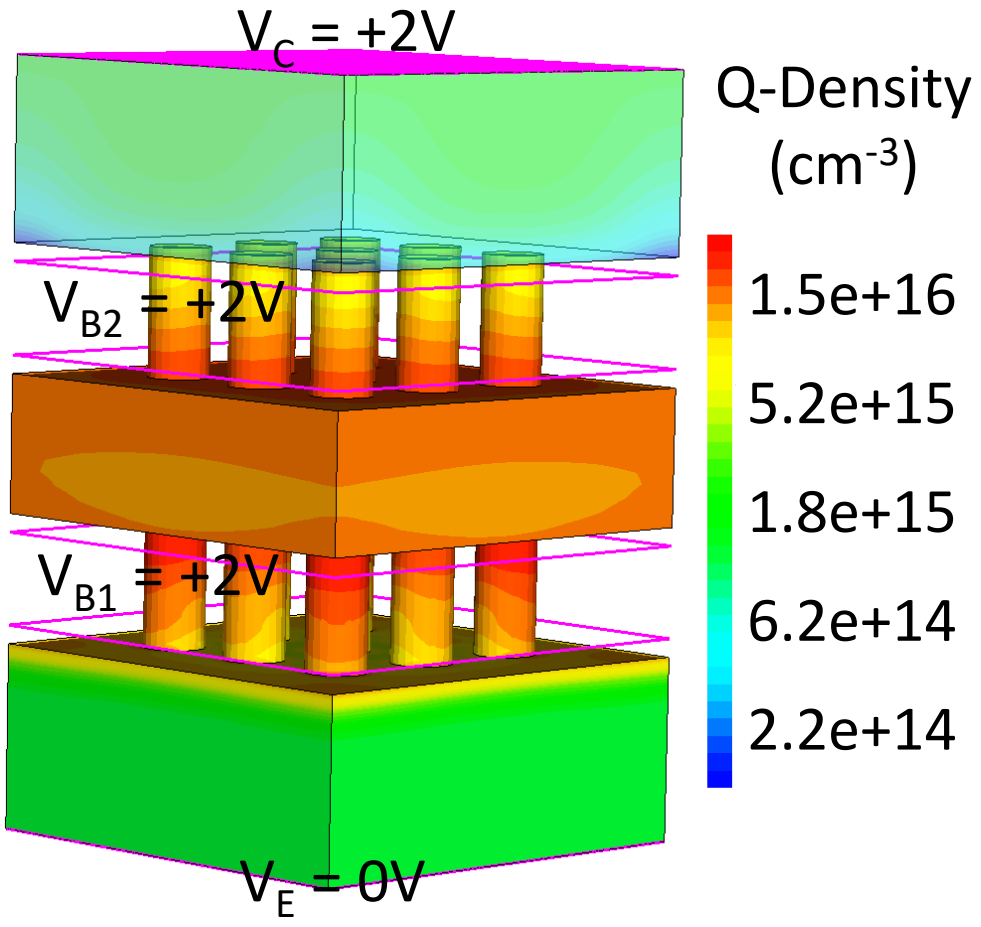
OPDBTs

- **Optimization** of C_{par}.
- μ_{Lat}=25 ----> μ_{Ver}=0.06 ($cm^2\,V^{-1}\,s^{-1}$).
- Engineering of R_C.



❑ $f_T \geq$ **1GHz** is realistic/achievable

(L_{ov}≤**1µm**, R_C≤100Ωcm, **µ**≥10).



[1] E. Guo *et al.,* "Vertical Organic Permeable Dual-Base Transistors for Logic Circuits", *Nature Communications*, 2020.

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Conclusion => **Compact Model**

Prof. W. Weber
TU Vienna
Thursday

- Si NW **RFETs**:
  - Dynamically switching polarity, number of devices down to 50%, technology design for **hardware security** (secure circuits).

Dr. H. Kleemann
TU Dresden
Thursday

- **OPBT**:
  - Great DC and record-high f_T and room for further improvements

- **Developing Compact Models**:
  - Novel **applications, circuit,** and **system** design**!**