Nanoscale MOSFETs with alternative channel materials

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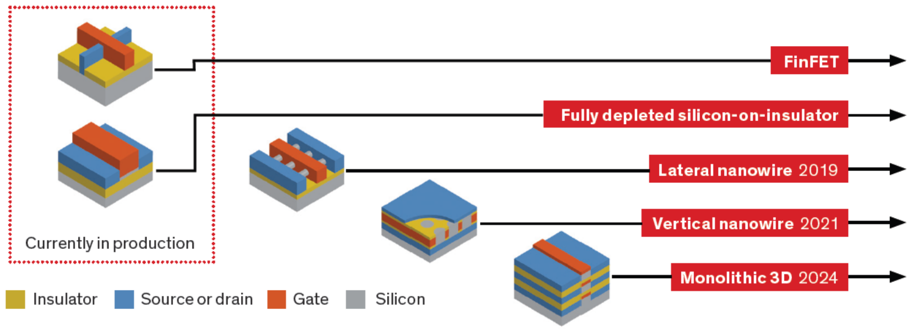
Thanks to ….

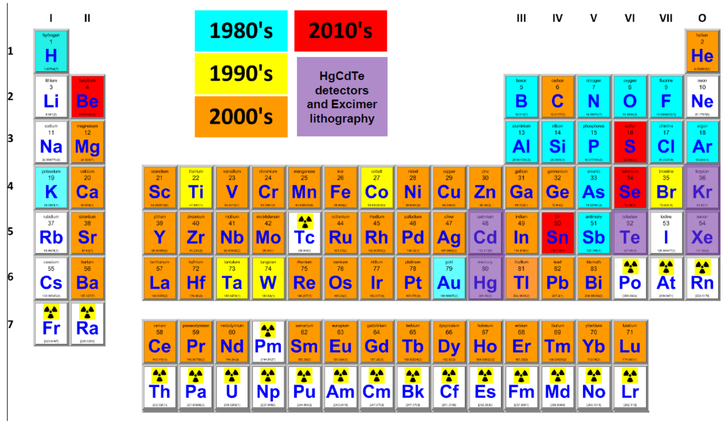
Framework

- Aggressive scaling has pushed L_G below 20nm

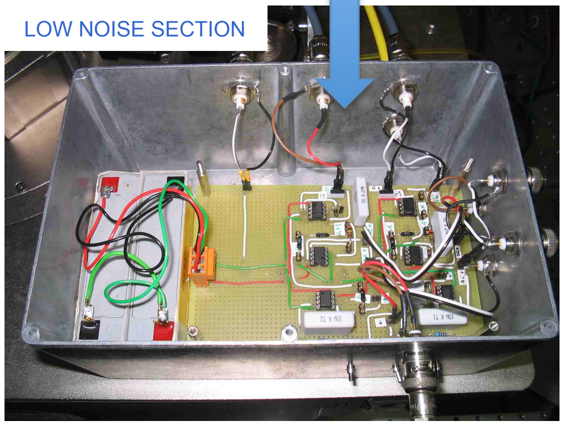
- Innovative device architectures (FDSOI, finFET, nanowires)



- New materials are being used for the channel, dielectrics, interconnects, …



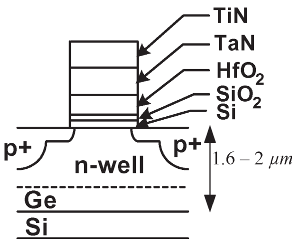
Experimental Characterization: Instrumentation (UniCAL)



Electrical characterization at wafer level: DC, pulsed and noise

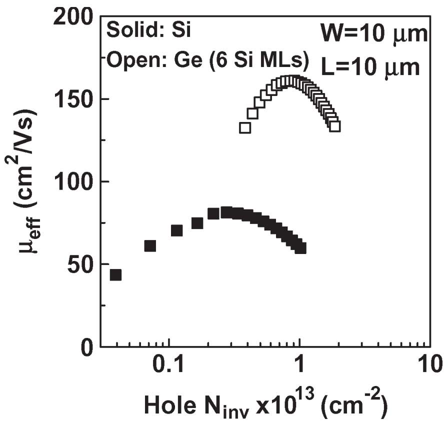
Set-up for design and realization of electronic boards

Experimental Characterization: Measurement (UniCAL)



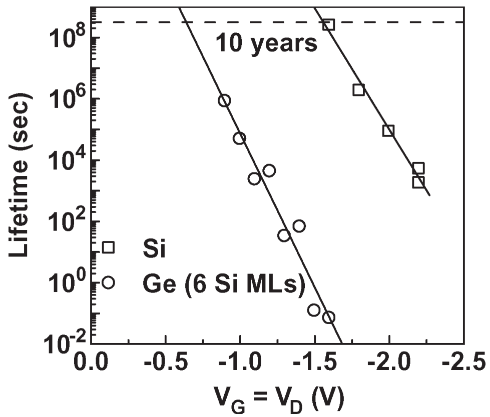
imec devices: Ge pMOSFETs versus reference Si pMOSFETs (same gate stack)

I-V, C-V



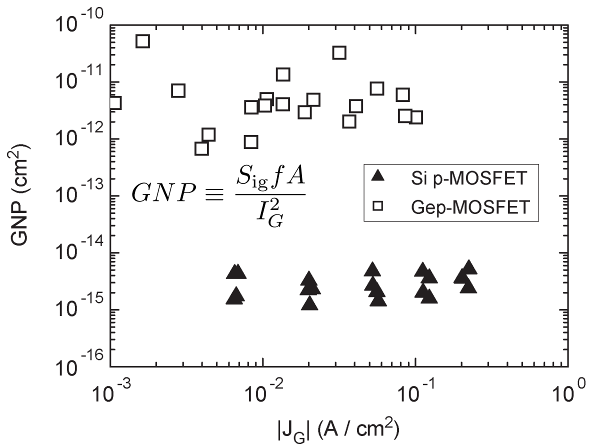
Higher mobility

Reliability: hot carriers (HC)



Worst HC degradation due to lower bandgap

1/f noise



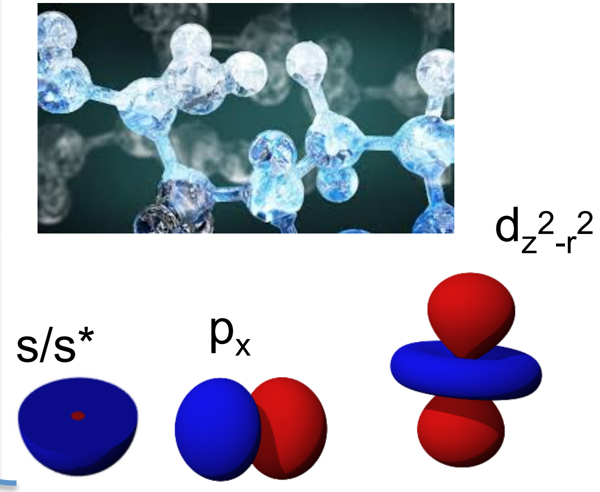
Higher 1/f noise due to Ge outdiffusion in the gate stack

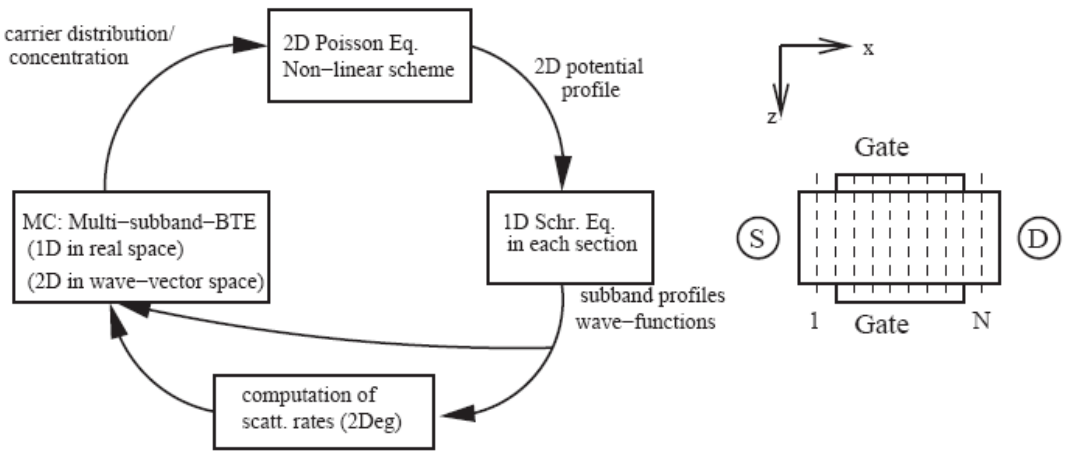
Modeling and simulation activities

- assessment of different channel materials (on-current, SS, scalability….)
- influence of gate dielectrics (e.g. mobility reduction in MOSFETs with high-k gate stack)
- comparison of device architectures (e.g. finFET vs. nanowire)

Simulation approaches

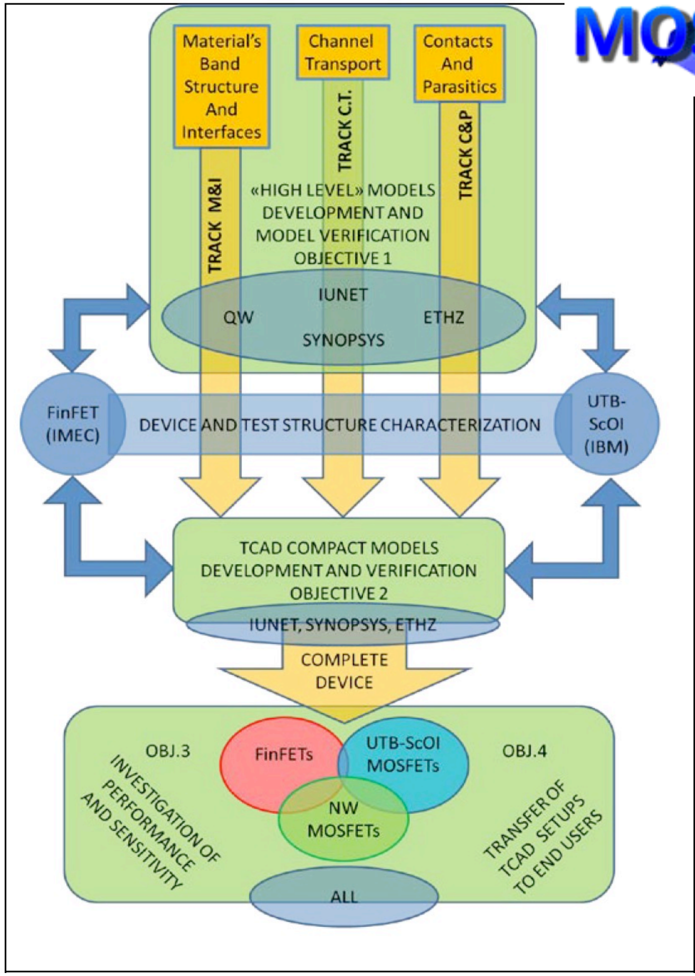
- Full quantum
  - Atomistic DFT / tight binding Hamiltonians
  - k·p Hamiltonian
- Multi-subband (semi-classical)
  - D-BTE
  - MSMC,
- Semi-classical MC
- Drift-Diffusion





Case study: III-V MOSFETs

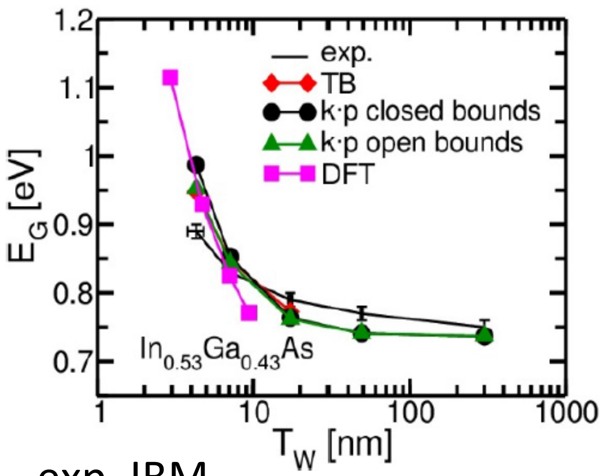
- E.U. project III-V-MOS
- target: III-V semiconductor based n-MOSFETs at and beyond the 14 nm node
- aims:
  - to develop high-level and TCAD models
  - to narrow down the technology development options
  - to deliver models to end users in semiconductor manufacturing industry and research labs



Case study: III-V MOSFETs

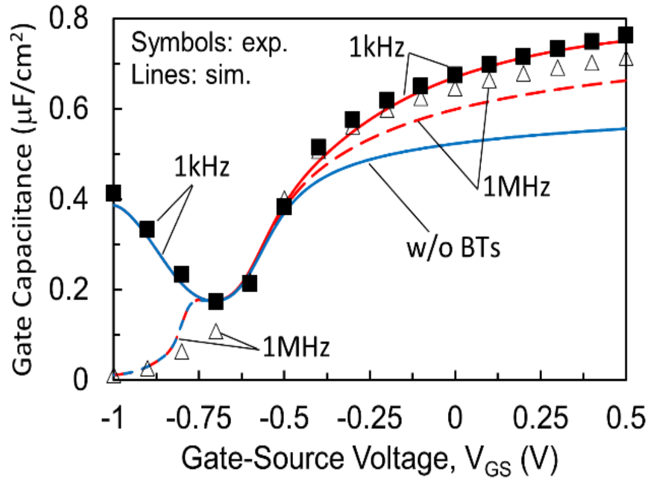
- High-level models vs. experiments, examples:

material properties



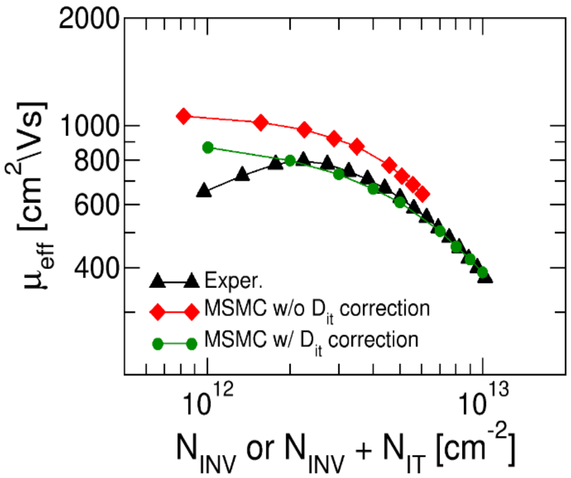
exp. IBM
k·p: UniBO+UniUD

interface properties



exp. IMEC
TCAD: UniMORE

carrier mobility

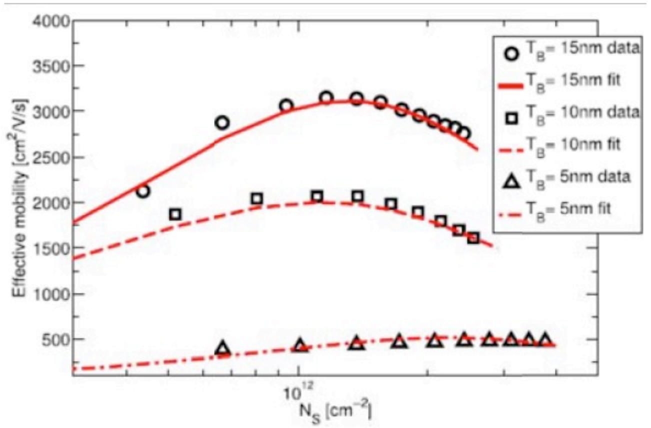


exp. IBM
MSMC: UniUD

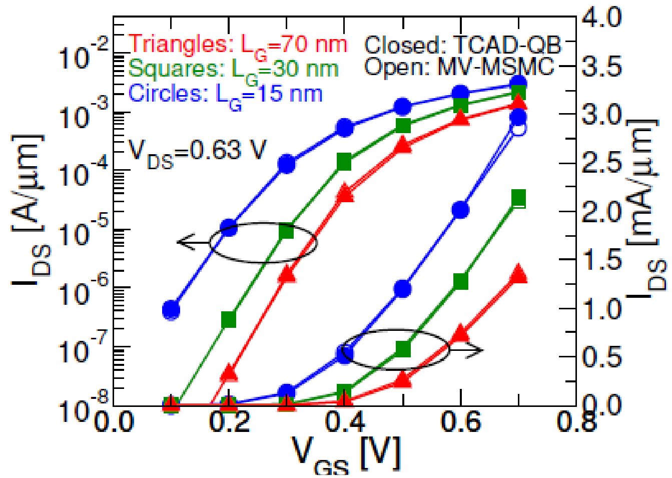
Case study: III-V MOSFETs

- TCAD models, examples:

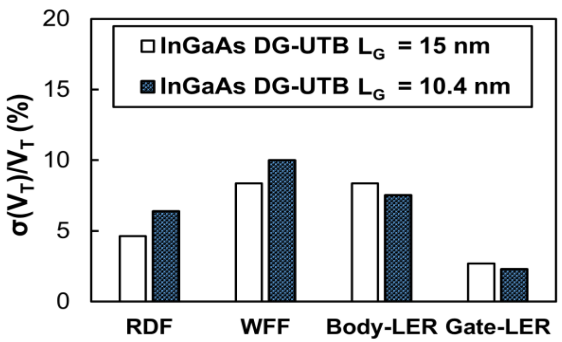
Mobility model calibrated on IMEC's data (UniBO)



model for short channels validated vs MSMC (Unibo+UniUD)

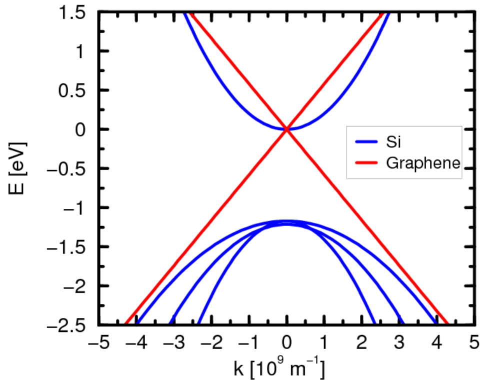


TCAD employed for variability studies (UniMORE)

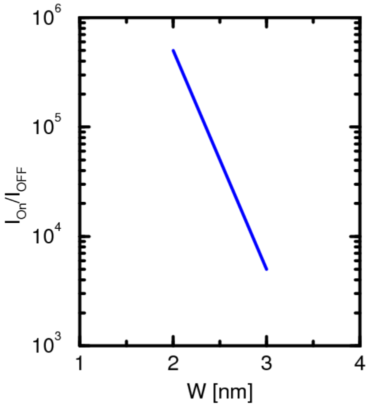


Graphene Transistors

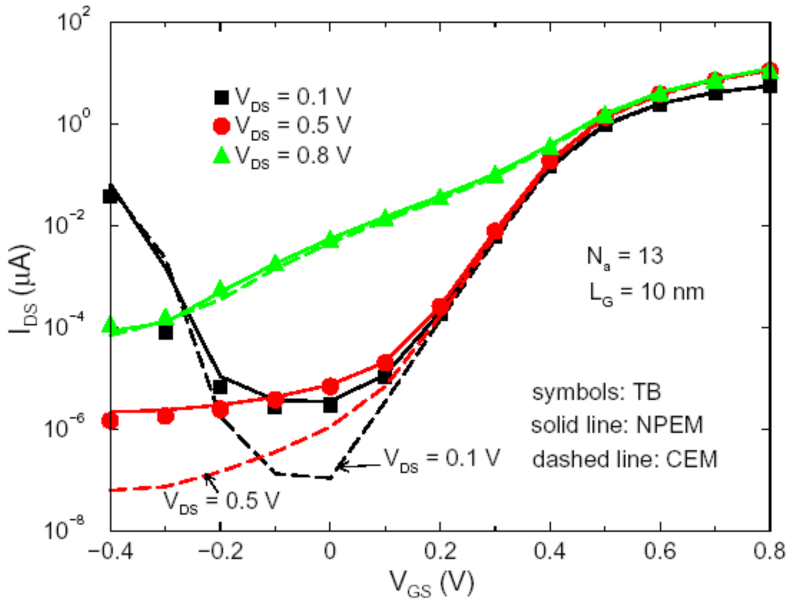
Graphene is a 2D crystal, gap-less with very high carrier velocity.



nano-ribbons have a gap and allow for reasonable Ion/Ioff



ballistic NEGF simulations: comparison between TB and constant or non-parab. effective mass (UniBO)

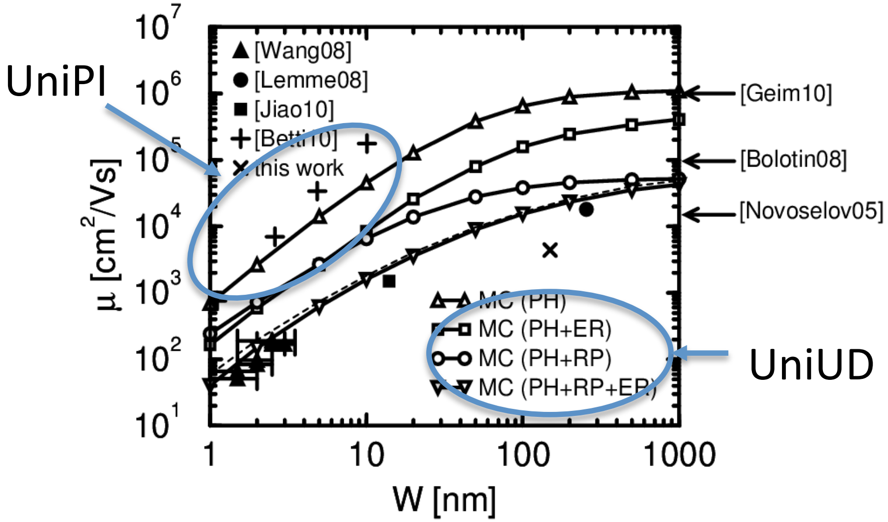


E.U. project GRAND

Graphene Transistors

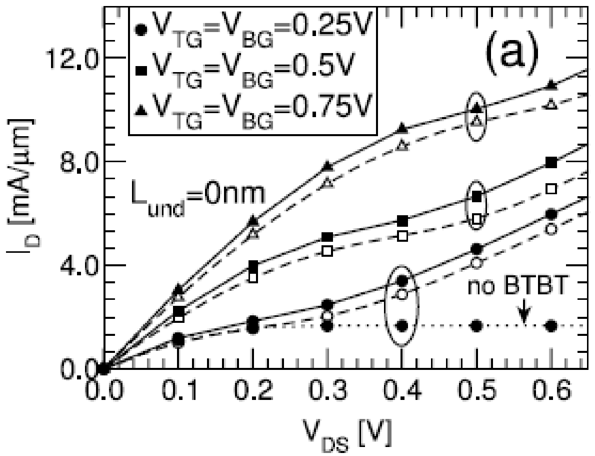
GRAphene ND

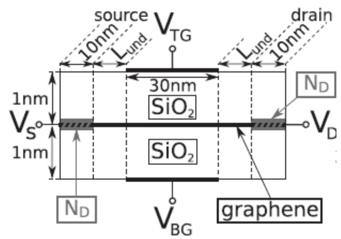
- Low mobility in nano-ribbons
- exp.: literature and partner AMO



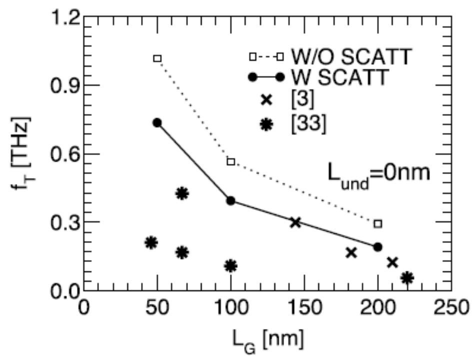
- Development of MC to include scattering
- sanity check:

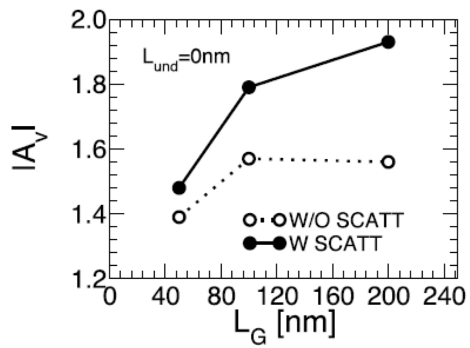
MC w/o scatt (UniUD) vs NEGF (UniPI)





- estimate of RF performance with scattering (UniUD)



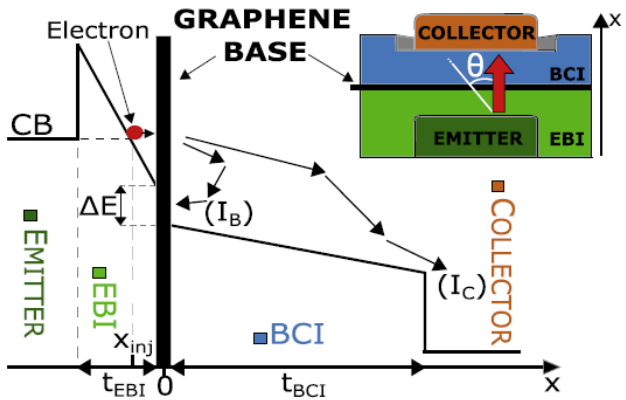


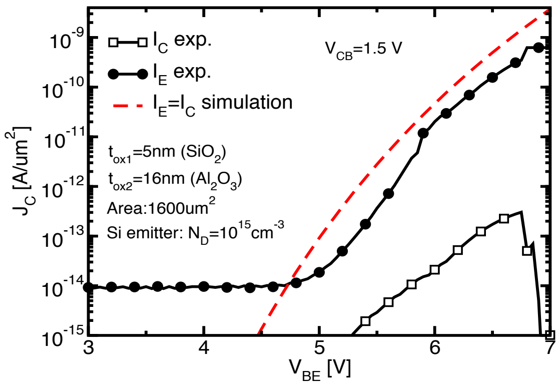
IU.NET

Graphene Transistors

Alternative transistor architectures (E.U. project GRADE)

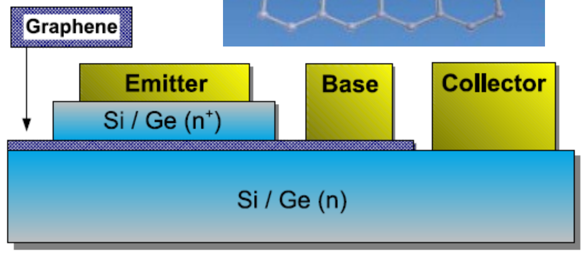
Graphene-Base-Transistor

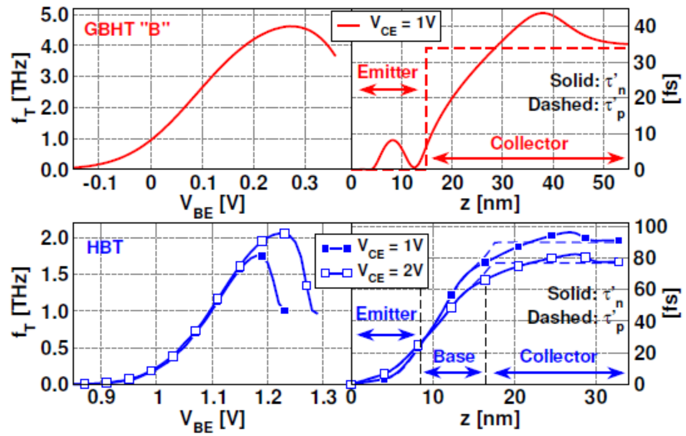




exp. form KTH
sim. : UniUD

Graphene-Base-Heterojunction-Transistor



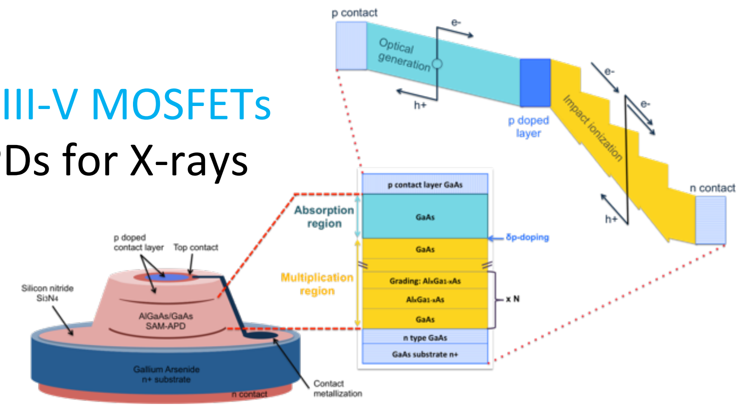


UniBO

Comparison with an optimized SiGe n-p-n HBT shows GBHT superior performance

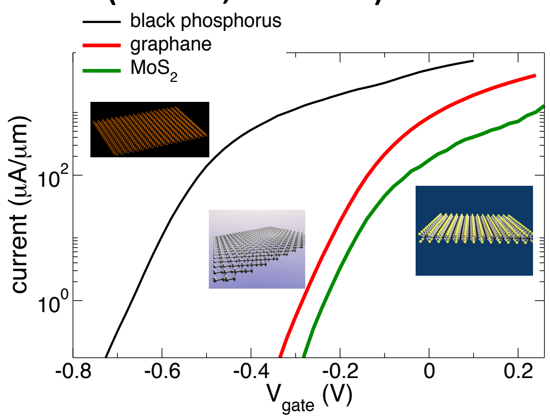
Future developments

- activities on III-V MOSFETs
  → III-V APDs for X-rays (UniUD)



  → proposal MONET (UniUD+PoliTO): III-V photo-detectors for ToF cameras

- activities on graphene
  →other 2D materials (UniPI, UniUD)



  → pressure sensor in graphene (UniUD+KTH)

- know-how on modeling of III-V and other materials can be exploited also in power devices (GaN, SiC)