Towards wide-frequency substrate model of advanced FDSOI MOSFET

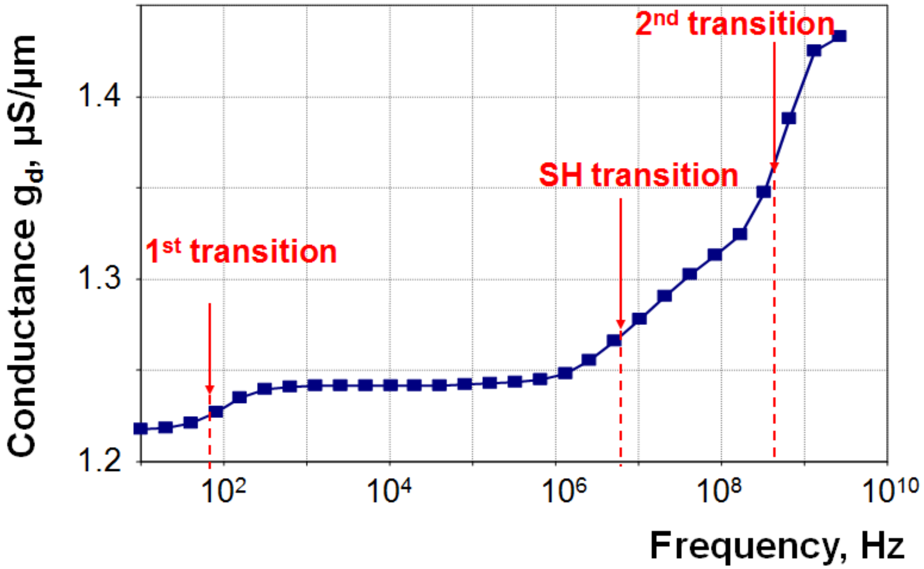
S. Makovejev, V. Kilchytska, J.-P. Raskin, D. Flandre
ICTEAM Institute, Université catholique de Louvain
Louvain-la-Neuve, Belgium

Outline

- Introduction and motivation
- Method
- Results
  - Accumulation
  - Inversion
- Summary and future work

Introduction

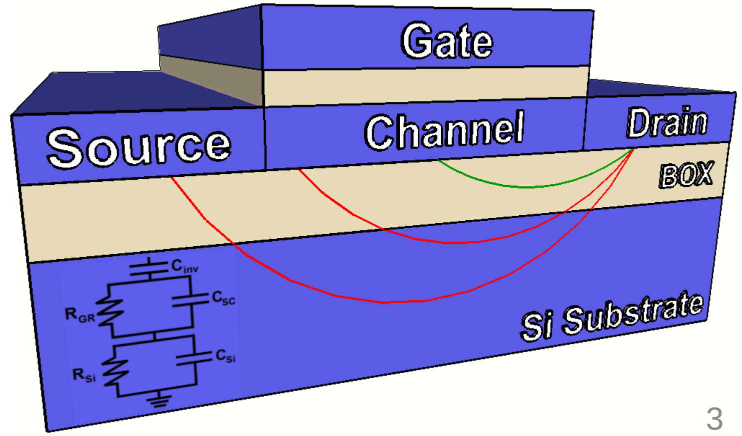
- In SOI MOSFETs g_d and therefore A_v are frequency dependent (not desirable for analogue circuits)
- Self-heating and substrate effects are the main mechanisms
- Self-heating is well known
- Substrate effects frequency dependence is not widely known



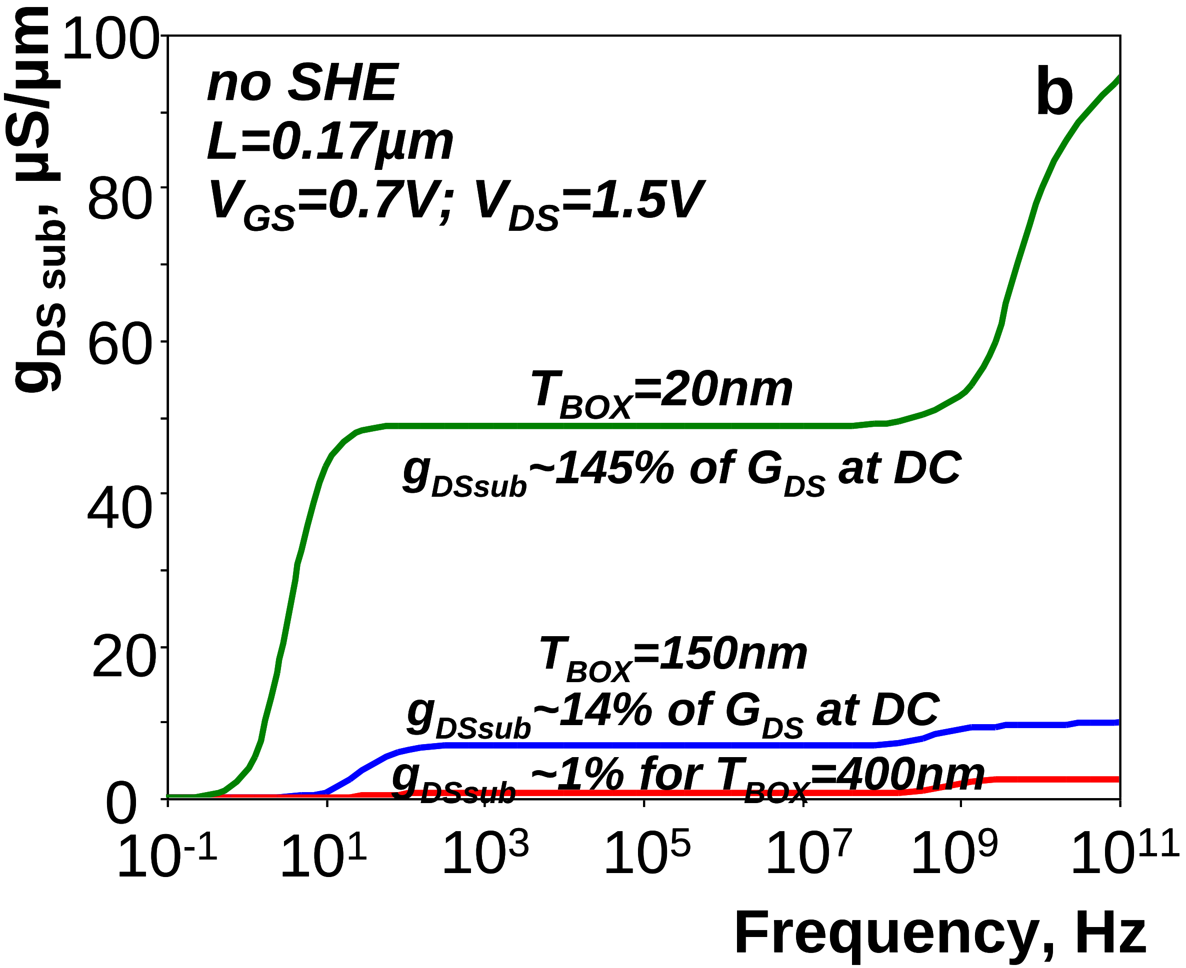
$$g_d(f) = g_{intr} + \Delta g_{FB}(f) + \Delta g_{d\_SH}(f) + \Delta g_{d\_SUB}(f)$$

CLM, DIBL

PDSOI only

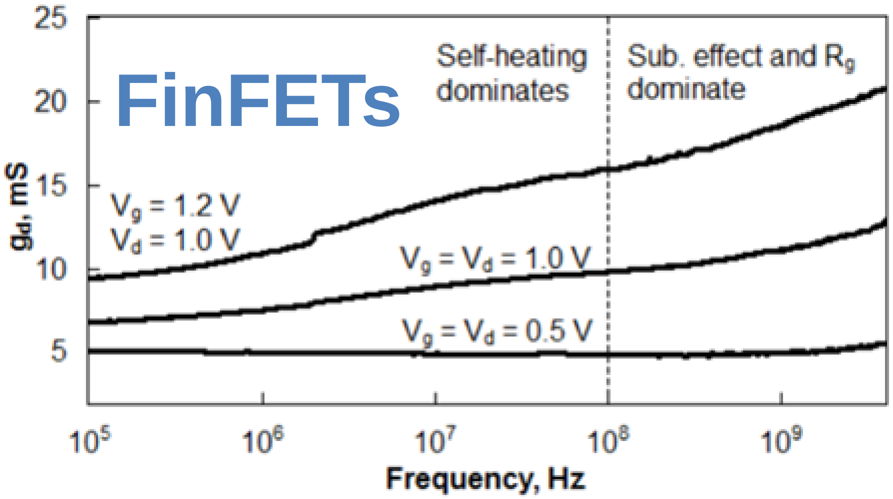


BOX Thinning

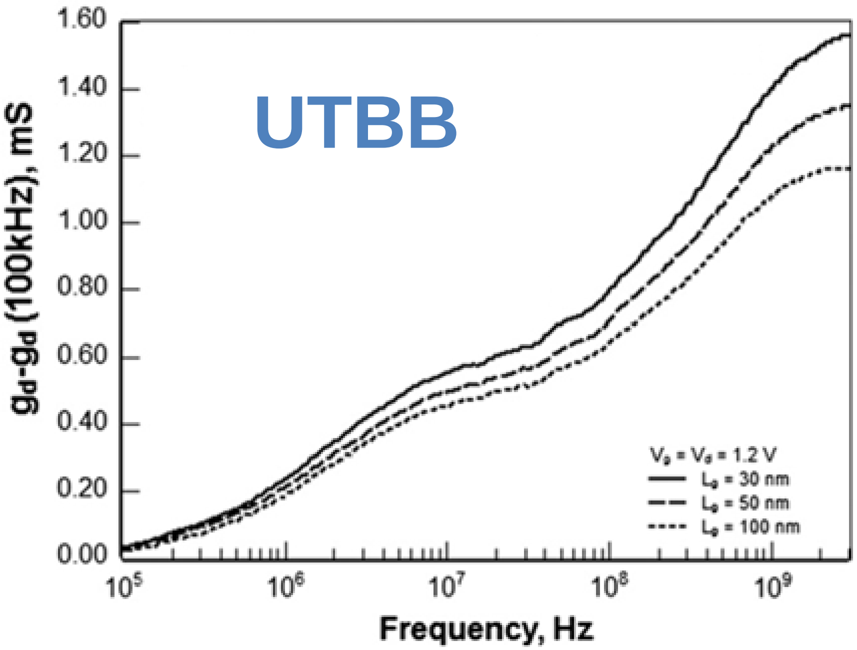


- BOX scaling results in strong increase of substrate-related effects
- BOX scaling with V_d scaling are expected to change the dominant effect in the frequency response

Experimental Confirmation



[Makovejev *et al.*, Intl. SOI conf. 2012]



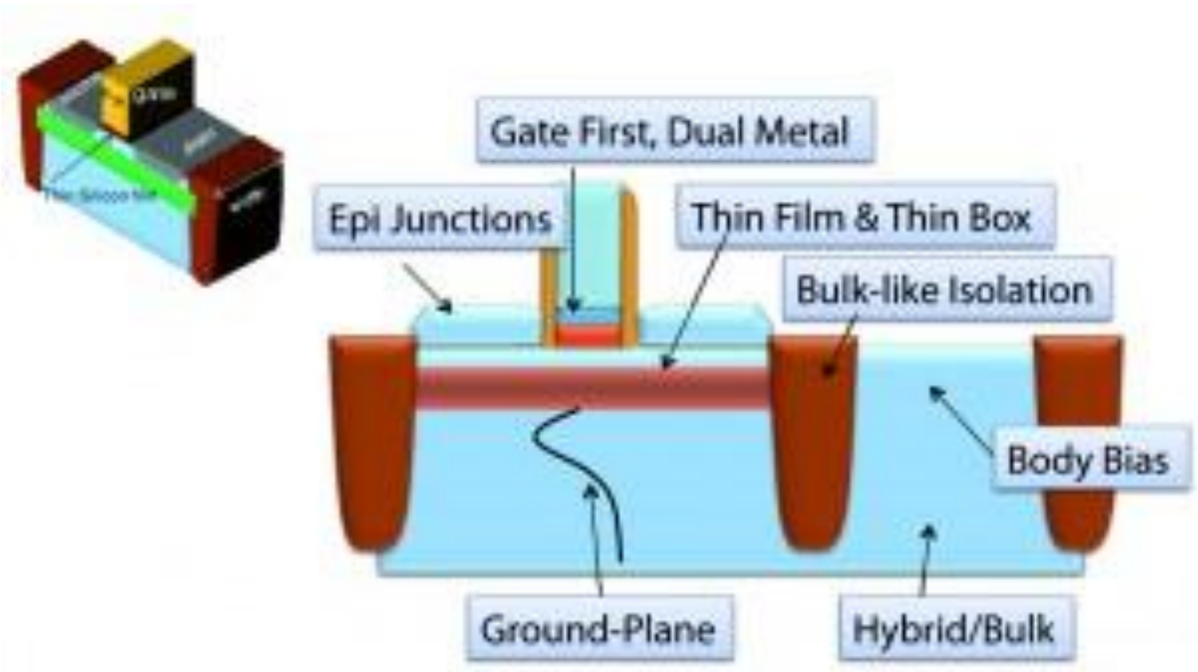
[Makovejev *et al.*, SSE 2012]

The substrate model is of interest particularly for UTBB technology

UTBB Substrate Complexity

Substrate realisation is rather complex in UTBB: GP, wells, p-n junctions

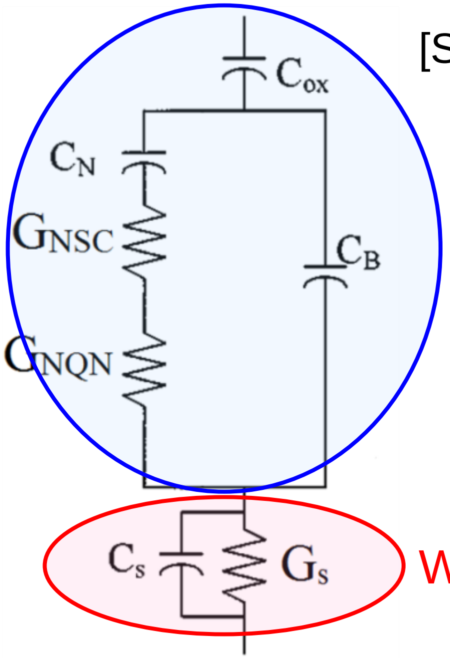
Substrate model becomes very complex



[ST-M]

Motivation and Aim

- Substrate model valid up to ~100 GHz has to be included in complete MOSFET model
- Reproduction of g_d and A_v frequency behaviour for analogue and RF



[Schroder *et al.*, TED 2000]

Was considered
(only up to few MHz)

Was neglected

Things changed:
- Thin BOX
- Highly doped GP
- Wells

Aim: describe the total substrate impedance

1st step: identify components to be included in the substrate model

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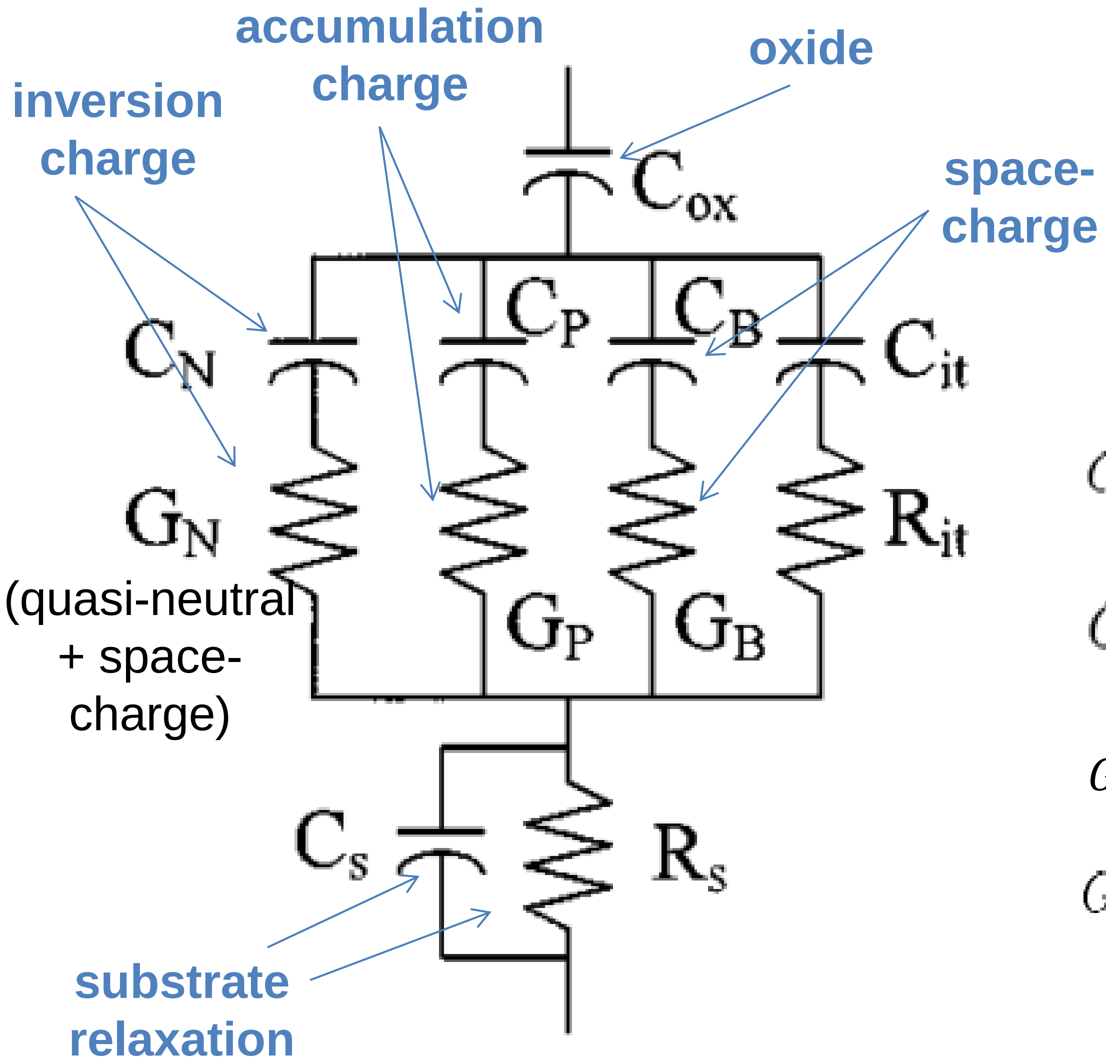
Equivalent Circuit and Fitting



accumulation charge

oxide

inversion charge

space-charge

(quasi-neutral + space-charge)

substrate relaxation

[Schroder *et al.*, TED 2000]

Fitting:

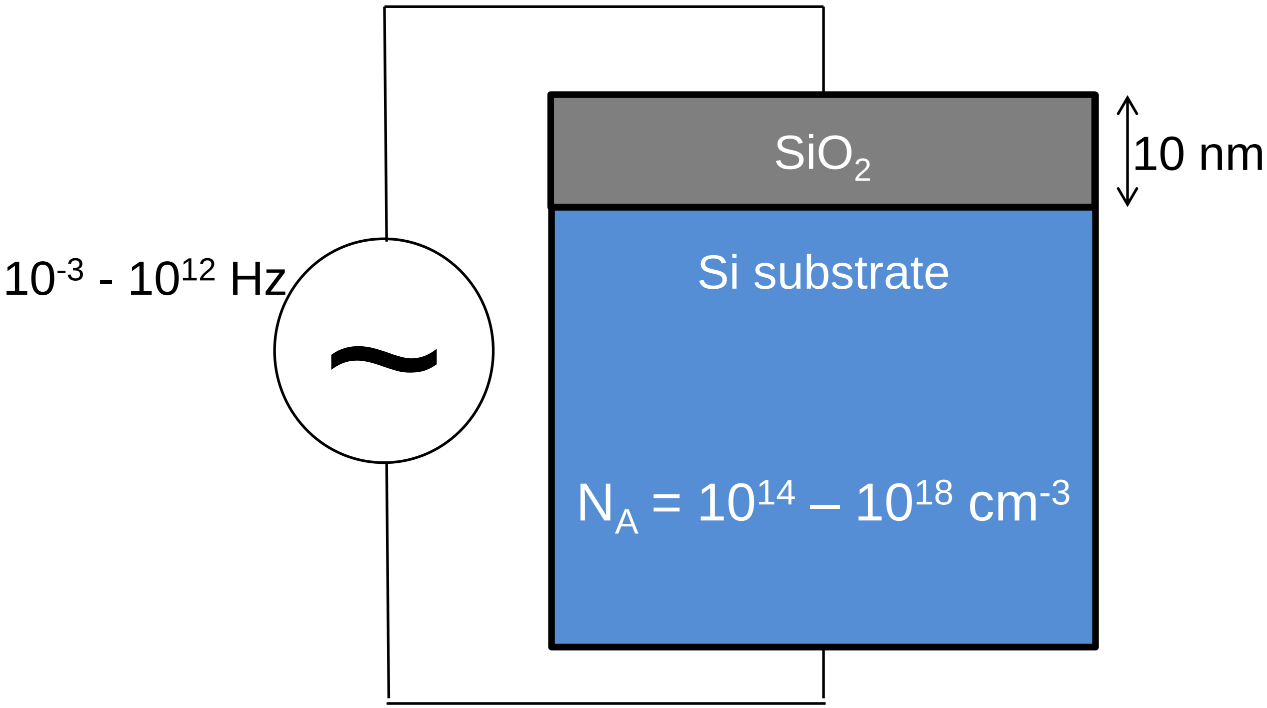
$$C_{ox} = \frac{K_{ox}\varepsilon_o A}{t_{ox}};$$

$$C_B = \frac{K_s\varepsilon_o A}{W};$$

$$G_s = \frac{Aq(\mu_n n + \mu_p p)}{t}$$

$$G_{N,\,\mathrm{scr}} + G_{N,\,\mathrm{qnr}} = \frac{2K_s\varepsilon_o A n_i}{\tau_g N_A W} + \frac{qA\mu_n n_i^2}{N_A L_n}$$

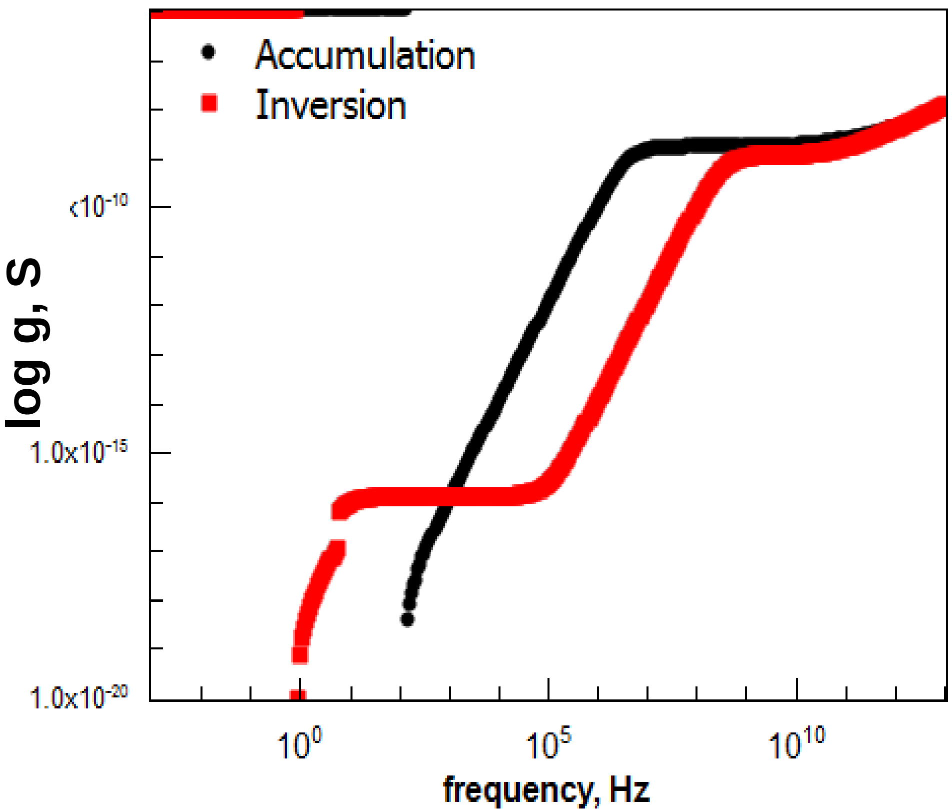
Atlas Simulations

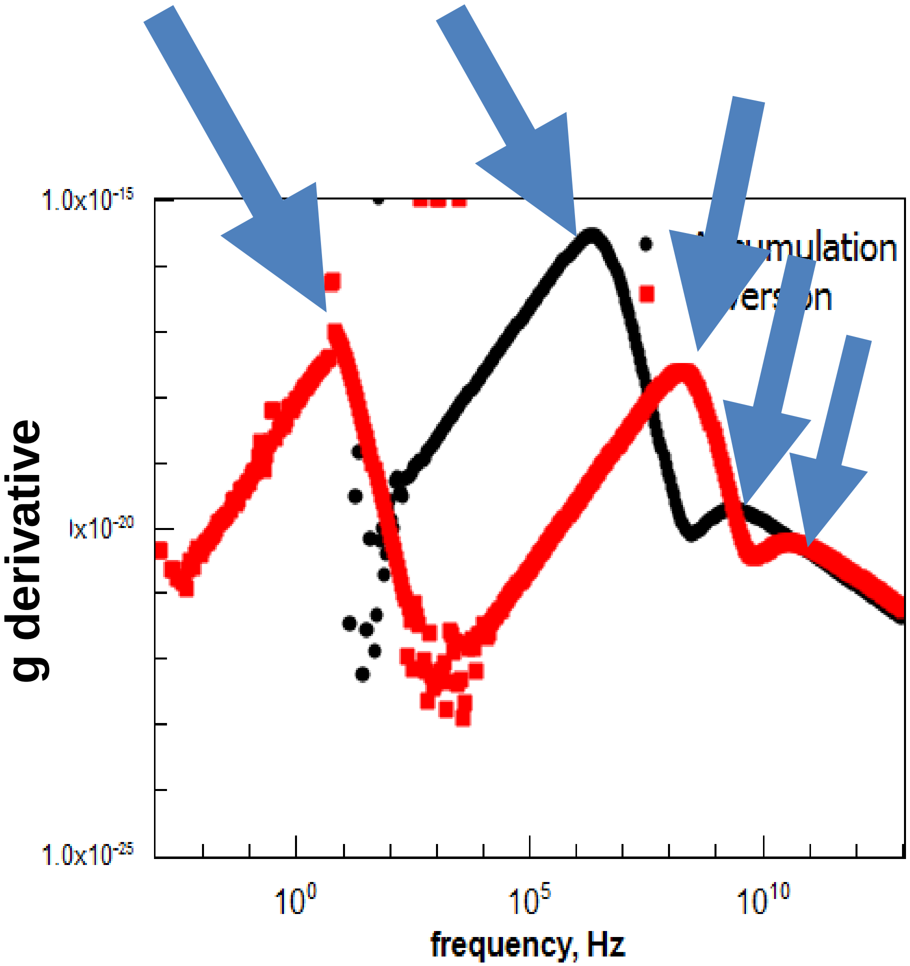


Temperature (300 - 675 K) and **doping** are varied in order to discriminate the mechanisms

Extraction

Characteristic frequencies were extracted from peaks of capacitance (or conductance) derivative





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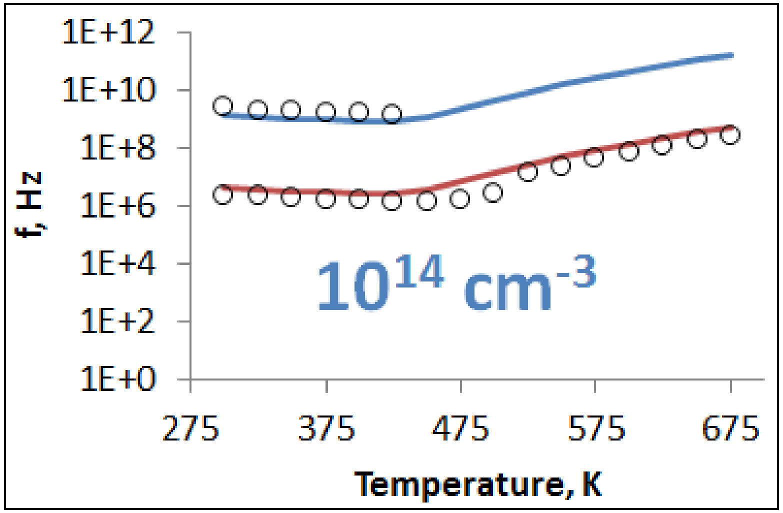
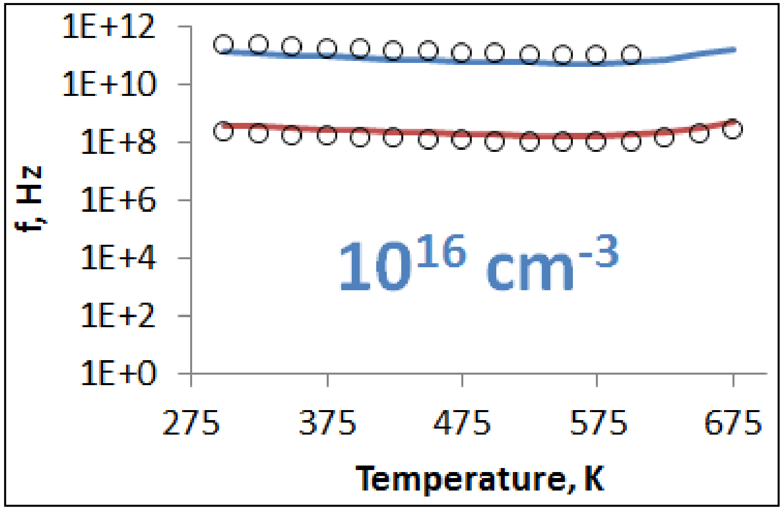
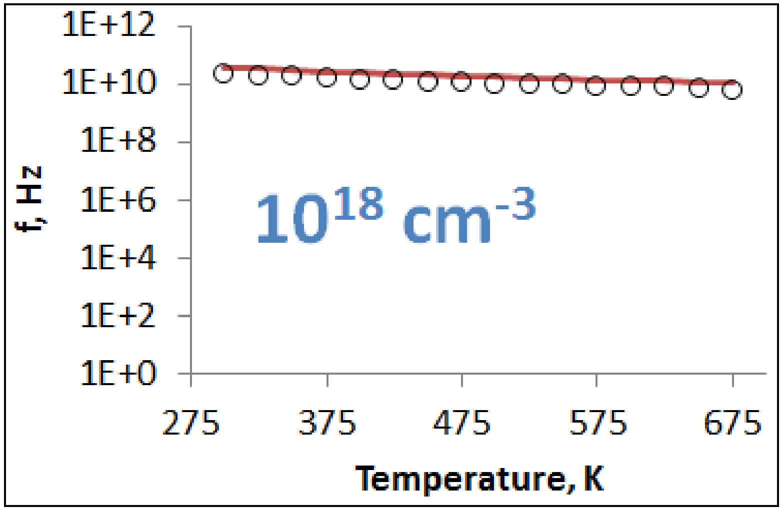
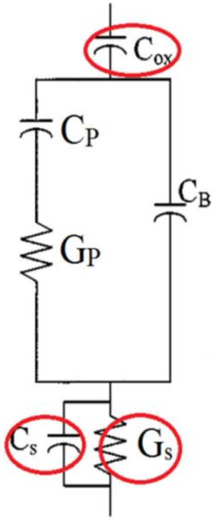
Simulations vs. Model - Accumulation





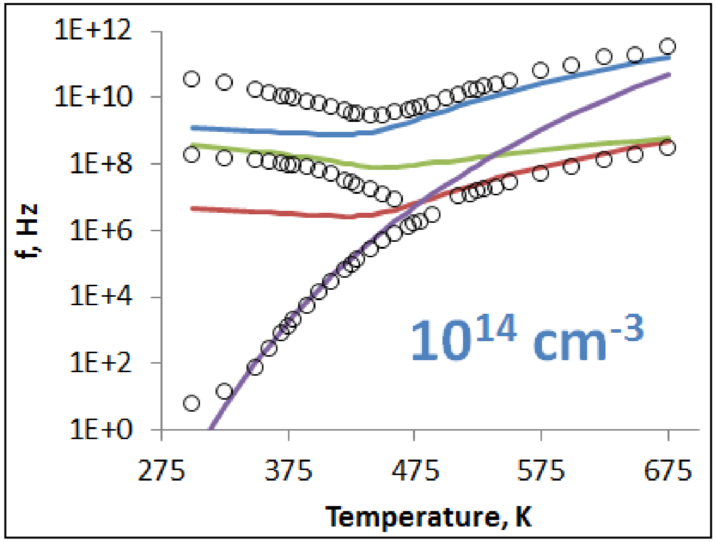


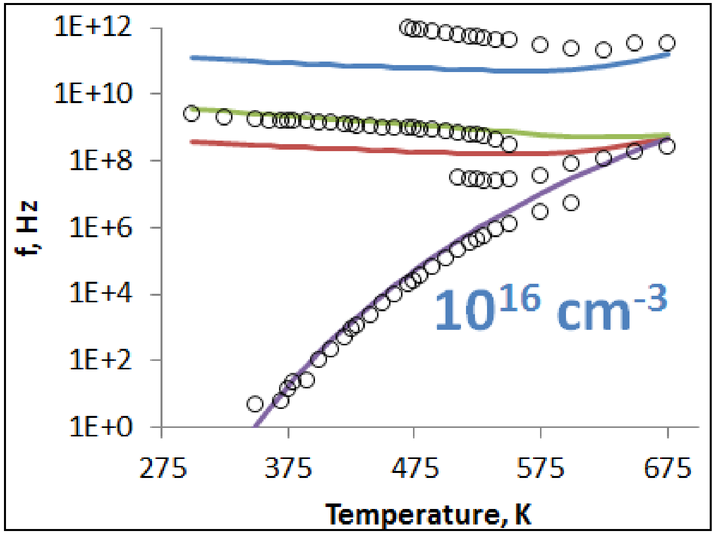


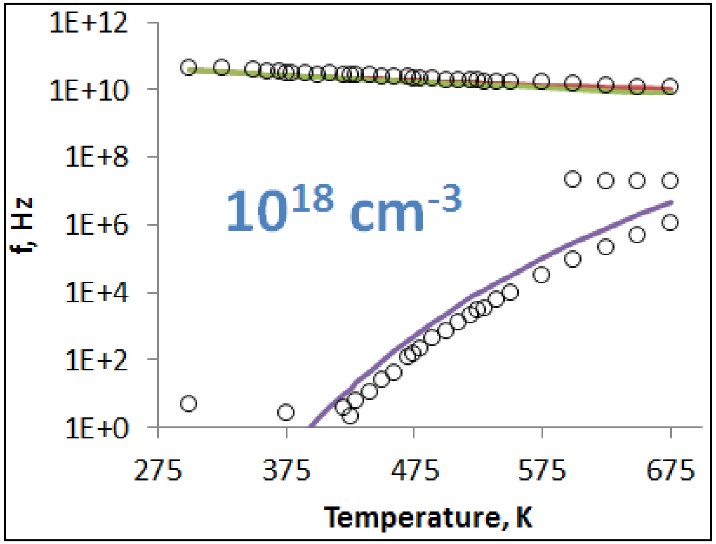
G_s/C_s and G_s/C_{ox} allow to reproduce simulated frequency behaviour up to 10^{12} Hz

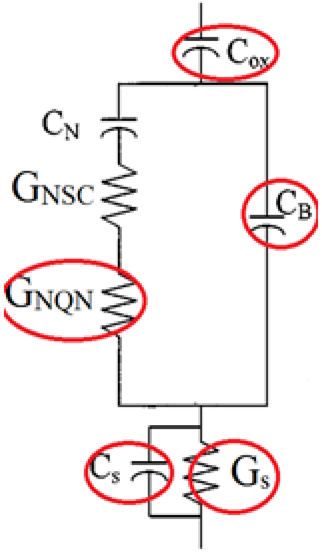
Symbols – simulated characteristic frequencies
Lines - fitting

Simulations vs. Model - Inversion









G_s/C_s, G_s/C_{ox}, G_s/C_b and G_{nqn}/C_{ox} allow to reproduce simulated frequency behaviour up to 10^{12} Hz

Symbols – simulated characteristic frequencies
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Summary and Future Work

- There is a need for a **substrate model** valid up to high frequencies in advanced FDSOI devices

- **Identified components** to be included:
  - In inversion G_s/C_s, G_s/C_{ox}, G_s/C_b and G_{nqn}/C_{ox}
  - In accumulation G_s/C_s and G_s/C_{ox}

- **Future work:**
  - Complex doping profile in substrate
  - MOSFET simulations
  - MOSFET model

The End