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Scattering mechanisms in shallow undoped Si/SiGe quantum wells

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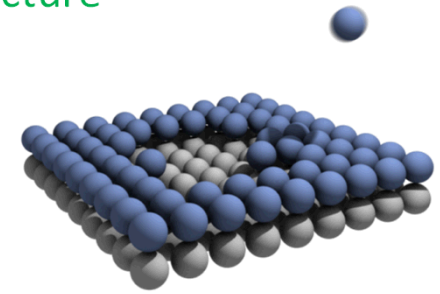
Motivation

Undoped structures :

- No additional disorder from dopants → increased mobility
- Large range of available density → requires an overall top-gate
- Potential to induce electrons and holes in a single structure

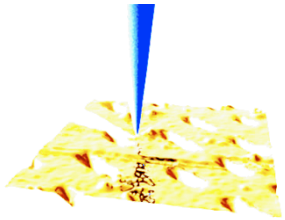


Shallow structures :

- 2DEG is closer from the surface
  - Increased nano-structure confinement
  - Increased disorder from surface states → decreased mobility

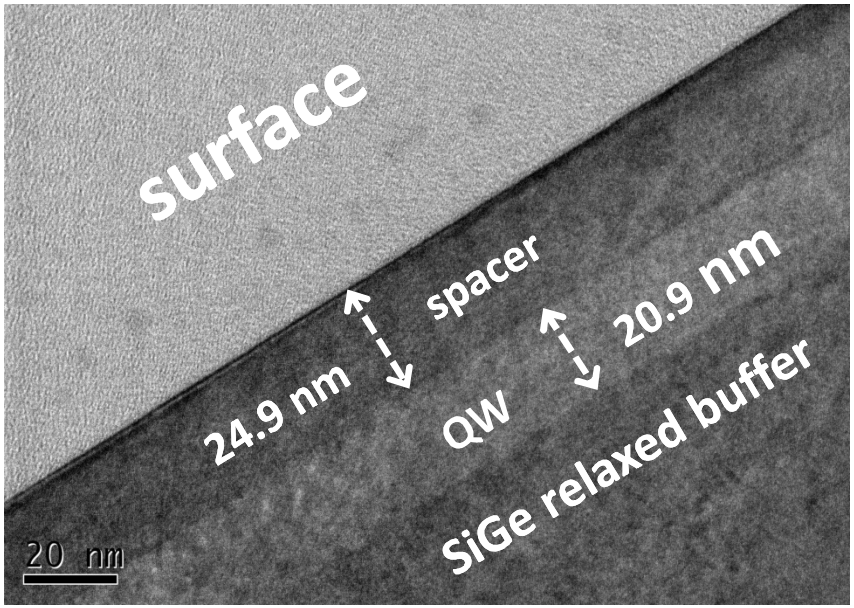
Future applications for Si/SiGe undoped shallow structures :

- Si-compatible nano-structures
- Artificial band-structure engineering
- STM/AFM induced disorder

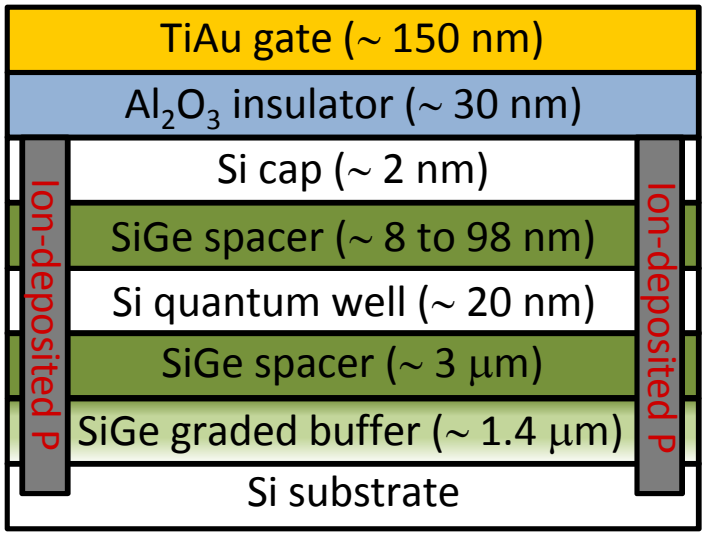


Device growth and fabrication

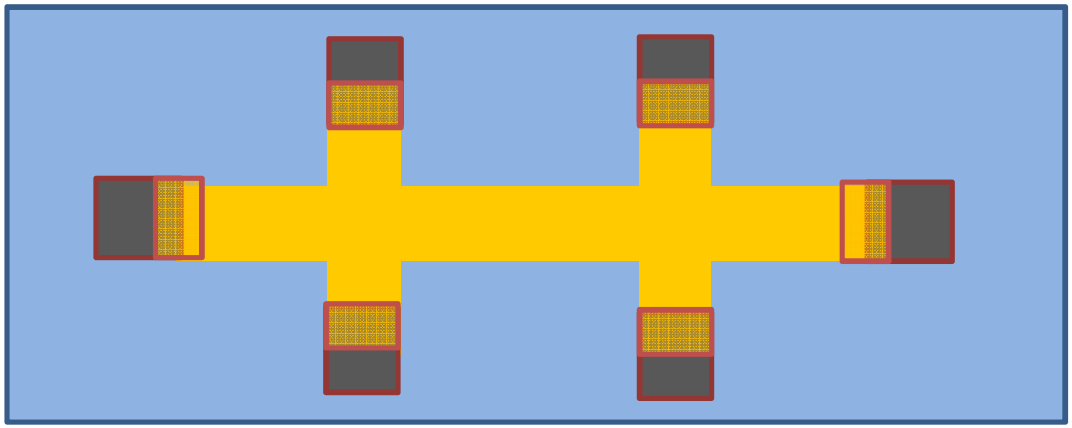
Side view : XTEM



Side view : Schematic



Top view : Schematic



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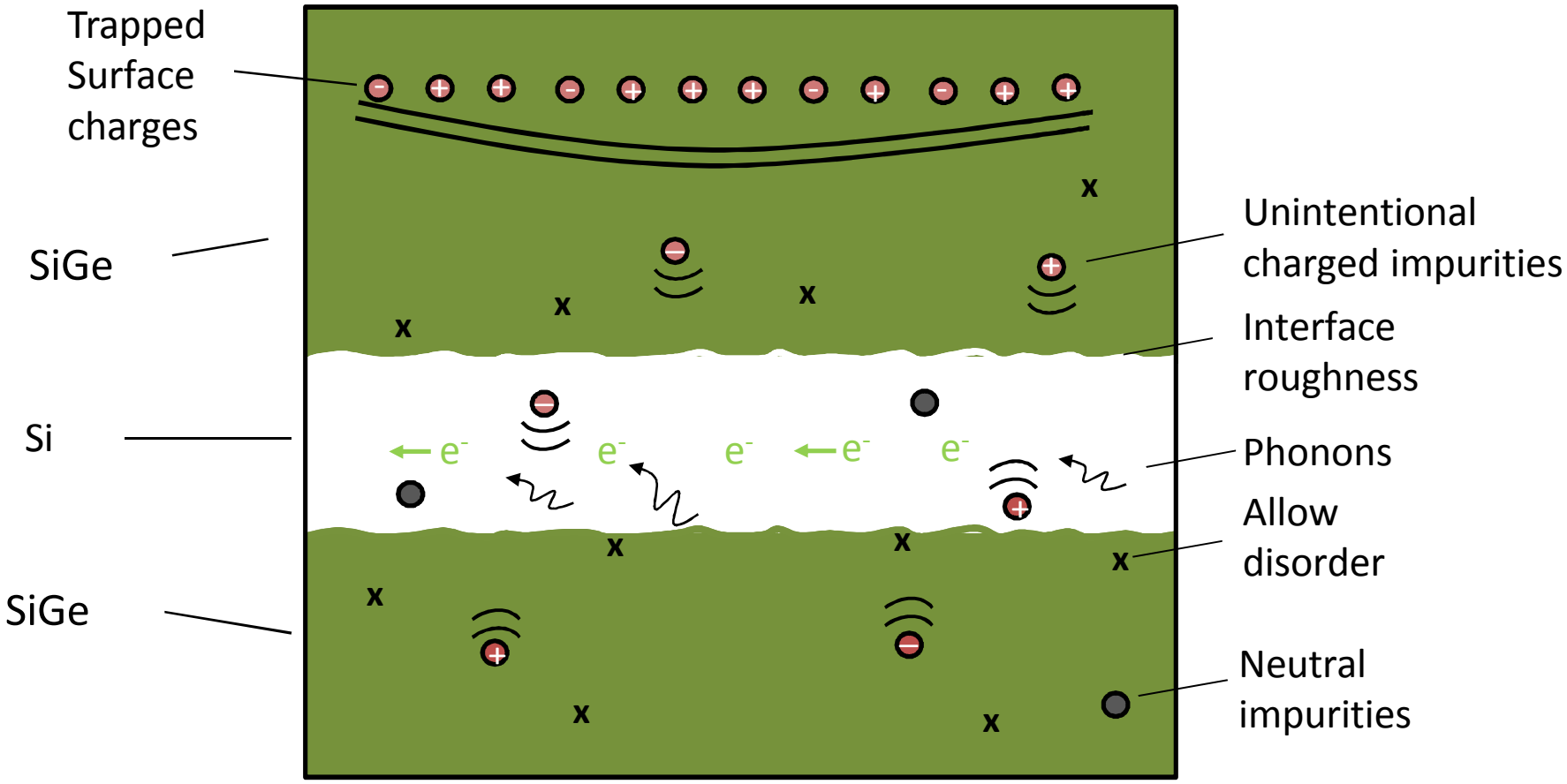
Disorder sources



?Add theoretical predictions?
?

Main disorder sources at low temperature

- Surface charges
- Unintentional charged imputities
- Interface roughness

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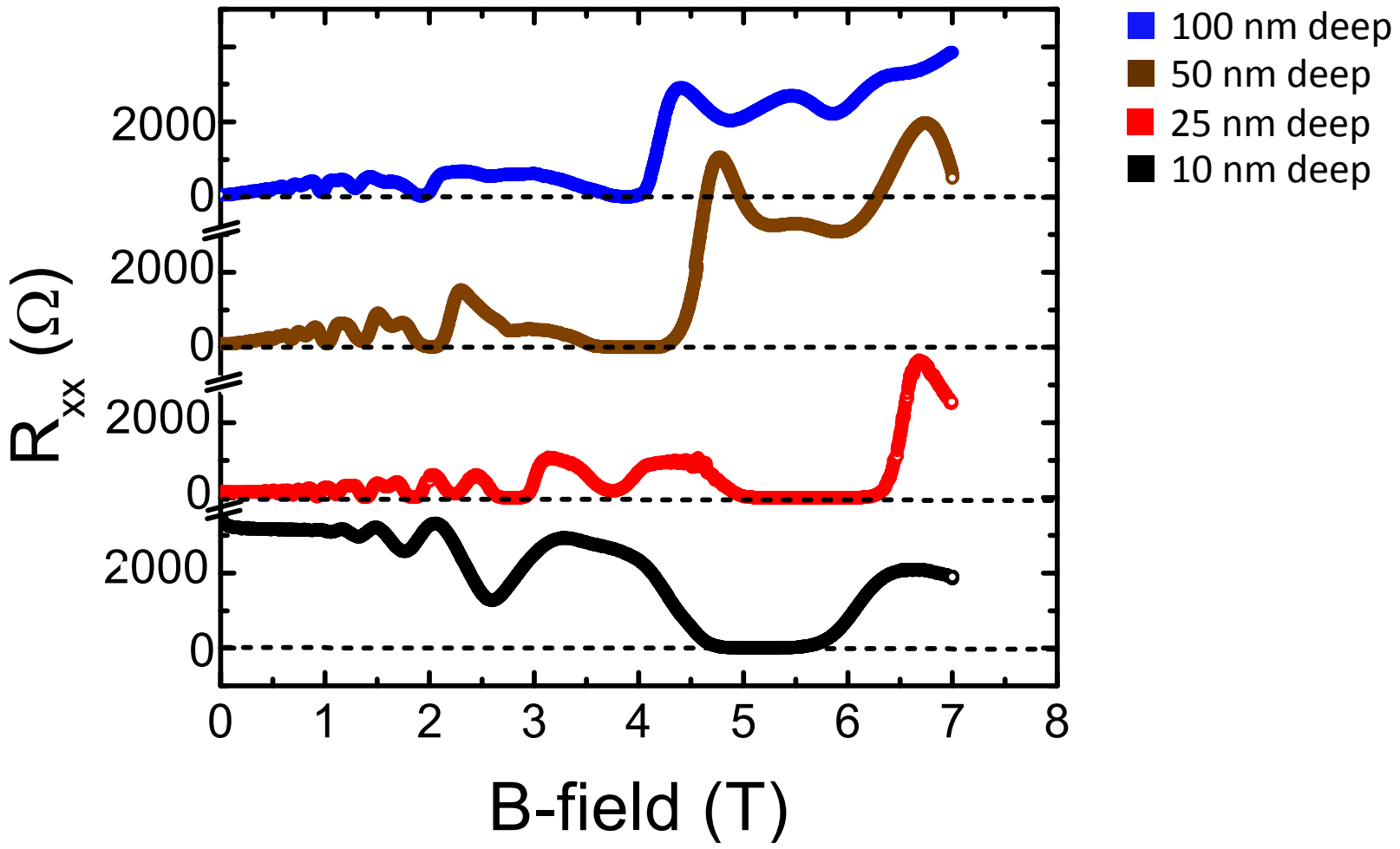
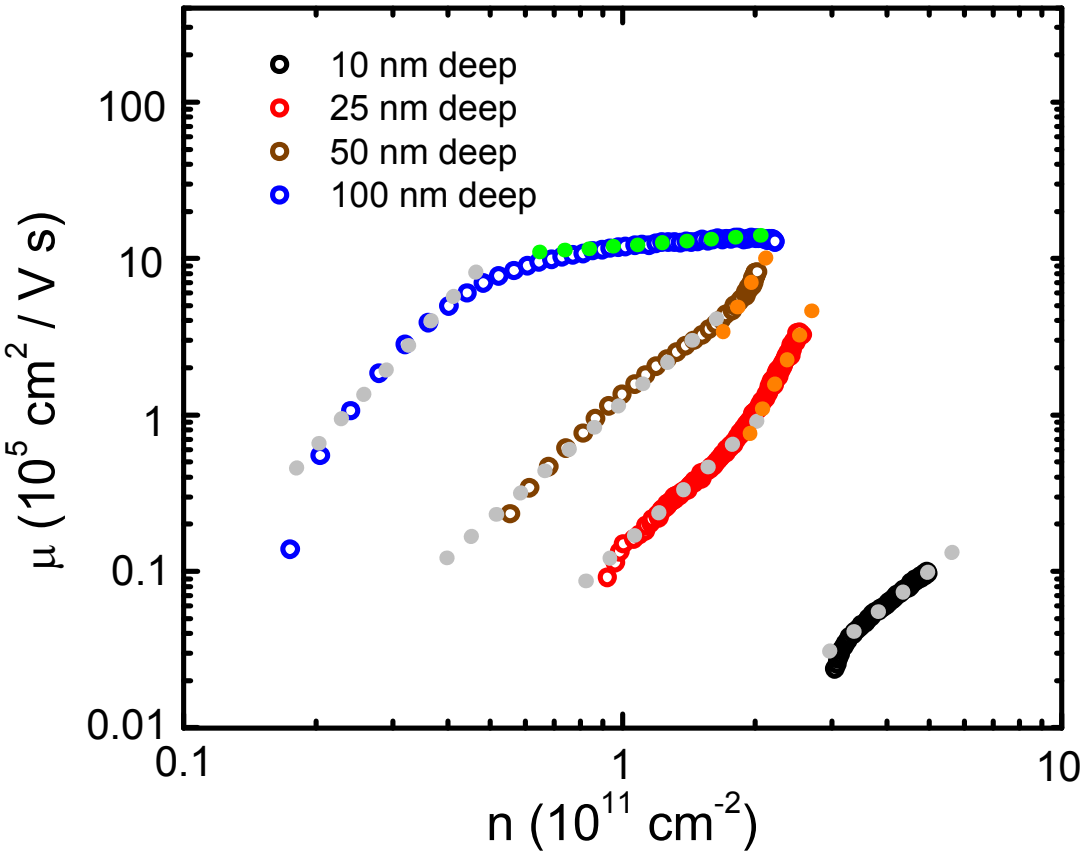
Initial R_{xx} characterization



Clean R_{xx} traces are observed for all 2DEGs depth

- Good sample quality

Density vs mobility



Mobility of ~ 3 x 10^5 cm^2 / V s is achived in 25 nm deep devices

- Intermediate density :
  $\mu \sim n^{\alpha}$; $\alpha \sim 2.5$
  - Remote charged impurities dominate scattering.
- High density, deep device :
  $\mu \sim n^{\alpha}$; $\alpha \sim 0$
  - Interface roughness is increasing
- High density, shallow devices :
  $\mu \sim n^{\alpha}$; $\alpha \sim 5$
  - Non-standard scattering mechanism.

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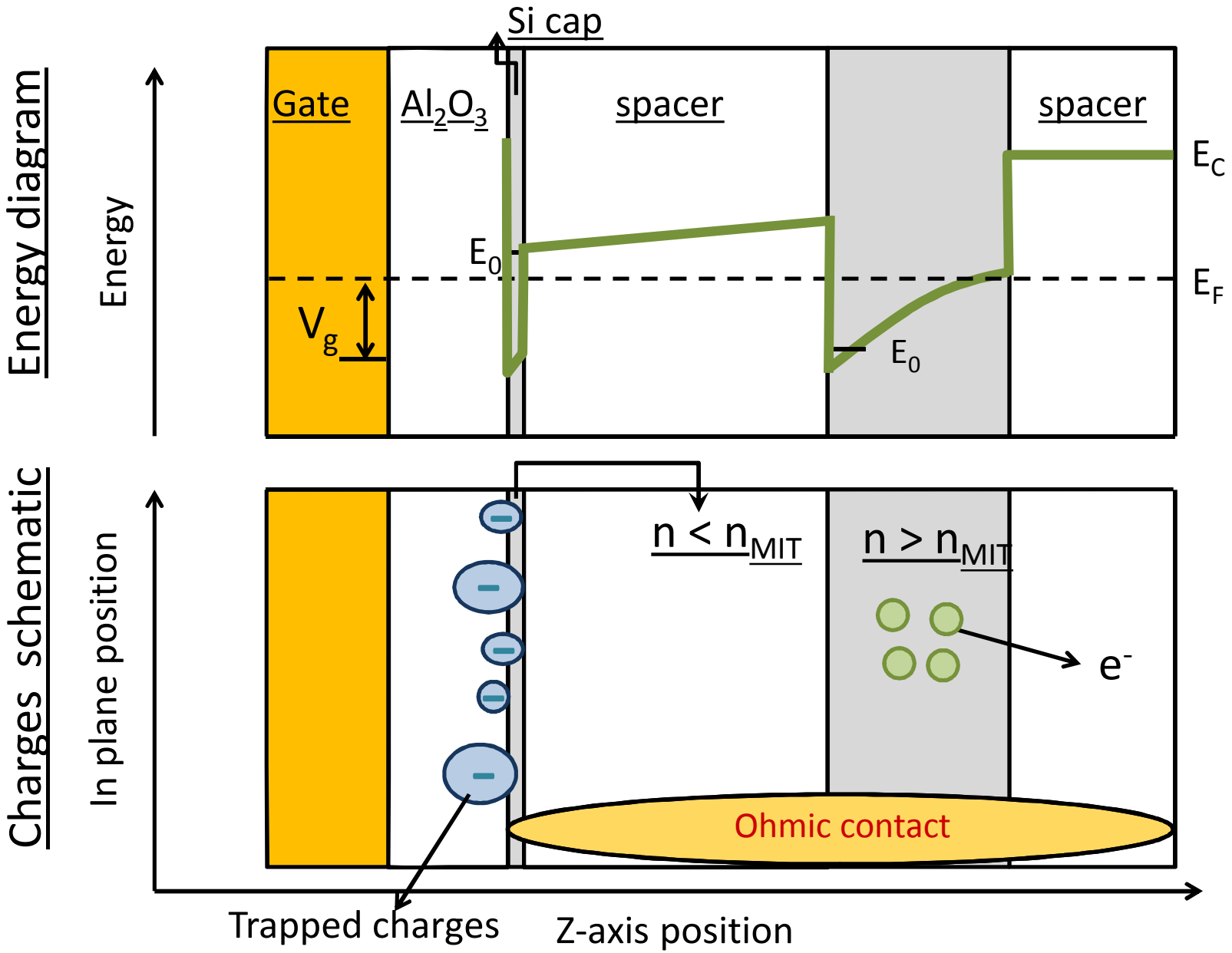
Non-equilibrium model



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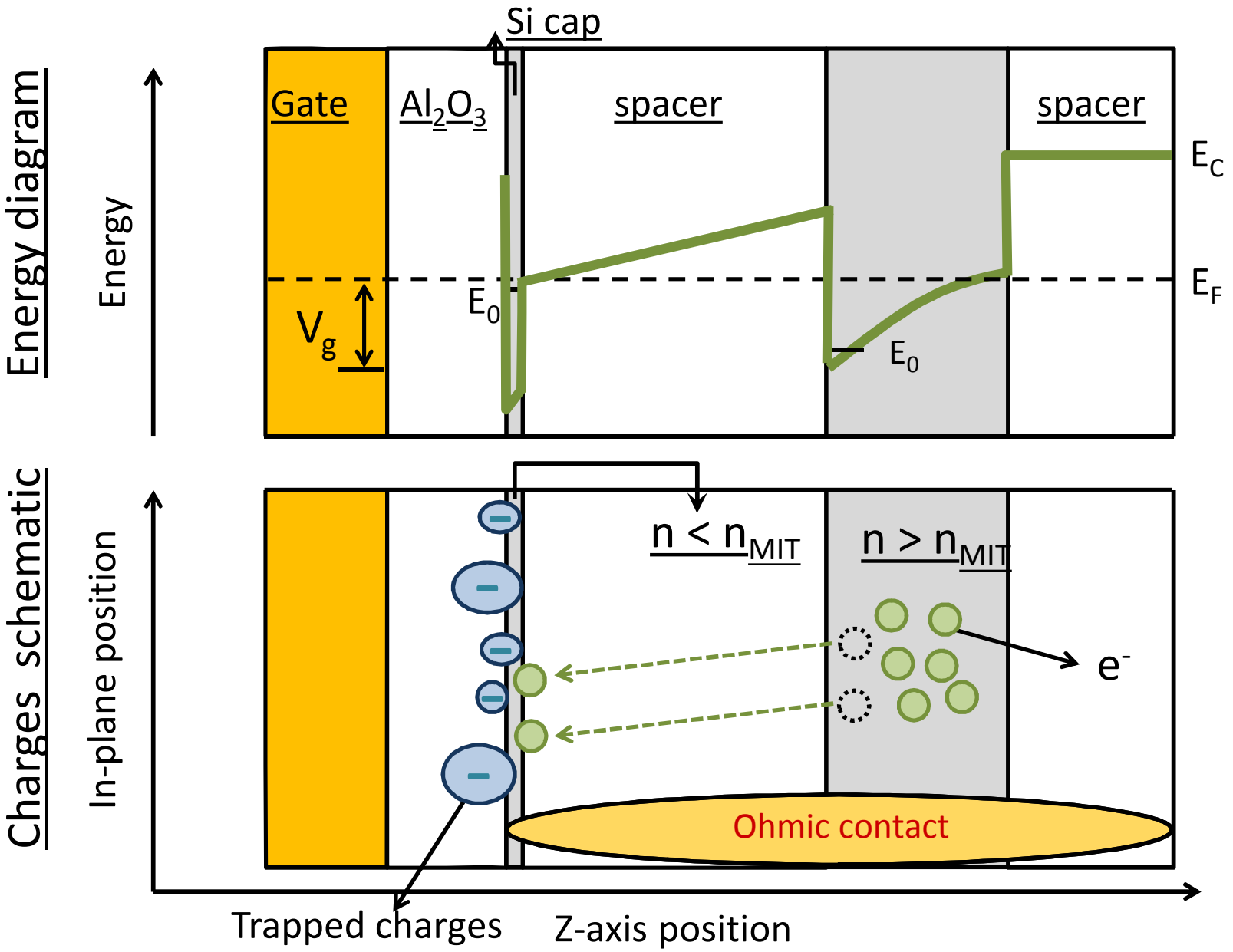
Non-equilibrium model



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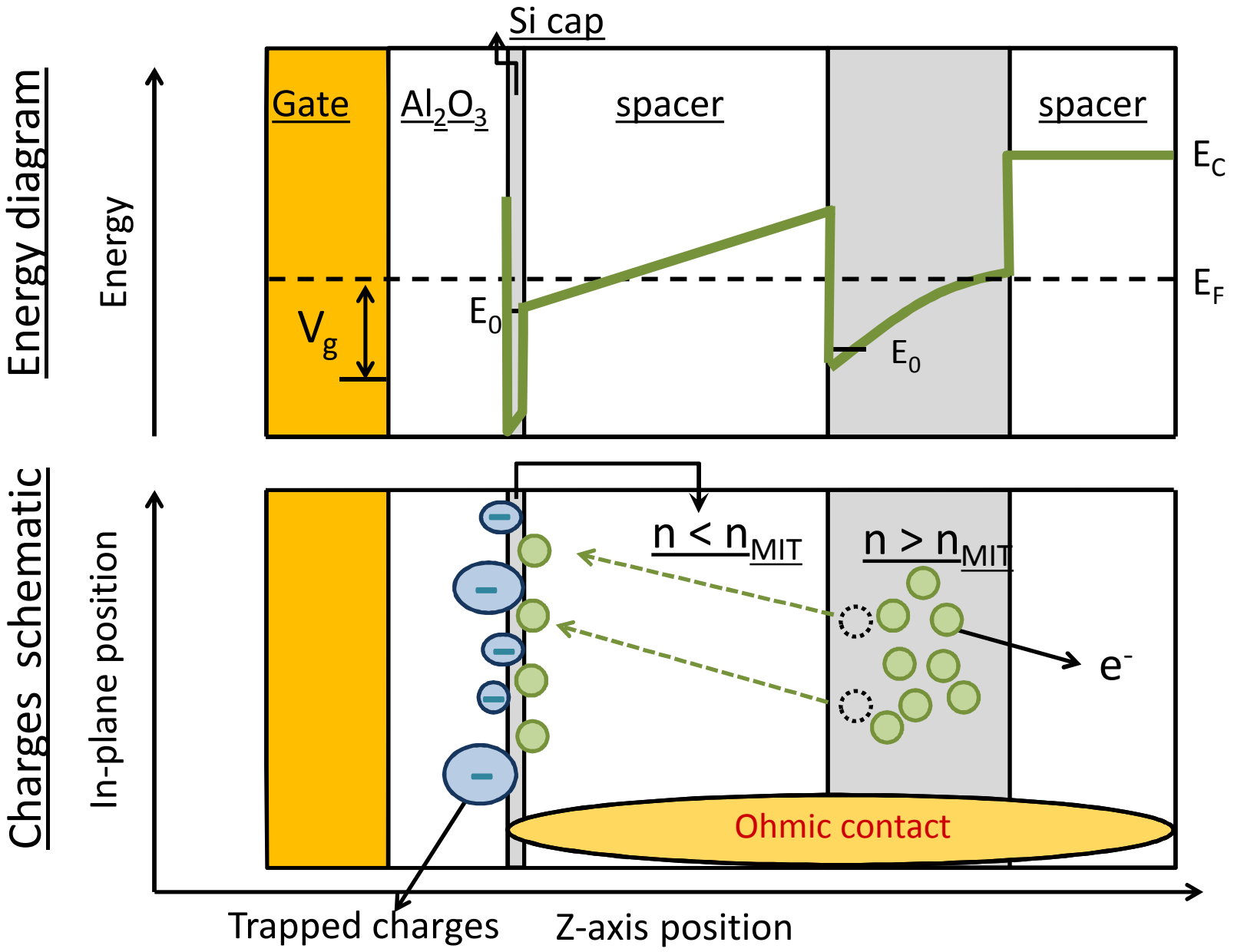
Non-equilibrium model



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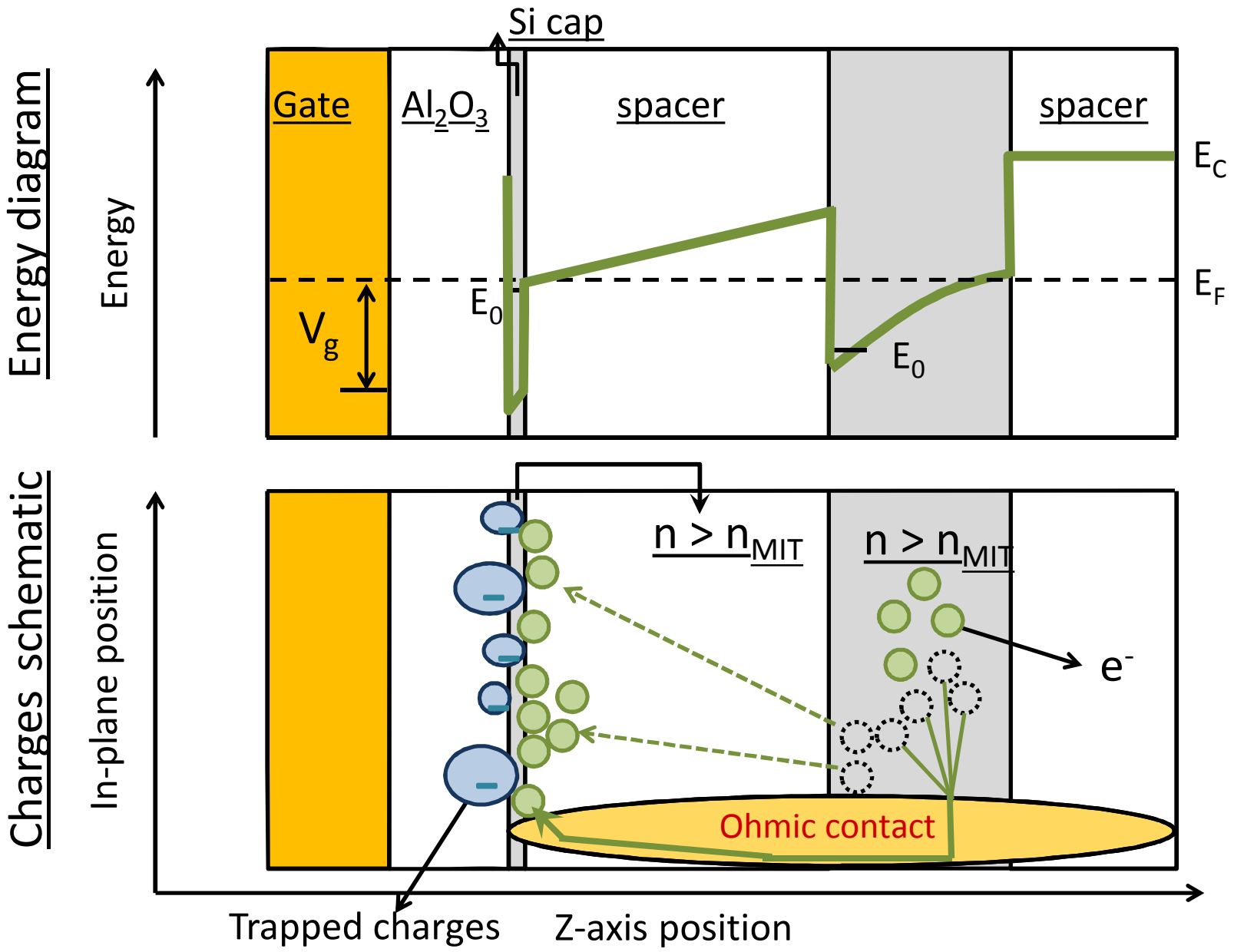
Non-equilibrium model



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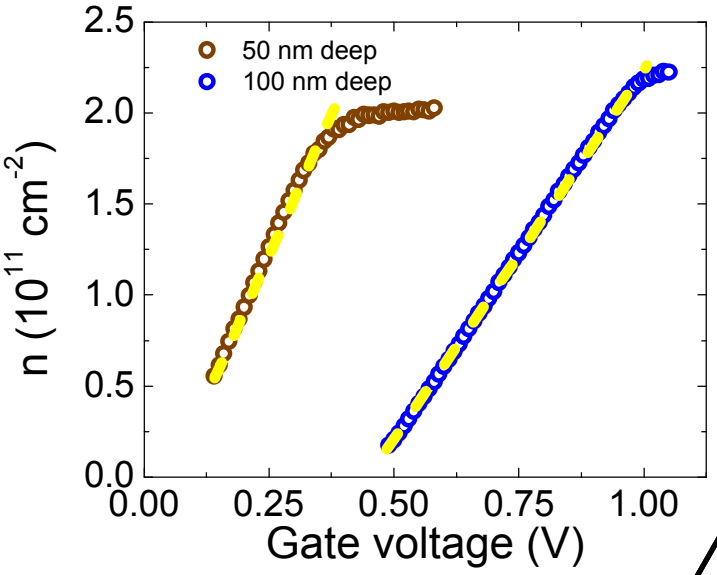
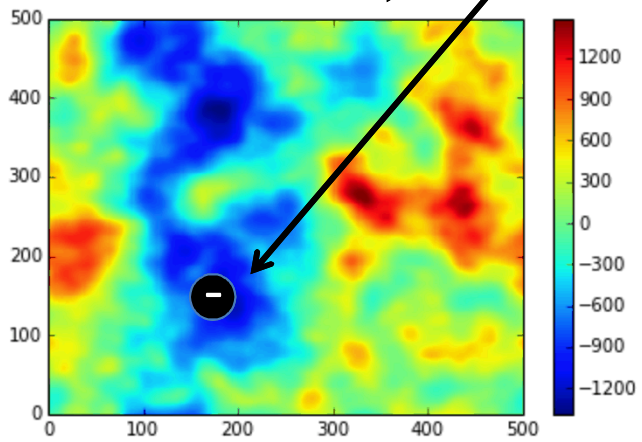
Simulation results

Measured density vs. extrapolated line
-> **screening density**





Method: for a given 2deg density,

1. Place random charges to form **disorder potential**.
2. Repeatedly place a single **screening charge** in *deepest* potential minima of previous disorder potential, until screening density is reached.
3. Compute mobility using screened potential using standard method (Ando).

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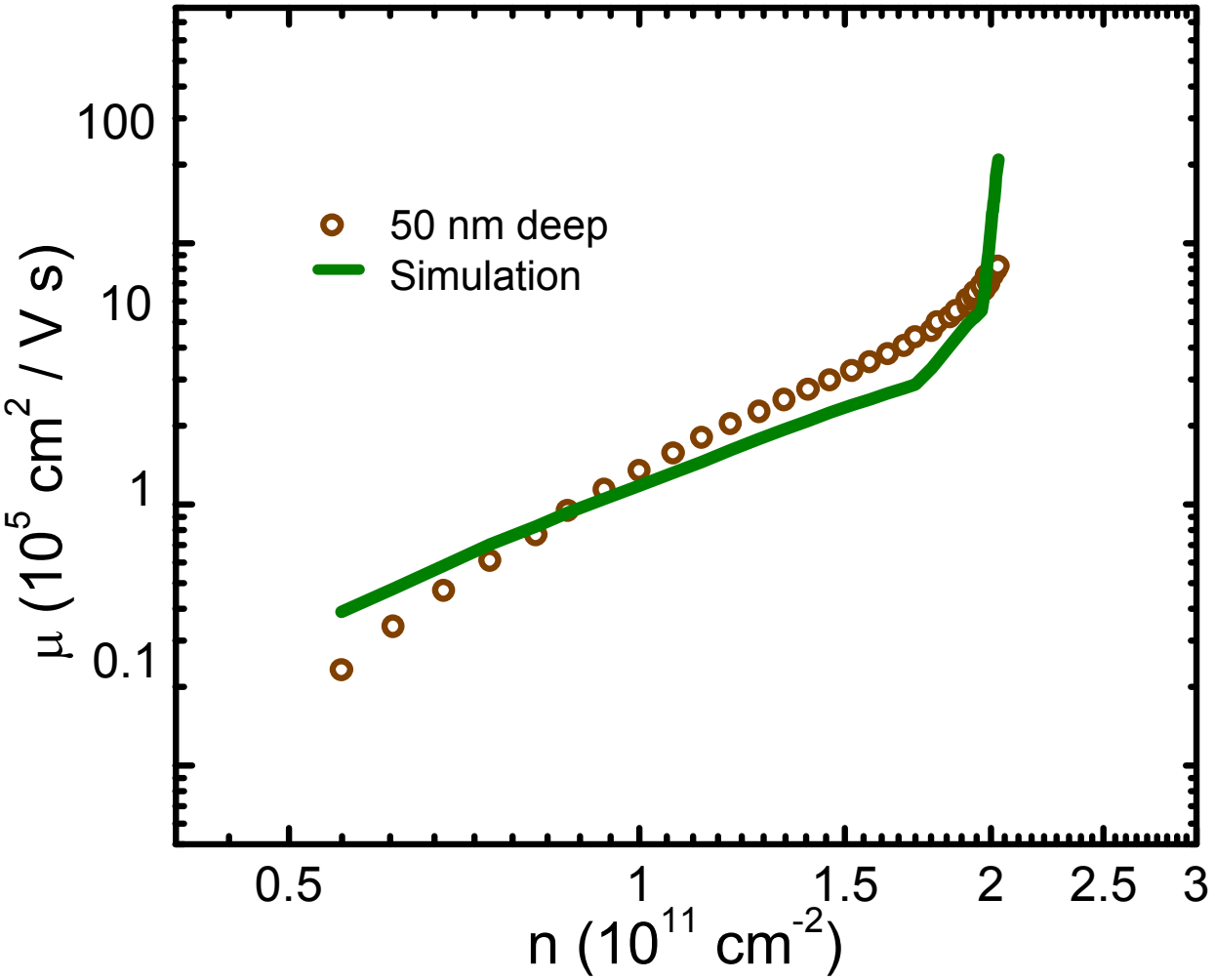
Comparison to experiment



Model qualitatively reproduces the data

Conclusion

Fabricated a series of increasingly shallow undope Si/SiGe 2DEGs :

- Devices only 10 nm deep were successfully fabricated and measured.
- Mobility in excess of 3 x 10^5 cm^2 / V s is achived in 25 nm deep devices.

Scattering mechanism analysis :

- Intermediate density regime
  - Mobility versus density dependence consistent with scattering from remote charged impurities trapped at the Si/Ge – insulator interface.
- High density regime
  - Non-equilibrium model required to explain the mobility versus density dependence.