Impact of interface traps on charge noise, mobility and percolation density in Ge/SiGe heterostructures

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(Dated: October 10, 2023)

Speaker: Artemii Efimov
20.10.2023

Motivation

Sweet-spot operation of a germanium hole spin qubit with highly anisotropic noise sensitivity

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(Dated: May 25, 2023)

Spin qubits defined by valence band hole states comprise an attractive candidate for quantum information processing due to their inherent coupling to electric fields enabling fast and scalable qubit control. In particular, heavy holes in germanium have shown great promise, with recent demonstrations of fast and high fidelity qubit operations. However, the mechanisms and anisotropies that underlie qubit driving and decoherence are still mostly unclear. Here, we report on the highly anisotropic heavy-hole g-tensor and its dependence on electric field, allowing us to relate both qubit driving and decoherence to an electric modulation of the g-tensor. We also confirm the predicted Ising-type hyperfine interaction but show that qubit coherence is ultimately limited by $1/f$ charge noise. Finally, we operate the qubit at low magnetic field and measure a dephasing time of $T_2^* = 9.2$ μs, while maintaining a single-qubit gate fidelity of 99.94 %, that remains well above 99 % at an operation temperature T>1 K. This understanding of qubit driving and decoherence mechanisms are key for the design and operation of scalable and highly coherent hole qubit arrays.

1/f charge noise!

Previous work

SETUP DESCRIPTION

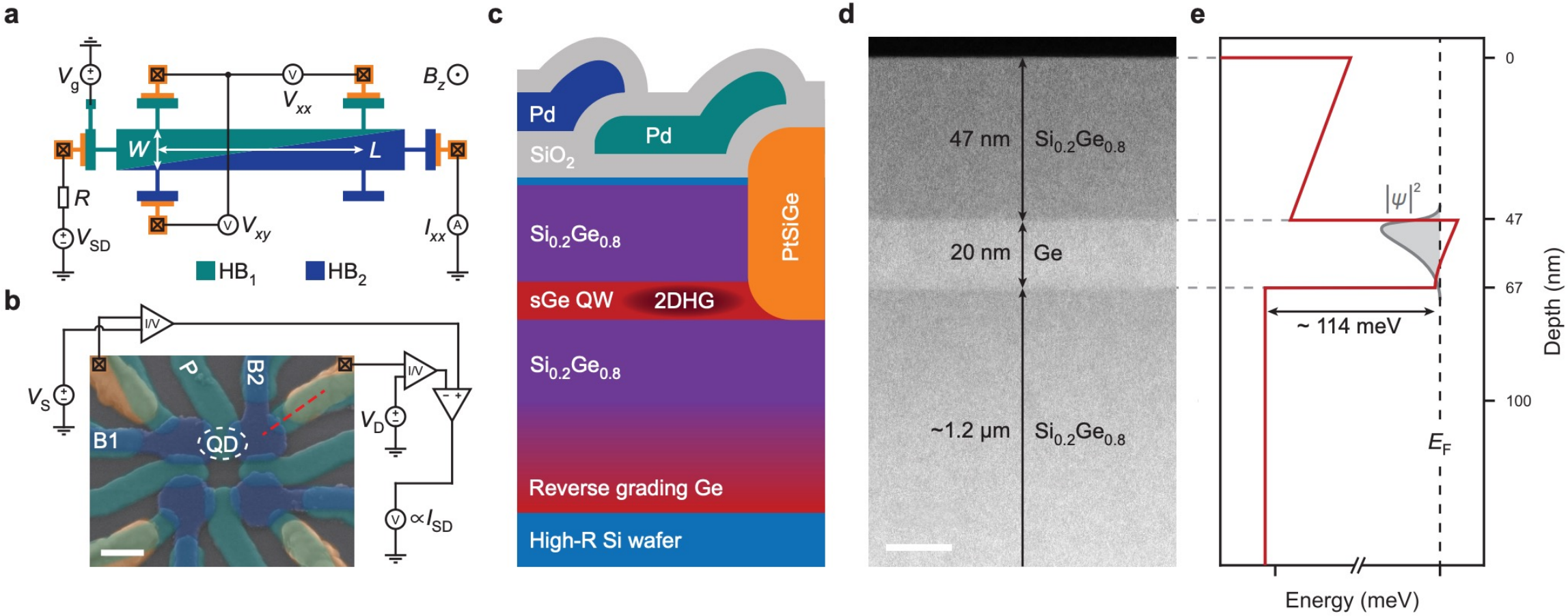
MEASUREMENTS PROTOCOL AND HALL BAR

METRICS TO THINK ABOUT

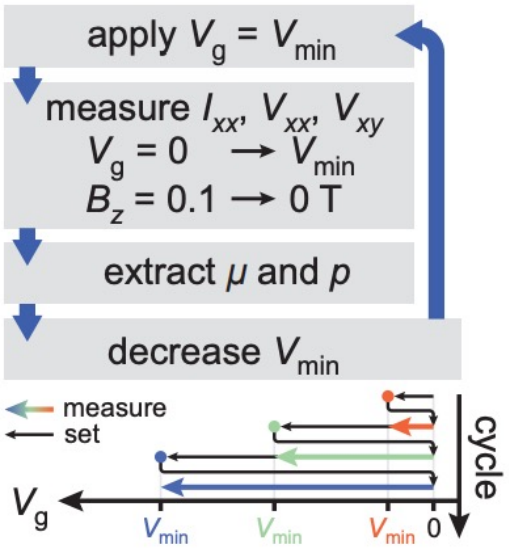
ANALYSIS

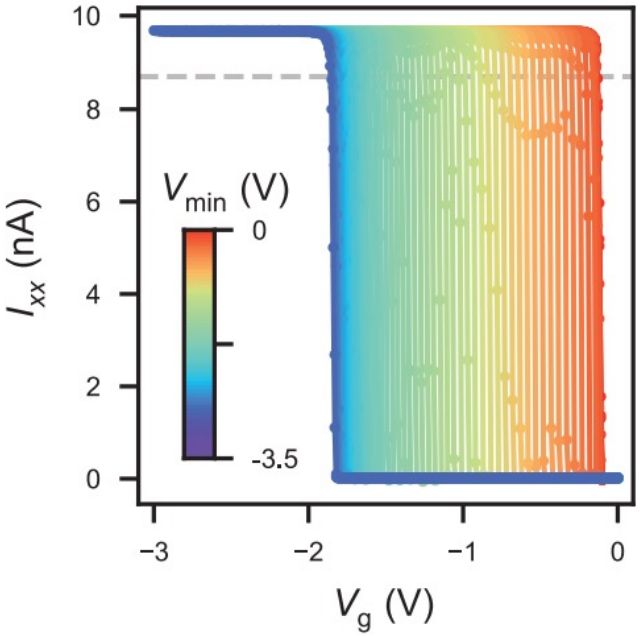
QD MEASUREMENTS, CHARGE NOISE

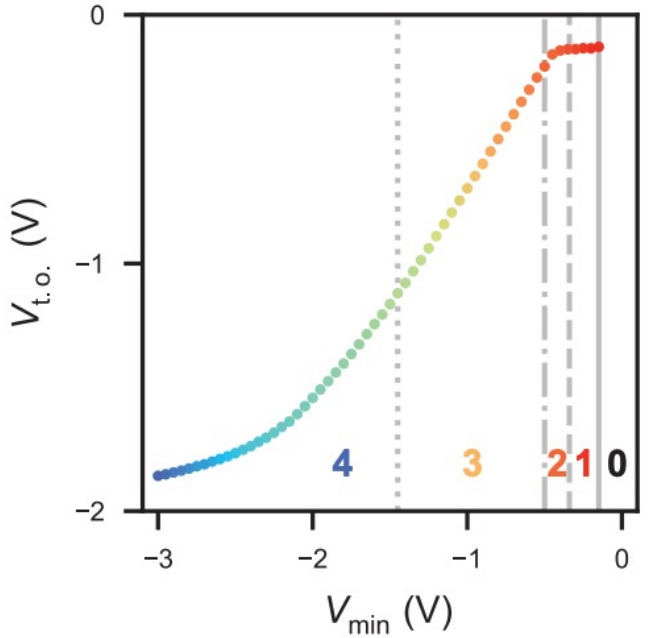
SETUP DESCRIPTION



MEASUREMENTS PROTOCOL AND HALL BAR

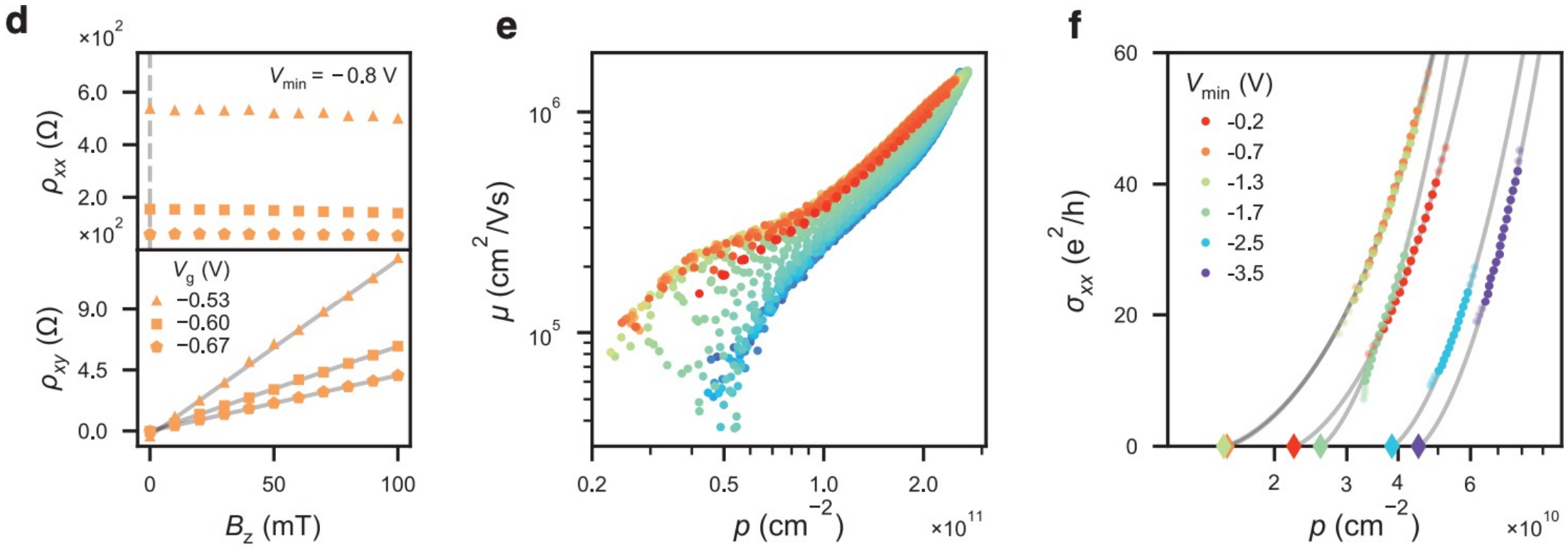






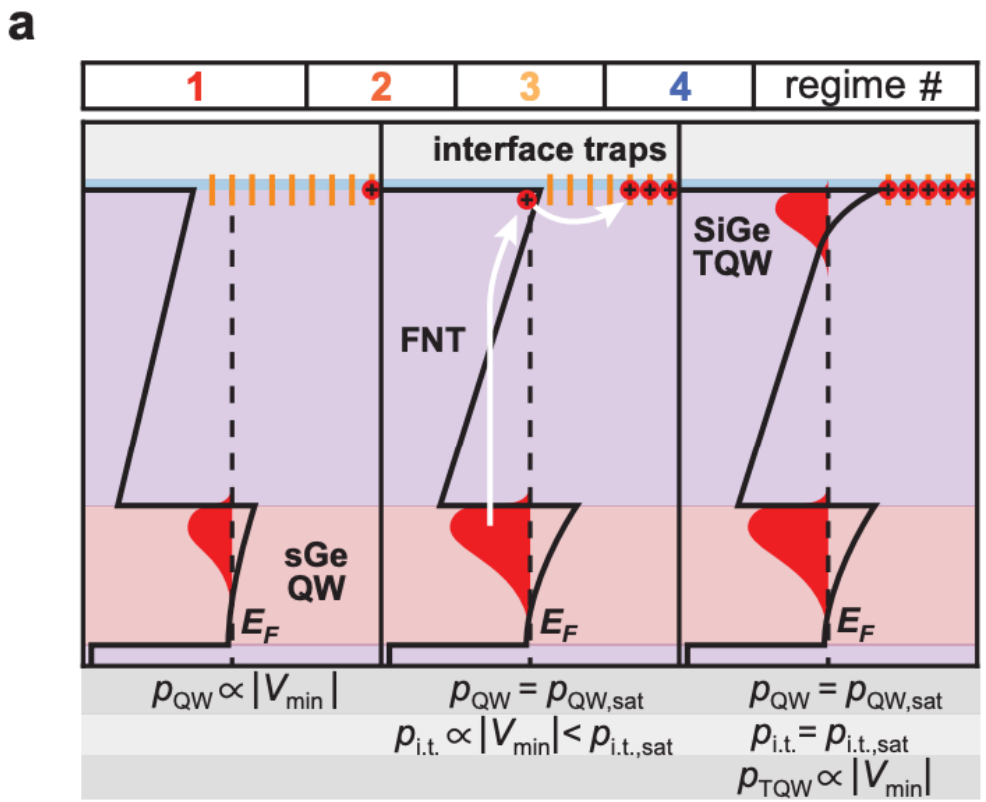
0. **Depleted regime**
1. **Non-hysteretic regime**
2. **Screening regime, onset of hysteresis**
3. **Linear hysteretic regime**
4. **Saturated regime**

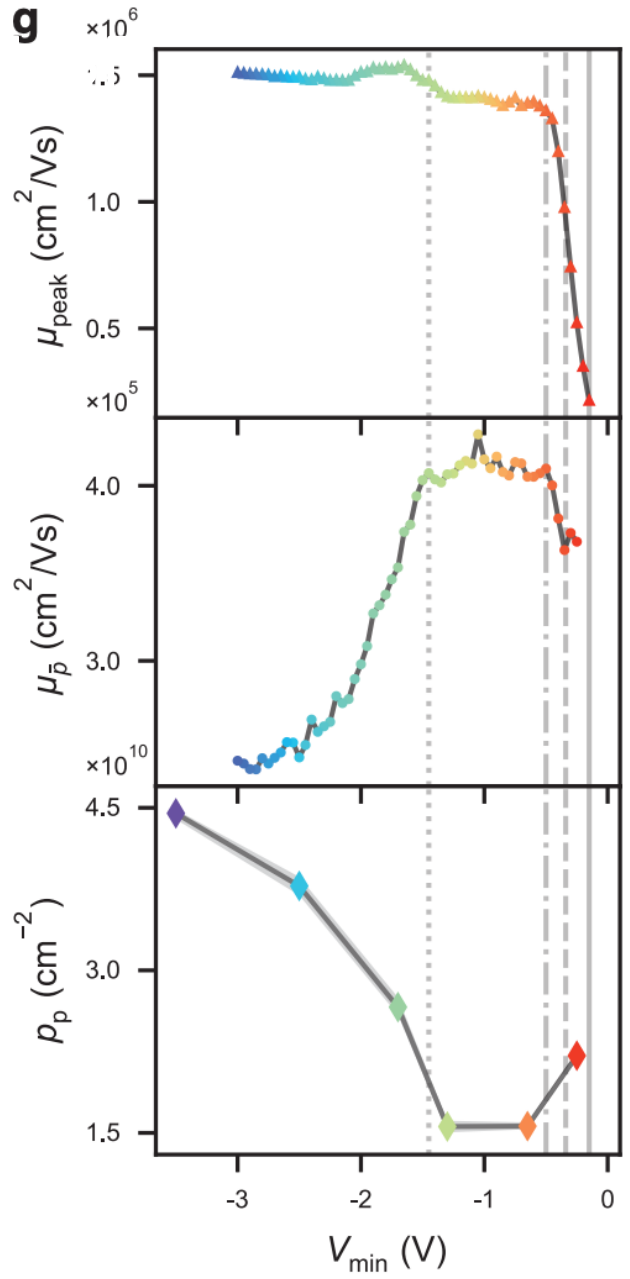
MEASUREMENTS PROTOCOL AND HALL BAR



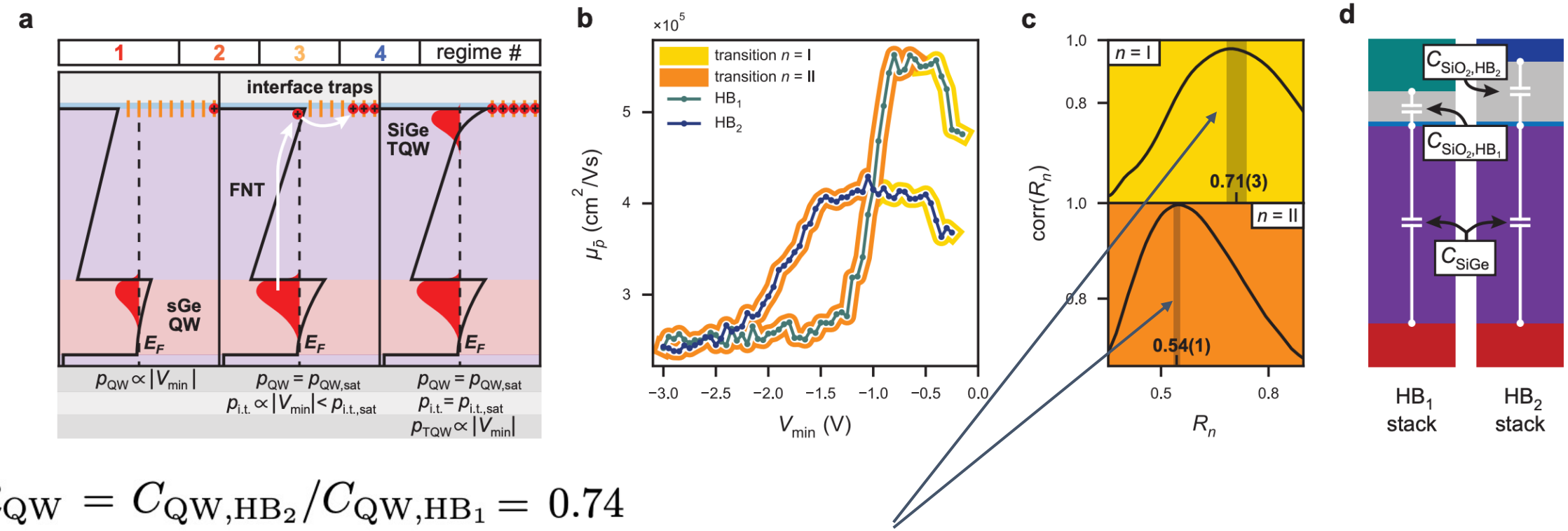
$$\sigma_{xx} \propto (p - p_p)^{1.31}$$

ANALYSIS


a
1
2
3
4
regime #
interface traps
SiGe
TQW
FNT
sGe
QW
E_F
E_F
E_F
$p_{QW} \propto |V_{min}|$
$p_{QW} = p_{QW,sat}$
$p_{i.t.} \propto |V_{min}| < p_{i.t.,sat}$
$p_{QW} = p_{QW,sat}$
$p_{i.t.} = p_{i.t.,sat}$
$p_{TQW} \propto |V_{min}|$


g
$\times 10^6$
1.0
0.5
μ_{peak} (cm^2/Vs)
$\times 10^5$
4.0
3.0
μ_p (cm^2/Vs)
$\times 10^{10}$
4.5
3.0
1.5
p_p (cm^{-2})
-3
-2
-1
0
V_{min} (V)

ANALYSIS



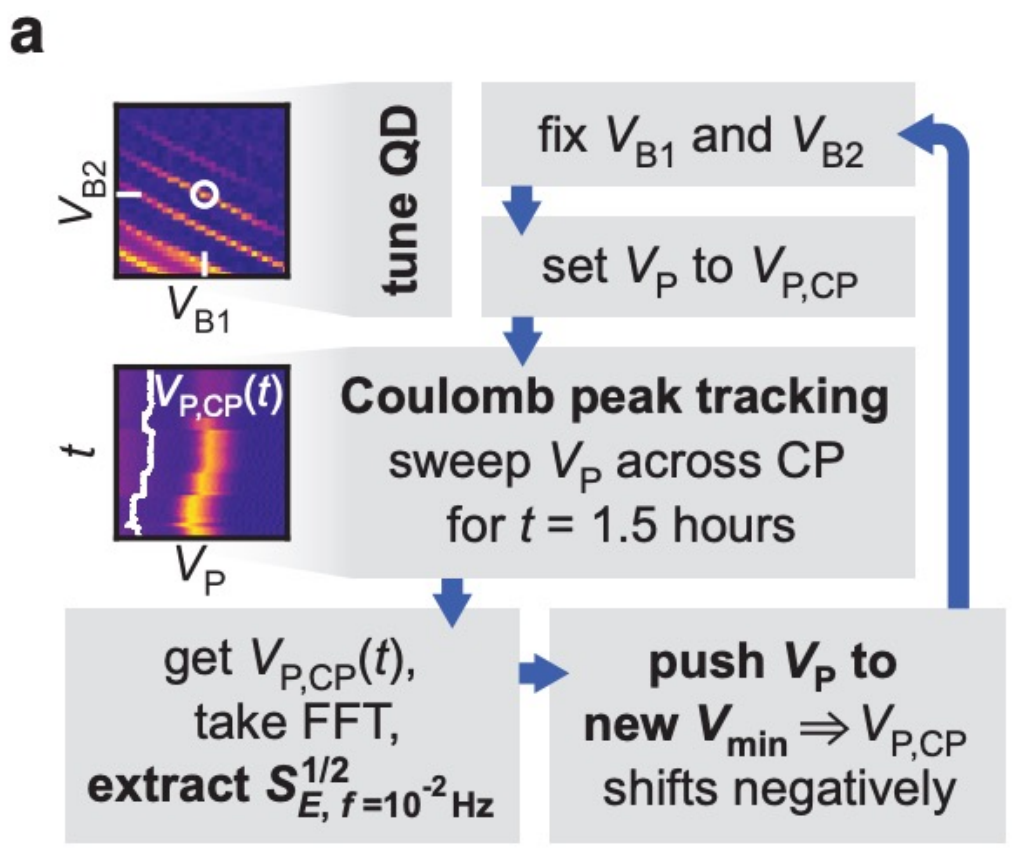
$$R_{QW} = C_{QW,HB_2}/C_{QW,HB_1} = 0.74$$

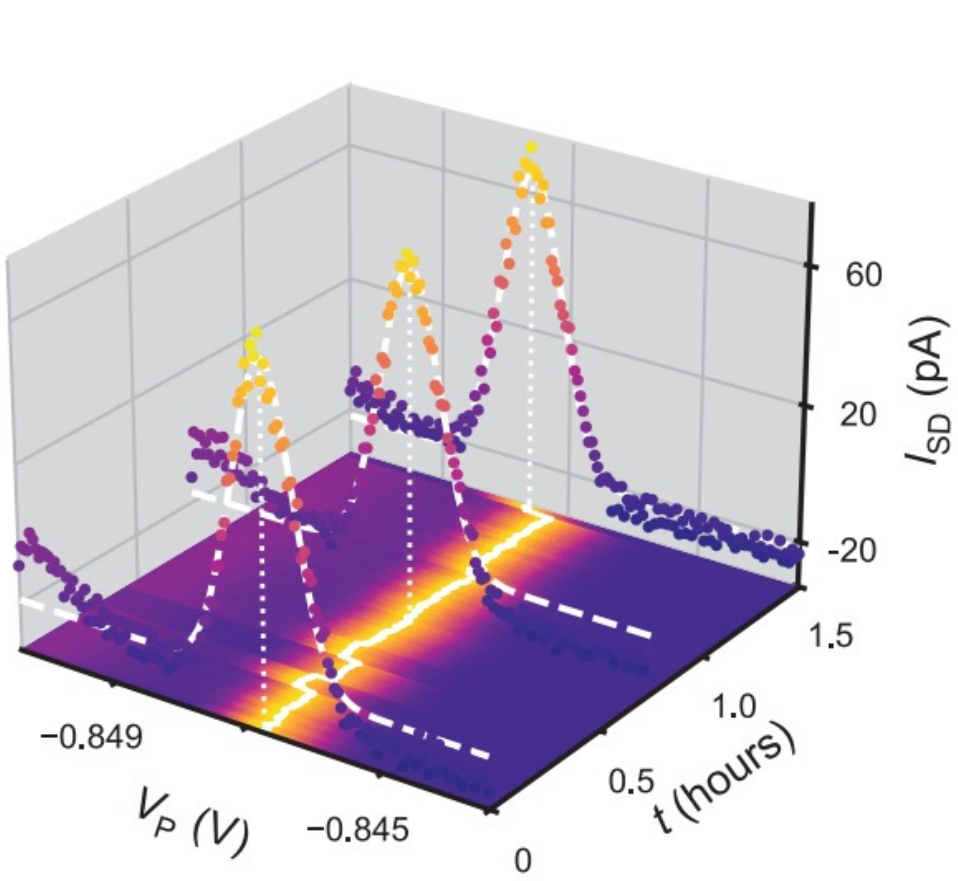
Very good fit with calculations

$$R_{SiO_2} \approx C_{SiO_2,HB_2}/C_{SiO_2,HB_1} = 0.55$$

=> SiGe-oxide interface!

QD MEASUREMENTS, CHARGE NOISE





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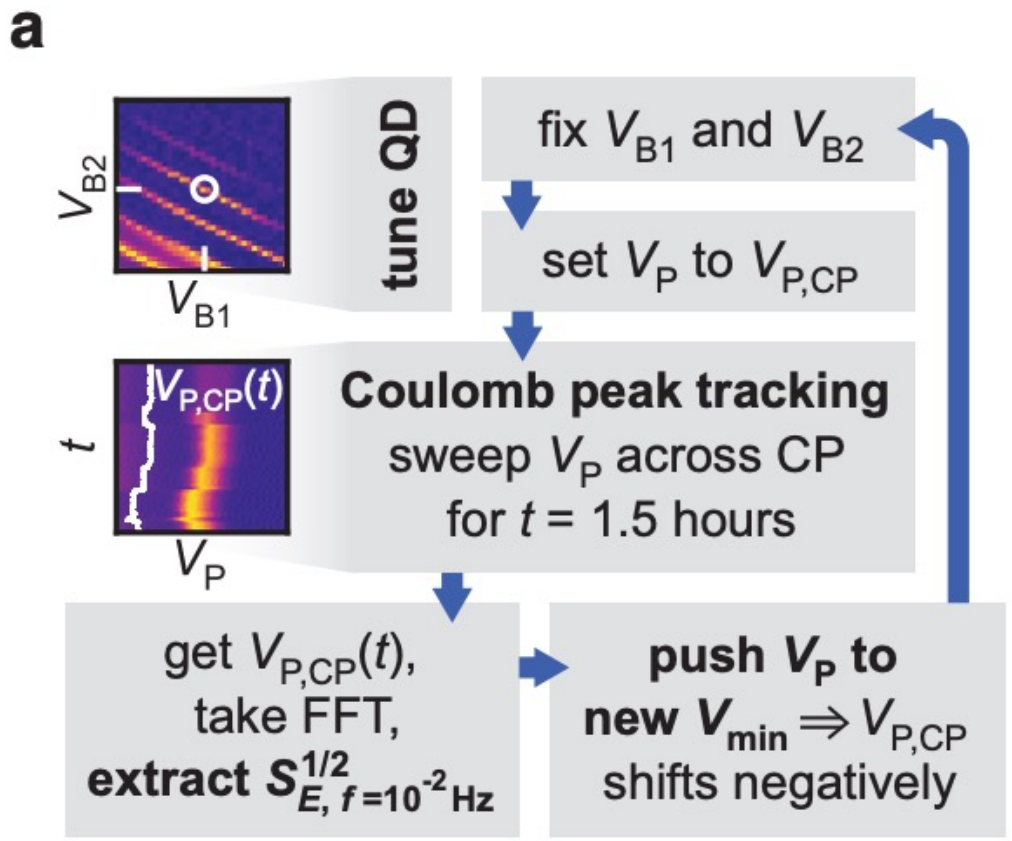
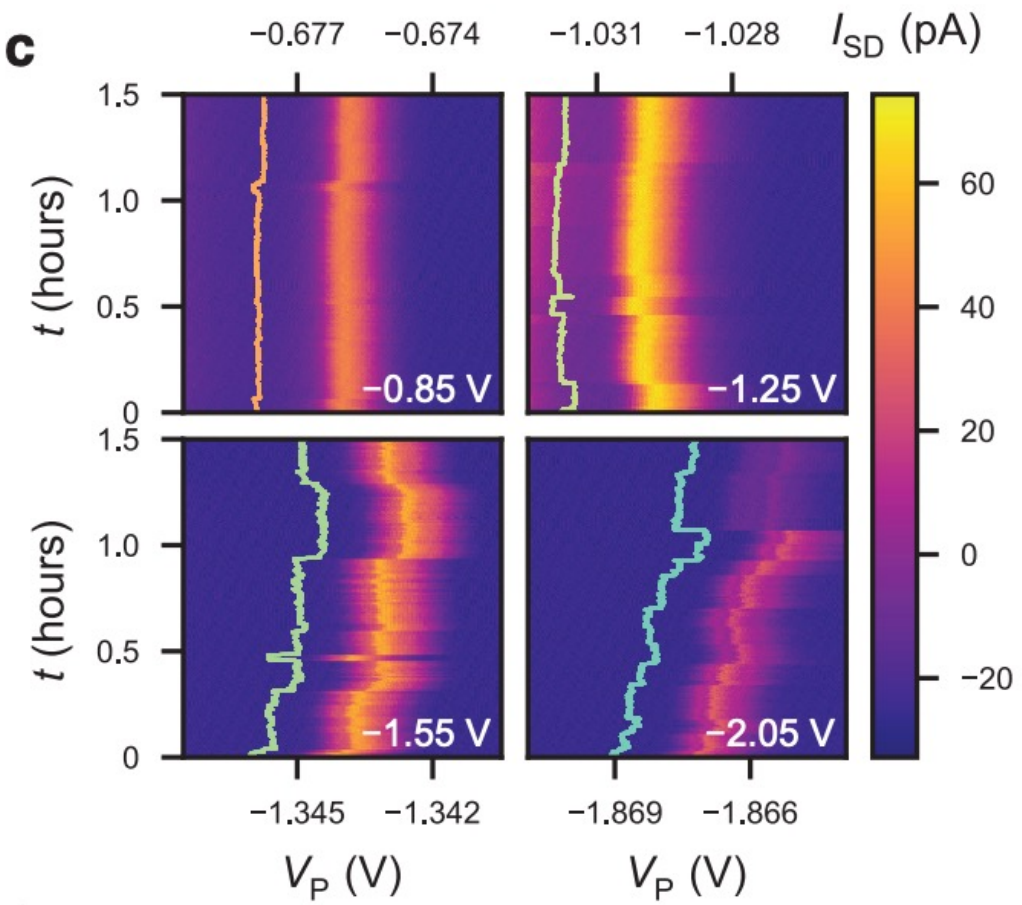
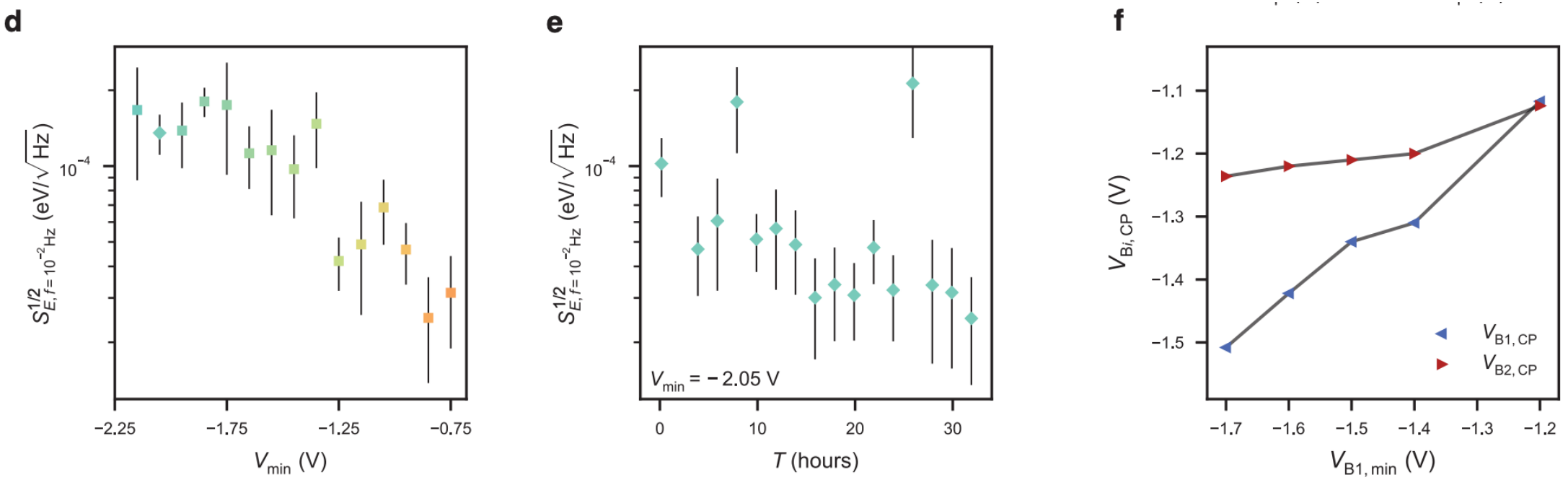


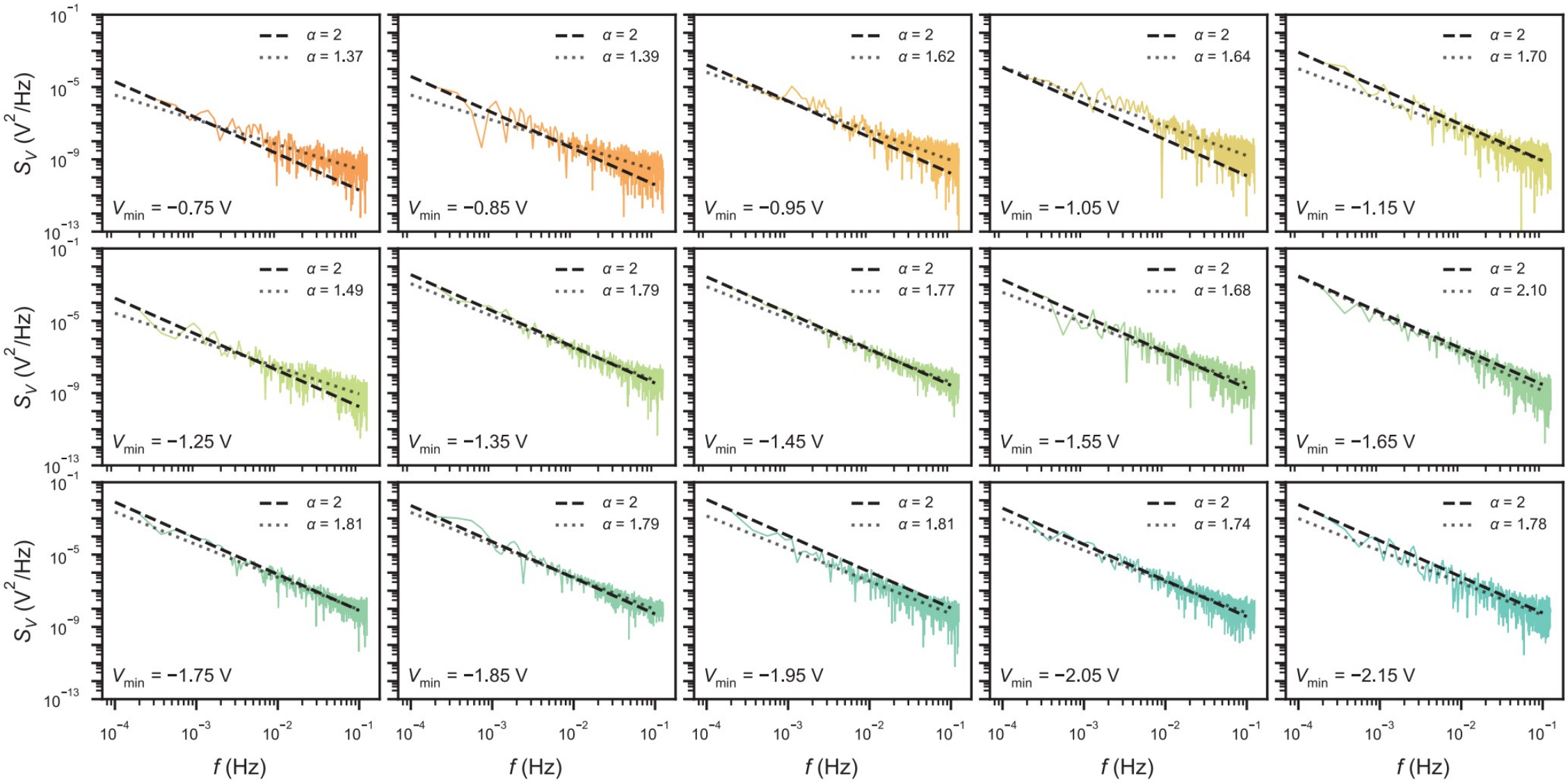


QD MEASUREMENTS, CHARGE NOISE



Summary

- Hysteretic behaviour in SiGe heterostructures
- Varying densing of charge traps at the SiGe-oxide interface
- Peak mobility as a not good benchmark for the quality of QM
- Noisy and slow relaxation process of the accumulated charges at the SiGe-oxide interface


S_V (V^2/Hz)
f (Hz)
$\alpha = 2$
$\alpha = 1.37$
V_{min} = −0.75 V
$\alpha = 2$
$\alpha = 1.39$
V_{min} = −0.85 V
$\alpha = 2$
$\alpha = 1.62$
V_{min} = −0.95 V
$\alpha = 2$
$\alpha = 1.64$
V_{min} = −1.05 V
$\alpha = 2$
$\alpha = 1.70$
V_{min} = −1.15 V
$\alpha = 2$
$\alpha = 1.49$
V_{min} = −1.25 V
$\alpha = 2$
$\alpha = 1.79$
V_{min} = −1.35 V
$\alpha = 2$
$\alpha = 1.77$
V_{min} = −1.45 V
$\alpha = 2$
$\alpha = 1.68$
V_{min} = −1.55 V
$\alpha = 2$
$\alpha = 2.10$
V_{min} = −1.65 V
$\alpha = 2$
$\alpha = 1.81$
V_{min} = −1.75 V
$\alpha = 2$
$\alpha = 1.79$
V_{min} = −1.85 V
$\alpha = 2$
$\alpha = 1.81$
V_{min} = −1.95 V
$\alpha = 2$
$\alpha = 1.74$
V_{min} = −2.05 V
$\alpha = 2$
$\alpha = 1.78$
V_{min} = −2.15 V