Low-Frequency Contact Noise mitigation in graphene-FETs

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Low-frequency noise (LFN) limits sensing applications of graphene

- Minimizing the noise level is crucial to maximize the sensitivity of the device

\[ I_{ds} = G_m \Delta V_{gs} \]

\[ \Delta V_{gs\text{-signal}} + \Delta V_{gs\text{-noise}} \]
How is noise power measured?

\[ S_I = \frac{a}{f^b} \quad b \approx 1 \]

\[ I_{ds-rms} = \sqrt{\int S_I \, df} \propto \sqrt{a} \]
What is the origin of noise?

- Charge trapping-detrapping noise
- Mobility fluctuation noise

\[
\frac{S_I|_{\Delta N}}{I_{ds}^2} \propto \frac{1}{n^2 A}
\]

Is noise generated at the contacts?

If current was injected mainly through the edge of graphene it’d be one or another

\[
\frac{S_{Rc}}{R_c^2} \propto \frac{1}{A_c n^2} \quad \frac{S_{Rc}}{R_c^2} \propto \frac{1}{A_c}
\]
What is the \textit{geometric dependence and origin} of contact noise?

We want to \textbf{measure contact noise}

We want to \textbf{eliminate} it
First, what is the **geometric dependence** of contact resistance?

- z-plane injection and edge injection have different geometry dependence
First, what is the geometric dependence of contact resistance?

- z-plane injection and edge injection have different geometry dependence

Injection through the edges dominates!
Then, what is the **geometric dependence** and **origin** of contact noise?

- Take the general equation:

\[
\frac{S_I}{I_{ds}^2} = \frac{S_{Rc} + S_{Rch}}{R_T^2}
\]

- If charge trapping-detrapping dominates:

\[
\frac{S_I}{I_{ds}^4} = \frac{k}{A_c n_c^2 V_{ds}^2} R_c^2 + \frac{k}{A_{ch} n_{ch}^2 V_{ds}^2} R_{ch}^2
\]

- If contacts contribution dominates:

\[
\frac{S_I}{I_{ds}^4} \propto L_c \quad \text{geometry}
\]

\[
\frac{S_I}{I_{ds}^4} \propto R_c^4 \quad \text{origin}
\]
Geometry and origin of contact noise:

\[ \frac{I_{\text{rms}}}{I_{ds}} \propto \sqrt{L_c} \]

Noise increases with \( L_c \)

\[ \frac{I_{\text{rms}}}{I_{ds}} \propto R_c^2 \]

Charge trapping-detrapping noise
Can contact noise be measured and reduced by geometric design?

- From the general noise equation:

\[
\frac{S_I}{I_{ds}} = \frac{kL_c}{V_{ds}^2W^3} + \frac{kL_{ch}}{V_{ds}^2W^3}
\]

Contact noise can be measured if \( L_c \gg L_{ch} \)

Contact noise can be minimized if \( L_c \ll L_{ch} \)
To summarize

- There is a contribution from contacts to noise

- The geometric dependence of the contact resistance and noise can be determined by changing $L_c$

- The relative importance of the contacts contribution to noise can be changed by design

$\rho_{\text{sh-channel}} \approx \rho_{\text{SU8}} \approx \rho_{\text{edge}}$

$U_{\text{gs-rms}}(\mu V) \propto \sqrt{L_c}$

$U_{\text{gs-rms}} @ U_{gs}-U_{CNP} = -0.1 V$

$L_c \gg L_{ch}$

$L_c \ll L_{ch}$