Trapping vs. Permanent Degradation in GaN HEMTs

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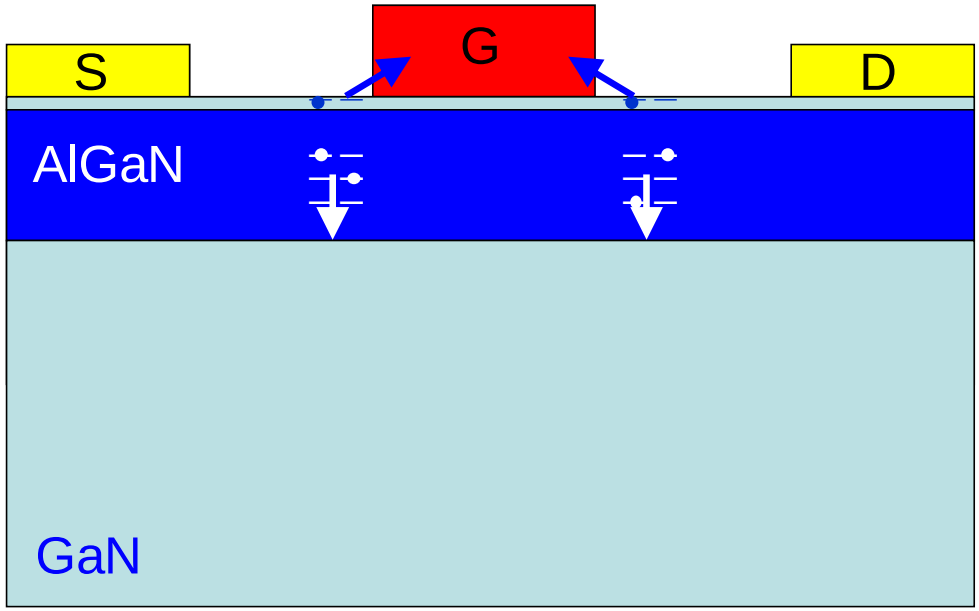
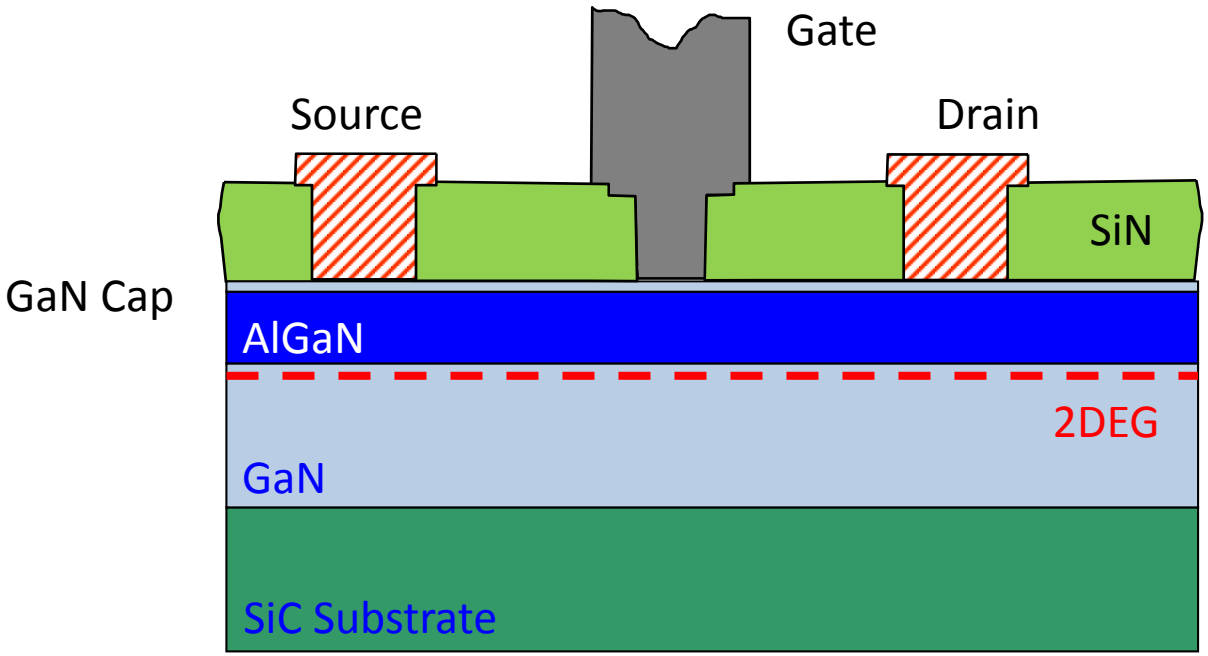
Motivation

- GaN HEMT reliability: big concern
- Performance degradation at high voltage:
  - Trapping-related (recoverable)
  - Permanent (non-recoverable)



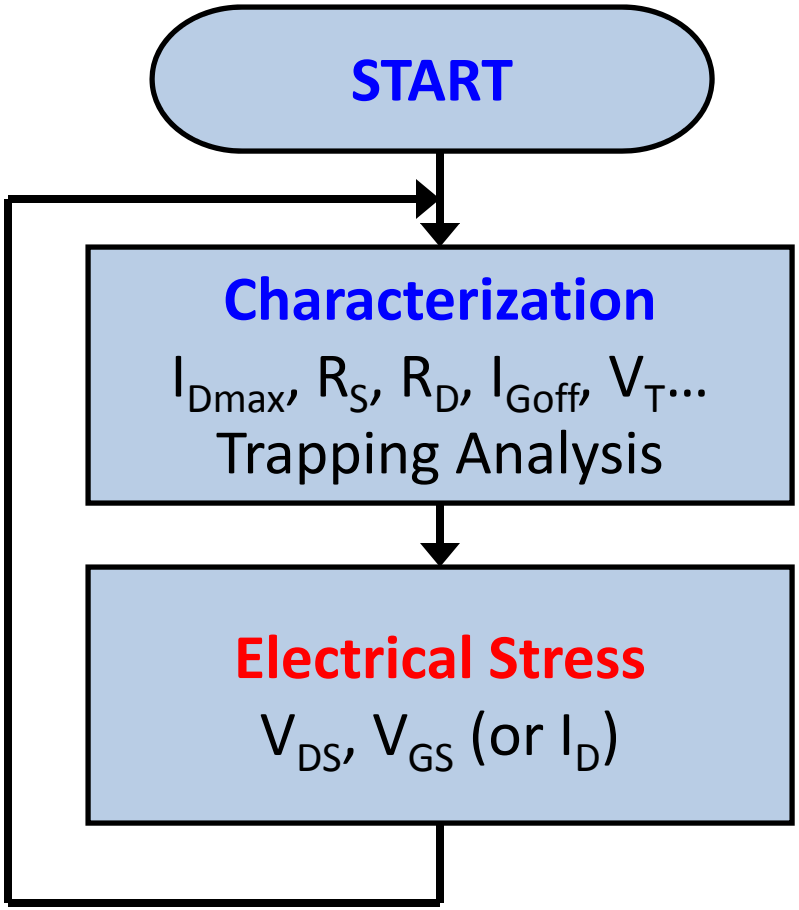
Experimental: GaN HEMT



Standard device with integrated field plate :

- L_G=0.25 um, W=2x25 um
- Fabricated by TriQuint Semiconductor

Electrical Stress and Characterization



Comprehensive but fast:

- Coarse characterization (<15 sec)
- Fine characterization (~30 sec)
- Trap analysis (30 min)

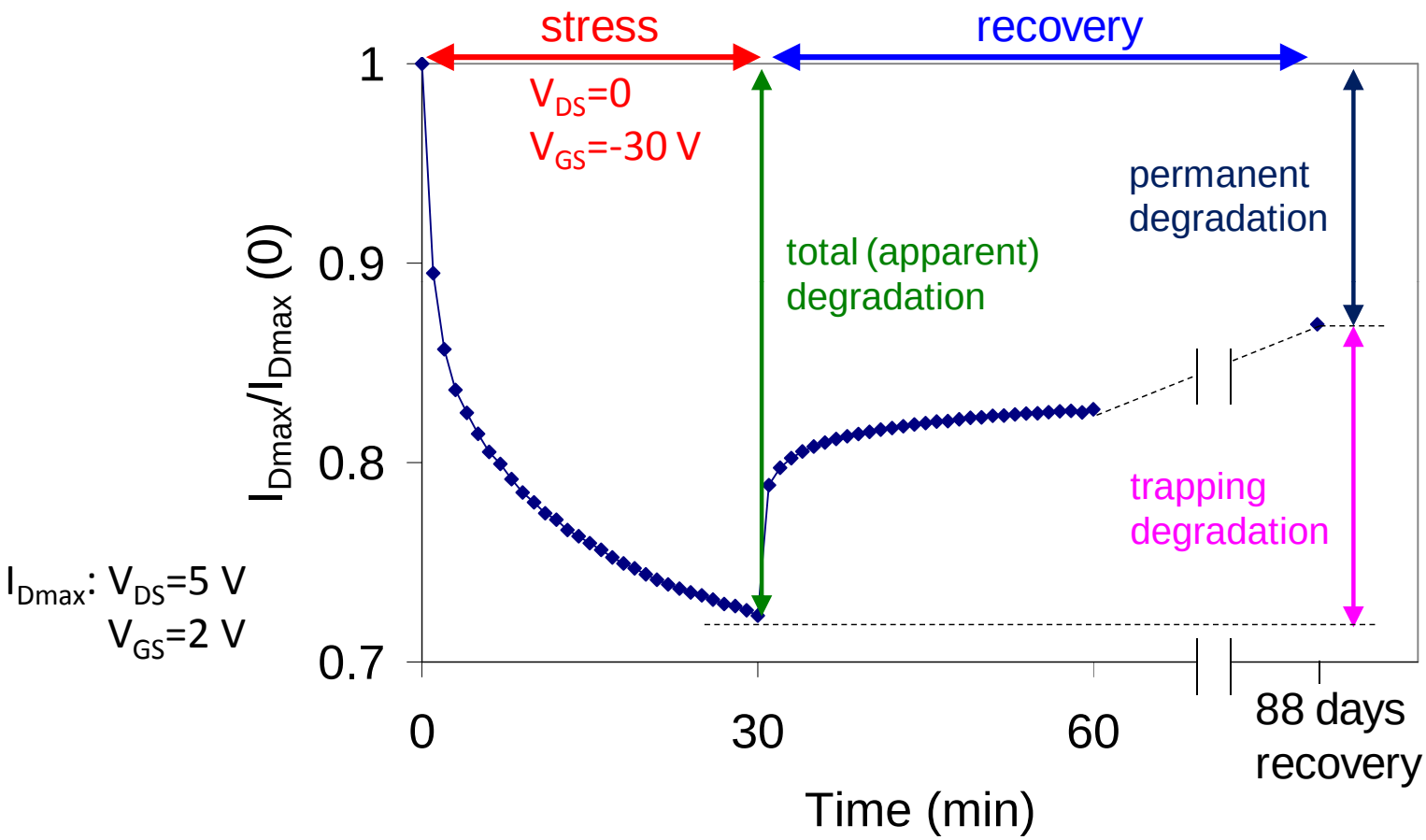
Frequent:

- Coarse characterization: every 1-2 mins
- Fine characterization: before and after stress and at important ponits

Benign:

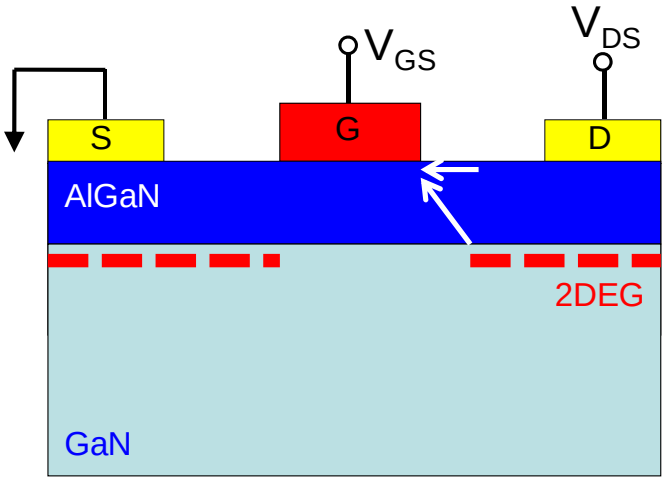
- Both sets of measurements to produce a change smaller than 2% on any extracted parameter after 100 executions

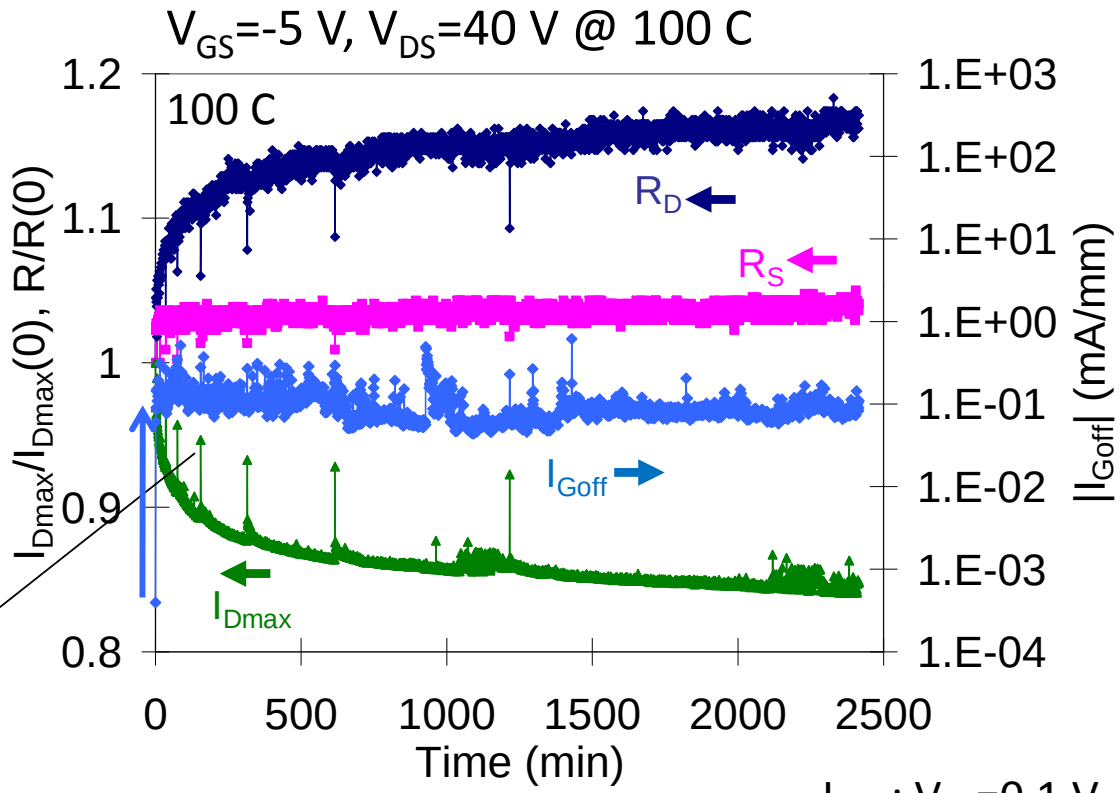
Permanent vs. Trapping



13 % permanent degradation + 15 % trapping degradation

OFF-state Stress @ 100 C



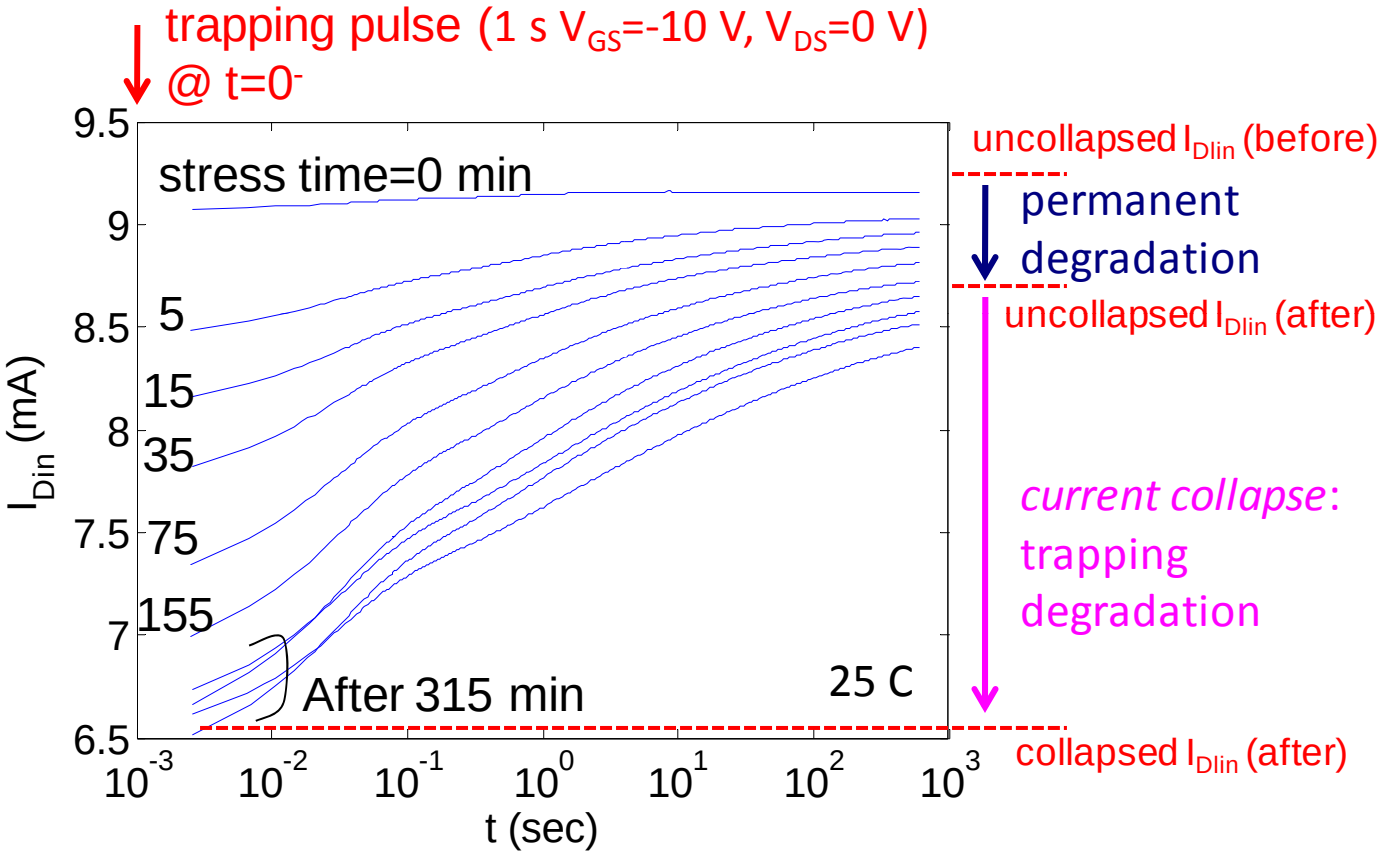


At these points, trapping analysis was performed at 25 C.

I_{Goff}: V_{DS}=0.1 V
V_{GS}=-5 V

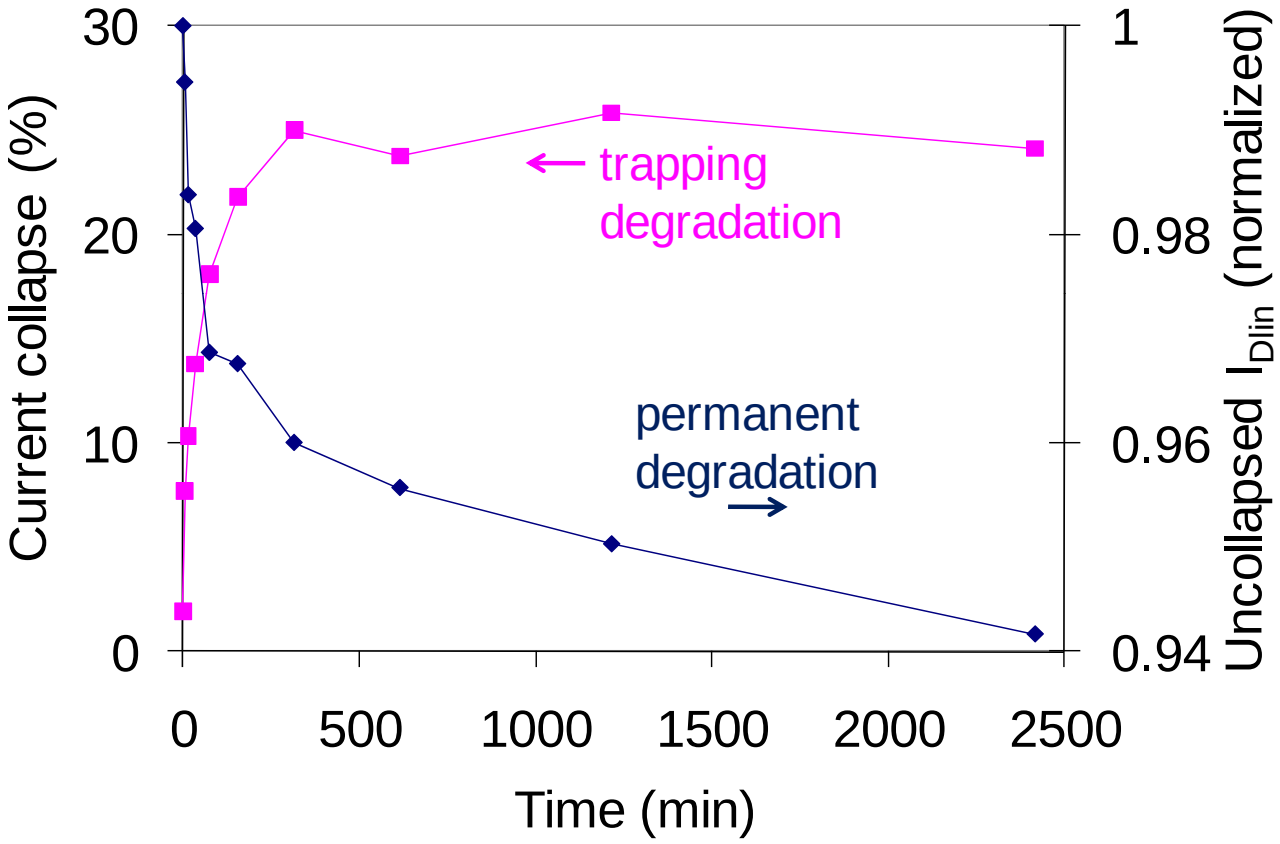
Fast and sharp I_G degradation
Slower I_{Dmax} & R_D degradation

Transient after V_{DS}=0 pulse



I_{Dlin} (V_{GS}=1, V_{DS}=0.5 V) transient after applying trapping pulse
Current collapse increases up to 300 min and saturates.

Trapping & Permanent Degradation



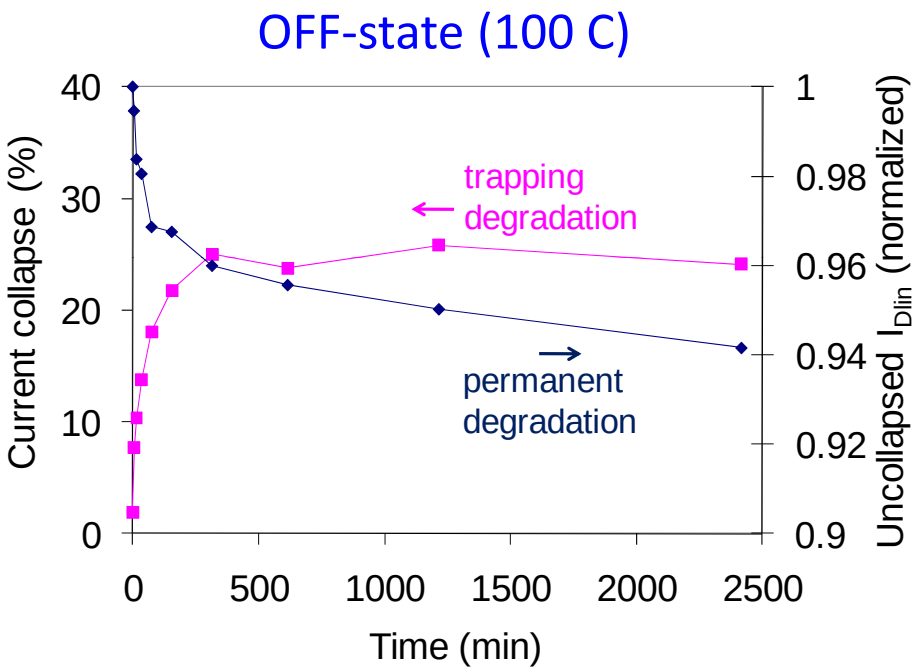
Permanent degradation:
uncollapsed I_{Dlin}

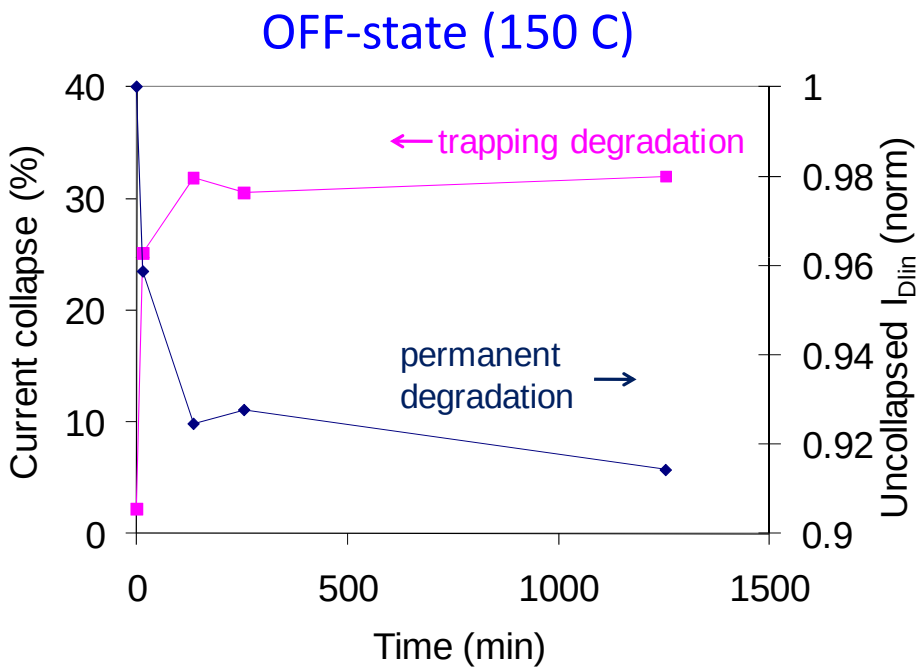
Trapping degradation:

$$\text{Current collapse} = \frac{\text{uncol. } I_{Dlin} - \text{col. } I_{Dlin}}{\text{uncollapsed } I_{Dlin}}$$

Trapping degradation mostly saturates after 300 min.
Permanent degradation keeps increasing.

Impact of Temperature



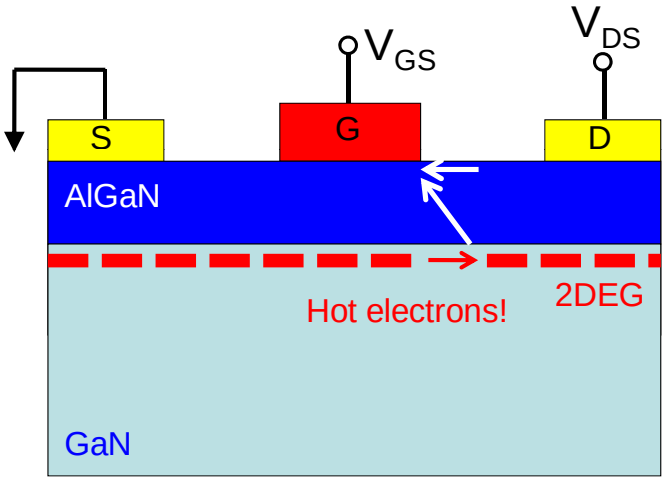


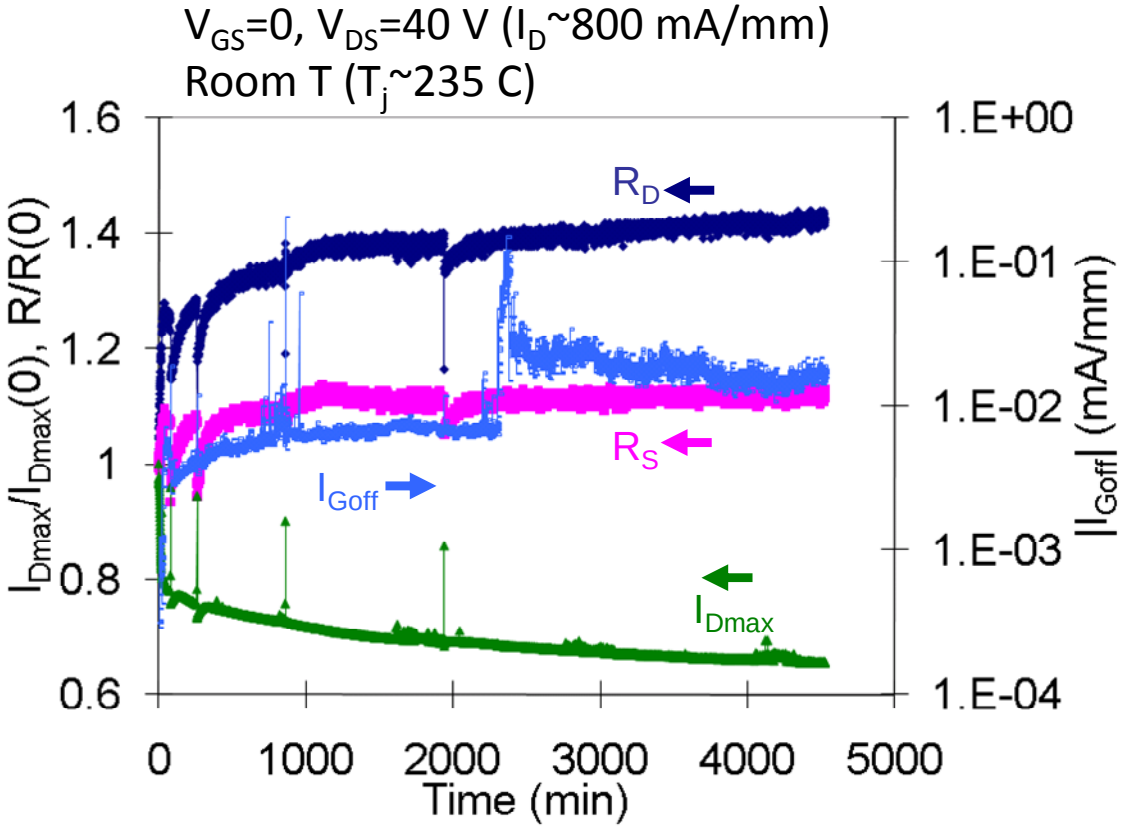
More degradation in trapping & permanent at higher T

→ Both degradations are thermally activated.

Increase in current collapse saturates faster than at 100 C.

Hot-electron Stress

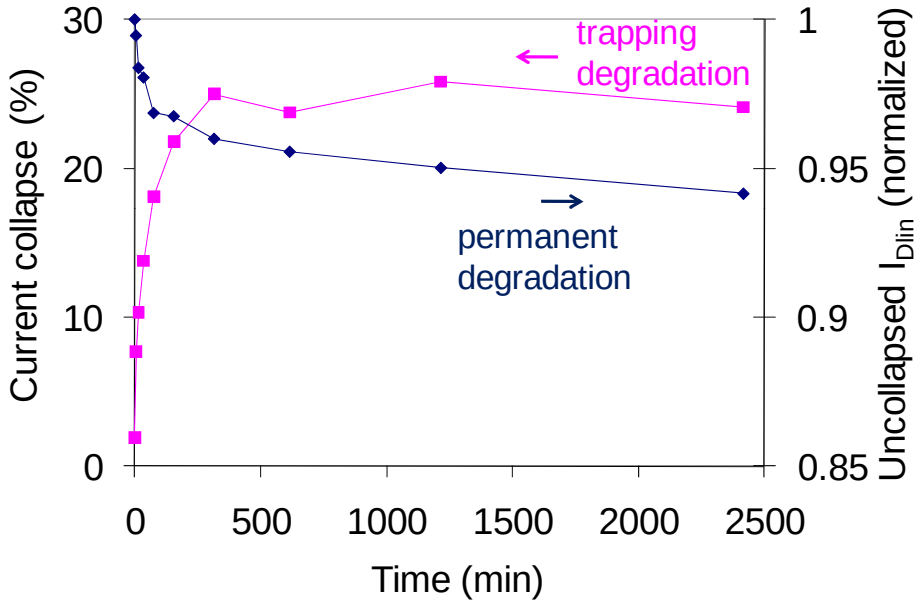




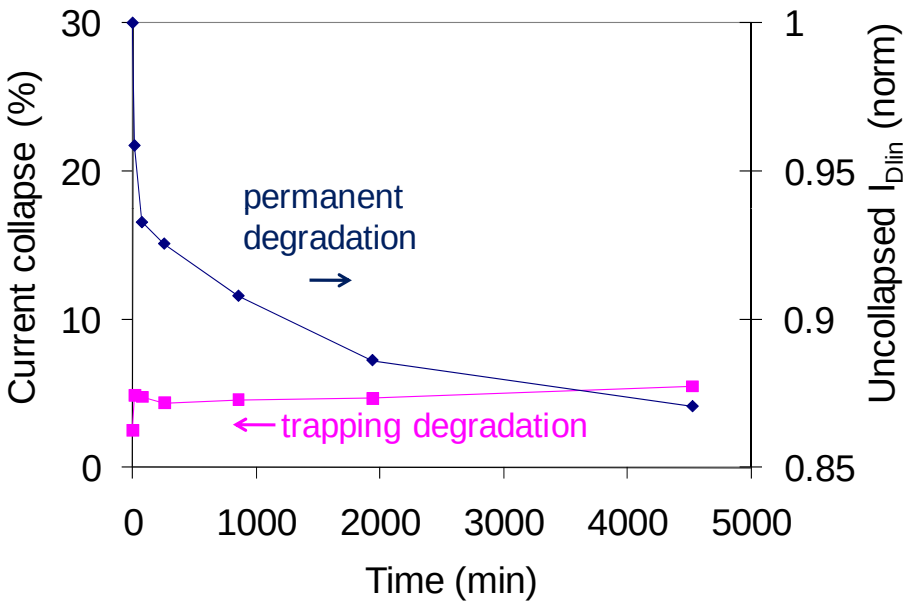
Much less degradation in I_G

OFF-state vs. Hot-electron Stress

OFF-state (100 C)



Hot-electron (RT, T_j~235 C)



More permanent degradation than OFF-state.

Less current collapse increase for V_{DS}=0 pulse.

→ less trap formation in high-power stress

Summary

- During all stress modes:
  1. Very fast I_G degradation (few minutes)
  2. Trapping-related degradation mostly saturates in a short time (few hours)
  3. Permanent degradation keeps increasing over time
- OFF-state:
  - More trapping degradation
  - Faster & more degradation at higher T.
- Hot-electron stress:
  - More permanent degradation