CASE STUDY

A-LFNA Success Story: Enabling Reliability Physics Insight via 1/f Noise

KEYSIGHT

Organization

- Imec

Challenges

- Reliability characterization is becoming harder for advanced devices.
- Conventional methods lack non-destructive, wafer-level insight.
- It is difficult to separate dielectric-trap effects from channel-related degradation.

Solutions

- Use Keysight E4727B A-LFNA for sensitive, non-destructive 1/f noise measurements.
- Combine 1/f noise with DC characterization to link electrical degradation with physical mechanisms.
- Apply wafer-level noise analysis to evaluate trap density, gate-stack quality, and device reliability.

Results

- Identifies band tail state broadening as the key degradation mechanism in IGZO TFTs.
- Enables wafer-level benchmarking of GAA nanosheet reliability against planar HKMG devices.
- Supports faster root-cause analysis, predictive reliability assessment, and process optimization.

Customer Challenges

Reliability characterization of advanced devices such as IGZO Thin-Film Transistors (TFTs) and Gate-All-Around (GAA) nanosheet transistors is increasingly complex. Conventional techniques struggle to provide non-destructive, wafer-level insight and cannot easily distinguish whether degradation originates from dielectric traps or channel-related mechanisms. This gap limits the ability to connect electrical degradation (e.g., Threshold voltage (Vt) shift, Subthreshold Swing (SS) degradation) to physical mechanisms.

Solutions

Keysight's E4727B Advanced Low-Frequency Noise Analyzer (A-LFNA) enables sensitive, non-destructive reliability analysis through 1/f noise measurements. When combined with DC characterization, A-LFNA helps correlate low-frequency-noise behavior with trap-related phenomena, density-of-states changes, and degradation mechanisms across individual devices and statistically meaningful wafer-level device populations.

Figure 1. Keysight E4727B Advanced Low-Frequency Noise Analyzer

IGZO TFT Reliability Root Cause [1]

Using combined DC and 1/f noise measurements, the study shows that the PBTI-induced negative Vt shift in IGZO TFTs is primarily linked to broadening of the IGZO conduction band tail states rather than new dielectric trap generation. The increase in 1/f noise correlates with subthreshold swing degradation in the subthreshold region, indicating an increase of trap-like sub-gap states below the conduction band minimum. Recovery experiments show that Vt, SS, and subthreshold noise nearly return to their fresh-device values after relaxation, confirming that the degradation is reversible and is more consistent with density-of-states modifications than with irreversible trap generation in the dielectric or channel. Physics-based simulations further show that BTI-induced hydrogen diffusion into the channel increases doping and is correlated with tail-state broadening, supporting the interpretation that the observed noise increase is driven by band tail state broadening.

1 R. Asanovski, P. Rinaudo, A. Chasin, Y. Zhao, H. F. W. Dekkers, M. J. van Setten, D. Matsubayashi, N. Rassoul, A. Belmonte, G. S. Kar, B. Kaczer, and J. Franco, “Band Tail State Broadening in IGZO TFTs After pBTI-Induced Negative VT Shift Revealed via DC and 1/f Noise Measurements,” IEEE Electron Device Letters, 2026.

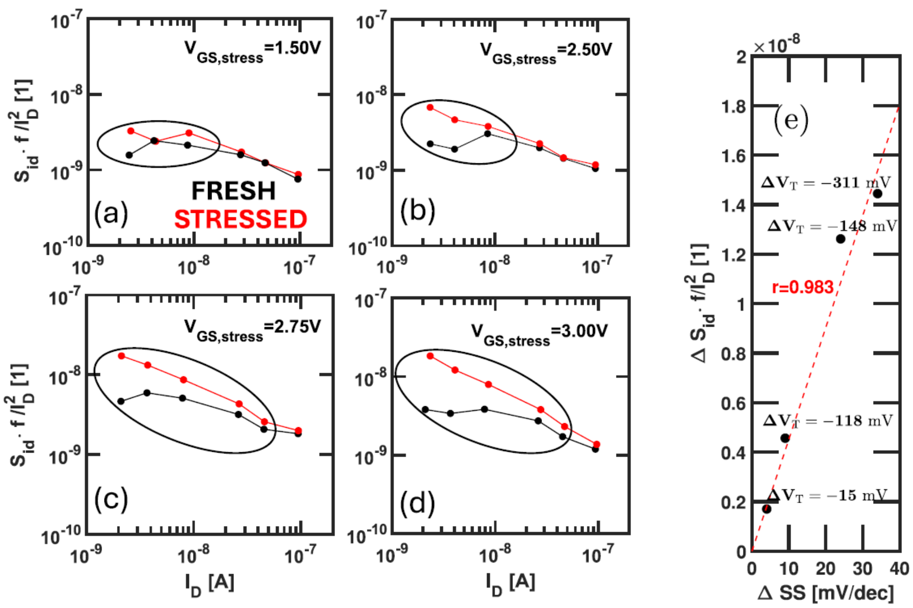

Figure 2. PBTI-induced 1/f noise increase correlates with subthreshold swing degradation, revealing band tail state broadening in IGZO TFTs

Wafer-Level Nanosheet Reliability Benchmarking [2]

In advanced CMOS nodes, A-LFNA enables statistically relevant wafer-level 1/f noise characterization of scaled devices. In the referenced study, 94 p-type nanosheet devices, corresponding to 188 nanosheets, were measured across multiple dies and benchmarked against large-area planar HKMG pMOSFETs with the same gate stack and comparable RMG thermal processing. Based on the carrier-number-fluctuation model, the 1/f noise data were used to estimate effective dielectric trap density, providing a physics-based link between measured noise behavior and gate-stack quality. After proper area normalization, the nanosheet and planar devices showed comparable noise amplitudes and extracted effective trap densities in the studied bias regime, indicating that the transition to GAA nanosheets does not introduce additional 1/f noise sources under these conditions. The results support the conclusion that gate-stack quality, rather than channel geometry alone, dominates the measured 1/f noise response and remains a key factor for reliability in scaled devices. The study also leverages previously established correlations between 1/f noise and BTI in planar HKMG devices, supporting the use of 1/f noise as a non-destructive wafer-level indicator for gate-stack quality and reliability assessment.

2 Ruben Asanovski, Anabela Veloso, Ben Kaczer, Naoto Horiguchi, and Jacopo Franco, "Wafer-Level 1/f Noise Characterization of Scaled P-Type Nanosheets and Benchmarking Against Planar HKMG Devices," IEEE International Reliability Physics Symposium (IRPS), 2026

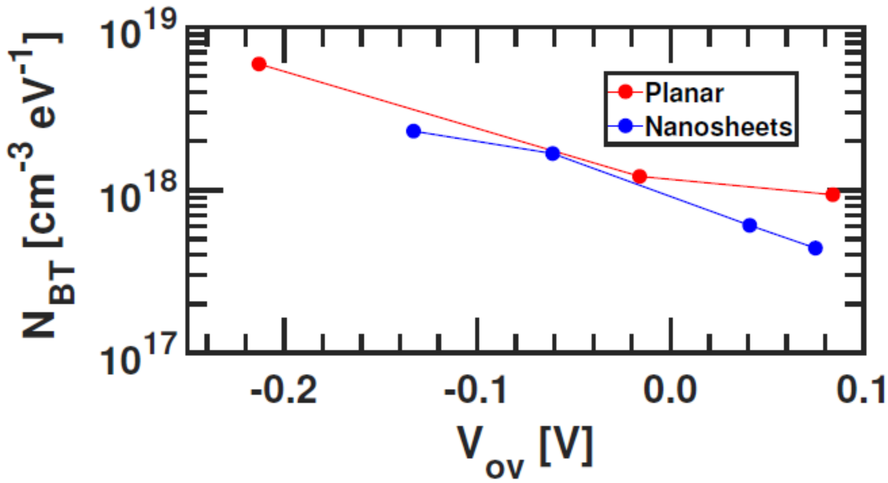

Figure 3. Effective trap density extracted from 1/f noise is comparable between nanosheet and planar HKMG devices with the same gate stack

Measured Impact and Business Value

By leveraging A-LFNA, customers can clearly separate channel-related degradation from dielectric-driven mechanisms, directly probe band tail states and density-of-states evolution, and extract effective trap density through 1/f noise measurements. This provides a non-destructive way to generate wafer-level statistics across large device populations while maintaining a direct link between electrical behavior and underlying reliability physics.

These capabilities help customers correlate 1/f noise with BTI behavior, enabling predictive reliability assessment, faster root-cause identification, and more efficient process optimization. As a result, A-LFNA turns low-frequency noise from a diagnostic signal into an actionable metric for improving device reliability and accelerating technology development.

> “The Keysight A-LFNA lets me focus on the experiments I want to run instead of the complexity of setting them up. The system is versatile and automated enough that implementing advanced measurements is straightforward.”
>
> **Ruben Asanovski, Reliability Researcher, Imec**

Conclusion

E4727B A-LFNA transforms low-frequency noise into a quantitative probe of reliability physics. It enables customers to identify band tail state broadening in IGZO TFTs and to benchmark gate stack quality in advanced nanosheet technologies. By linking electrical behavior with physical mechanisms, A-LFNA accelerates technology development and improves confidence in next-generation devices.

For more information on Keysight E4727B A-LFNA, visit:

Advanced Low-Frequency Noise Analyzer