Stimulus-Gated 2D Materials-based PUF Watermarking for Hardware Security

Presenting Author: Prof. Dipak K. Goswami
Co-authors: R. Banerjee, P. Rani, S. Mallik, R. Sadhukhan,
Department of Physics, IIT Kharagpur, Kharagpur - 721302
Co-authors: A. Pradhan, M. Banerjee
Midnapore College (Autonomous), Mindapore - 721101
Contact: dipak@phy.iitkgp.ac.in

Abstract
Counterfeit integrated circuits and IP piracy demand security primitives that are invisible in routine operation yet reliably verifiable by the rightful owner. We introduce a physically unclonable, stimulus-gated neuromorphic watermark using UV-responsive synaptic phototransistors fabricated from 2D siloxene nanosheets integrated with an organic semiconductor channel on a low-voltage gate stack. The devices exhibit light-tunable synaptic plasticity, creating history-dependent electrical states that naturally support challenge-response authentication. By patterning optical accessibility across a flexible device array, we encode a hardware watermark that remains dormant to conventional electrical probing and is revealed only under a manufacturer-held optical stimulus sequence. This work merges 2D-material device physics with neuromorphic dynamics to provide a scalable route to robust anti-counterfeiting and IP protection for next-generation (including flexible) electronics.

References

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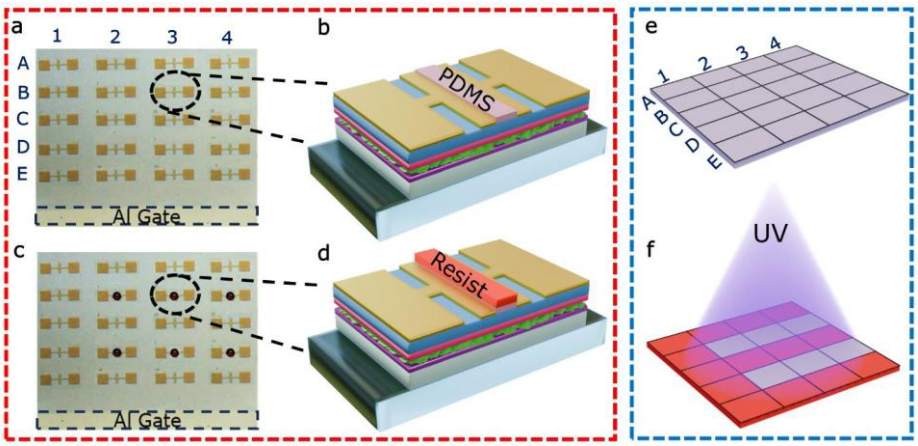
[2] S. Sethumadhavan, A. Waksman, M. Suozzo, Y. Huang, J. Eum, *Commun. ACM* **58** (2015) 60.
[3] R. Banerjee *et al.*, "Stimulus-Gated Neuromorphic Watermarking with 2D Siloxene-Based UV Synaptic Phototransistors for Next-Generation IC Security", Small (accepted) **DOI:** 10.1002/smll.202509193

Figures



Siloxene phototransistor array for hardware-security watermarking. a) Flexible 5 × 4 synaptic phototransistor array. b) Schematic of an uncoated device. c) Array with selected devices (B2–B4, D2–D4) photoresist-coated to encode the watermark "E". d) Schematic of a resist-coated device. e) Pixel-map representation of the array. f) Watermark "E" revealed under the correct UV pulse sequence.