Development of Nanomaterial-Based Physically Unclonable Functions and Dedicated Measurement and Testing Devices

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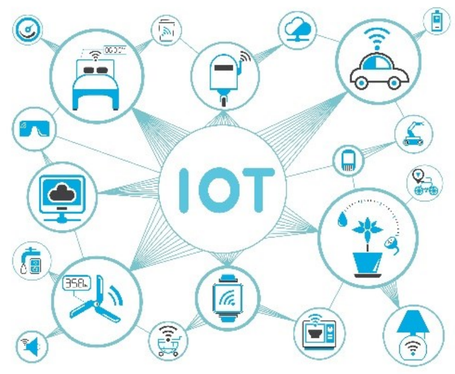
Introduction and Motivation

Progressive digitalization of connected cyber-physical systems in recent years accelerated by…

- Autonomous driving – Trustworthy sensor data?
- Internet of things – Privacy?
- 5G / 6G / Edge computing – Secure communication?

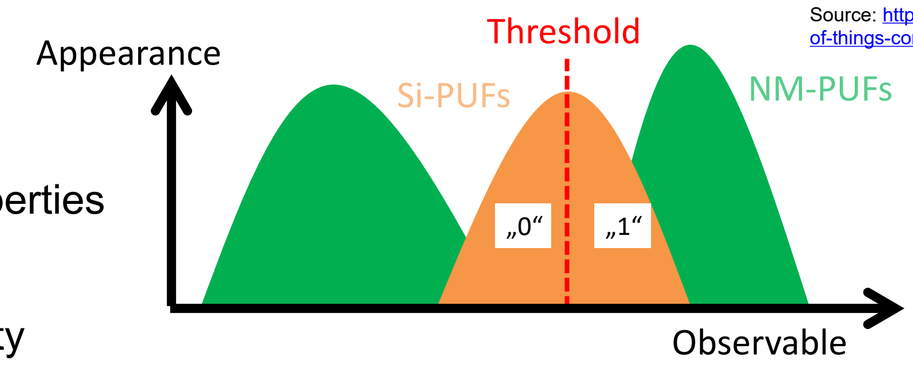
➢ High demand for embedded hardware security solutions – **Physical Unclonable Functions (PUFs)**



Source: https://www.colourbox.com/vector/internet-of-things-concept-iot-icons-vector-41962950

Unique selling points for nanomaterial PUFs (NM-PUFs)

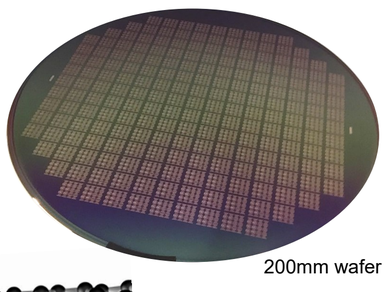
- Miniaturization
- Multi-bit keys – multi-entropy sources
- High key robustness – non-normal distributed NM-FET properties
- High tamper-evidence – surface-only nanomaterial
- Multifunctional – CNT-FET for electronics, sensors & security

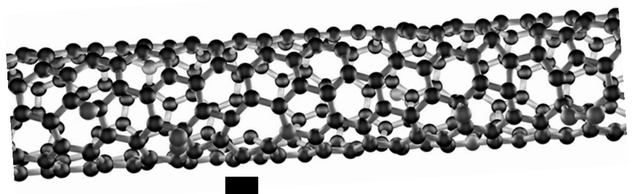


CNT Transistor Fabrication

CMOS-compatible 200mm nanodevice technology platform (TU Chemnitz)

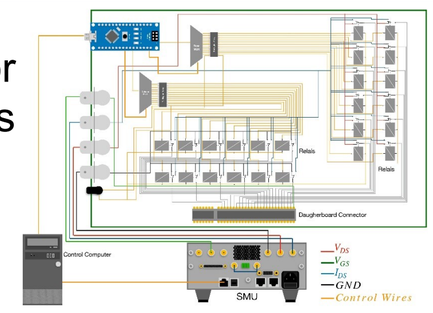
Systematic variation of process parameters & device geometry for highest entropy of ternary bit PUFs


200mm wafer


Carbon nanotube

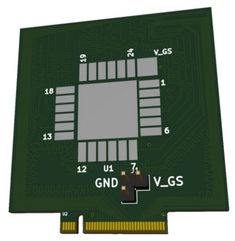
Measurement and Testing Setup

Construction of adequate test setup for systematical and statistical investigations (University of Passau)

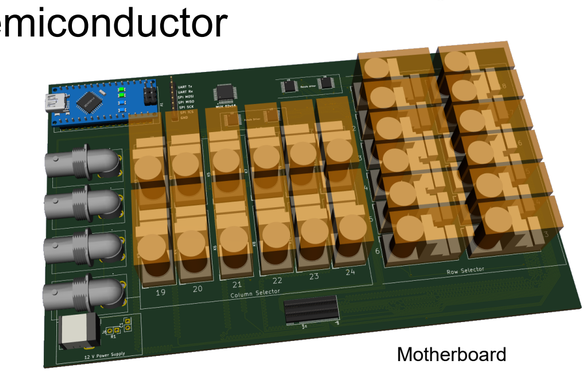


Mother- / Daughterboard configuration:

- NM-PUF mounted and wire-bonded on daughterboard
- Readout switch matrix on motherboard with connectors to a Source Measurement Unit (SMU), which acts as a semiconductor parameter analyzer



Daughterboard

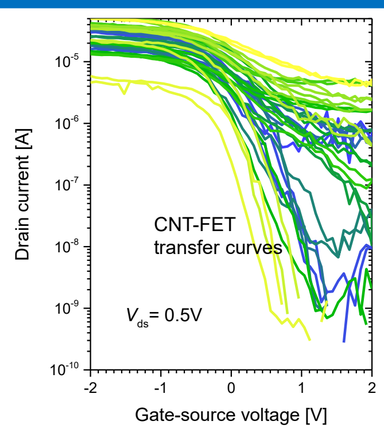

Motherboard

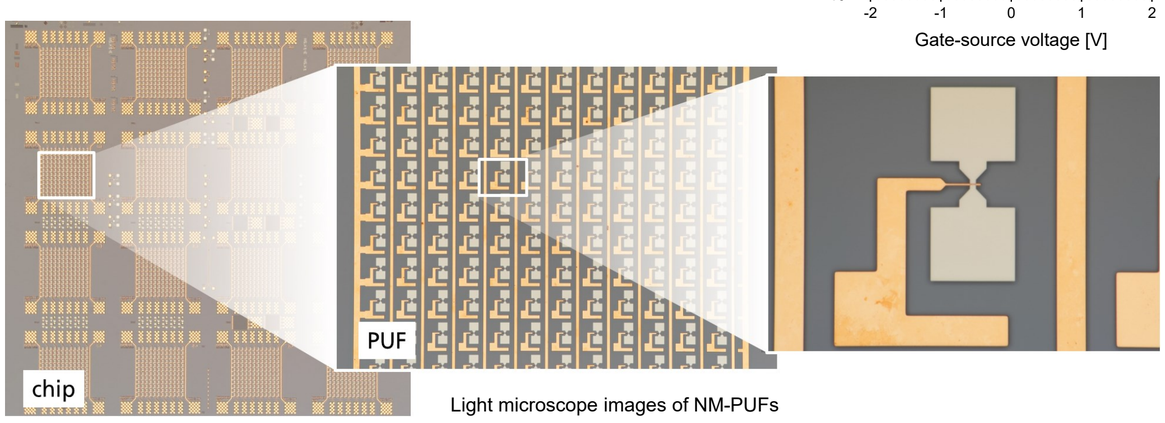
Results

Fabrication of 144-bit NM-PUFs based on CNT-FET arrays on 200mm silicon wafers

CNT integration method

- Printing approach with water- or solvent-based inks (CNT dispersions)





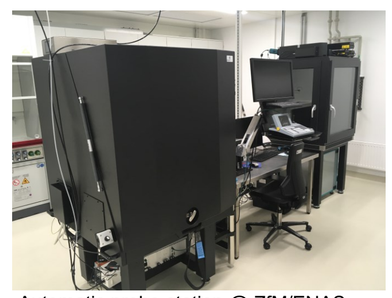
Light microscope images of NM-PUFs

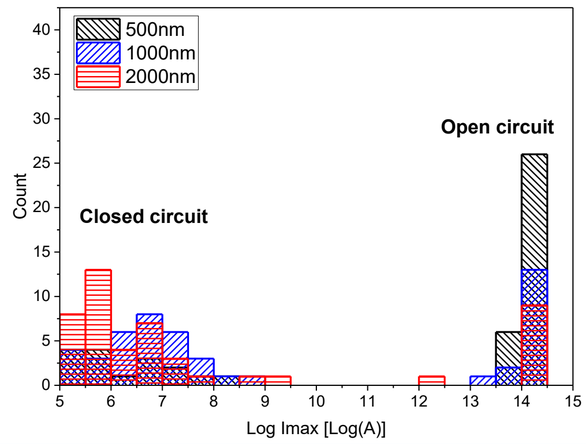
Automatic I-V scanning of more than 8000 sites per wafer @ V_{DS} = 0.1 V

Distribution of open circuit (“0”) and closed circuit (“1”) strongly depends on width of transistor channel

Systematic study:

➢ Revealing binary and ternary NM-PUFs with the highest entropy


Automatic probe station @ ZfM/ENAS



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