P1.20

TCAD simulation of the inefficiency of a Single Electron Bipolar Avalanche Transistor (SEBAT) coupled to a THz detector

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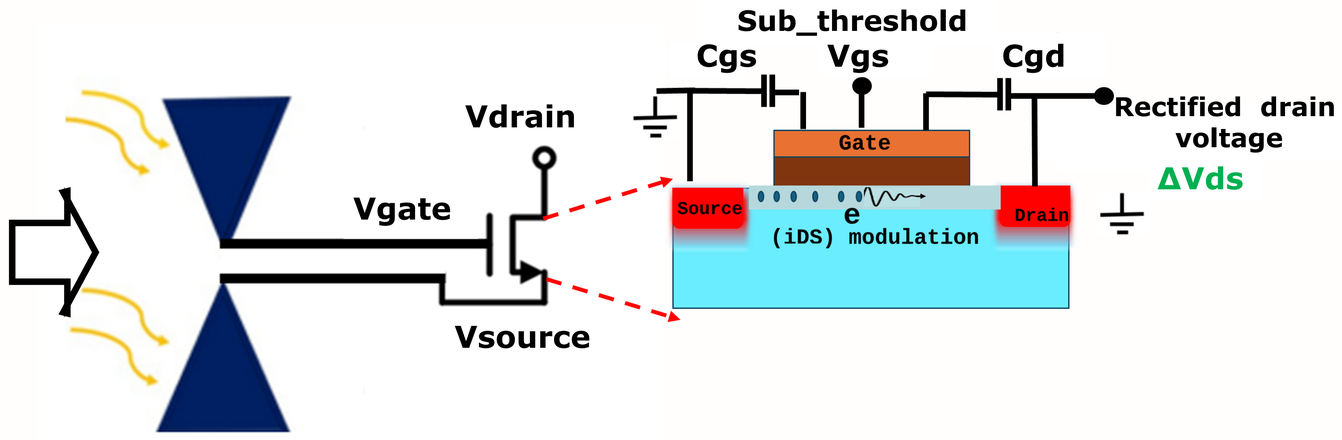
IRIS INTEGRATED READOUT ASICS AND IMAGE SENSORS

SONY

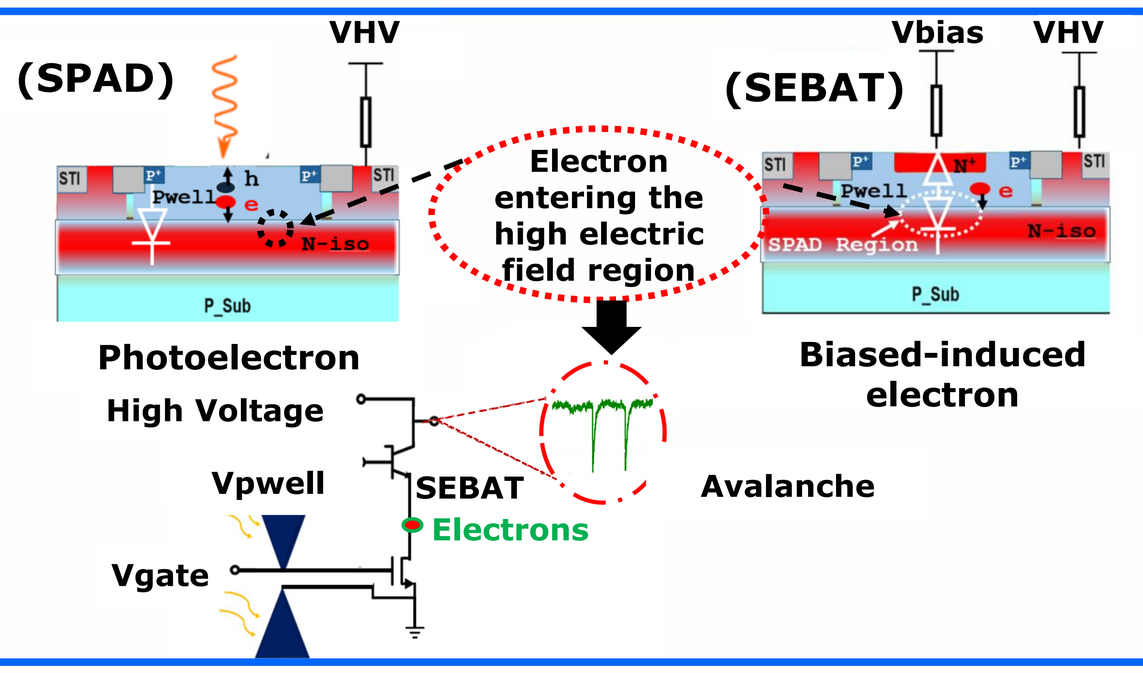
FET-based terahertz Detection

- **Challenges of THz Detection**
  - Large area requirements
  - High power consumption
  - Complex interface electronics
- **CMOS FET THz Detectors**
  - NMOS transistor with integrated antenna
  - Compact, low-power solution
  - Requires high-gain amplification



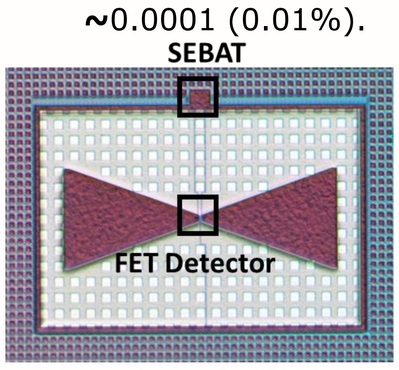
THz Pixel - SEBAT-based Detector

- **SEBAT Device Structure**
  - Similar to SPAD with injector layer
  - Base-collector junction in Geiger mode
  - Avalanche pulses from injected electrons
- **Advantages of SEBAT**
  - Single-electron sensitivity
  - Direct digital output
  - Low noise, internal amplification
- **Integration with FET Detector**
  - SEBAT amplifies FET's small THz signal
  - Avalanche pulse rate varies with THz radiation intensity

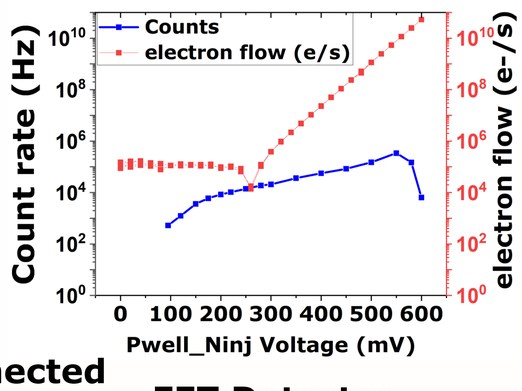


SEBAT challenges

- **SEBAT efficiency :**
  ratio of avalanche pulse rate to injected electron rate.
- **Theoretical efficiency:**
  limited by avalanche triggering probability
- **Measured efficiency**
  ~0.0001 (0.01%).



The implemented SEBAT in 150nm CMOS technology

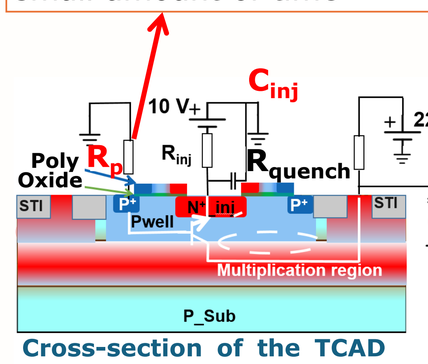


SEBAT ⟷ Connected ⟷ FET Detector

- Understanding the source of the inefficiency using TCAD simulation and make the device more efficient.
- Identify any areas where improvements can be made to optimize its efficiency.
- Make a SPICE model for the device.

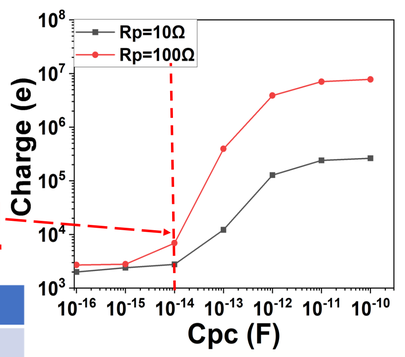
TCAD Simulation and Analysis

Basic mechanism: during the avalanche pulse, due to the total base resistance (semiconductor + contact + metal), the **n+/Pwell junction forward bias is increased** for a small amount of time



Cross-section of the TCAD simulation domain of the SEBAT transistor

SEBAT electrode pads were bonded to an external circuit.
Resultant capacitance ≈ 1 pF



Injected charge per pulse as function of the capacitance at the cathode.

R_p	R_{inj}	C_{inj}	R_{quench}	C_{pc}
10 Ω	1 TΩ	100 fF	1 M Ω	1fF – 100pF
100Ω				

Key Observations

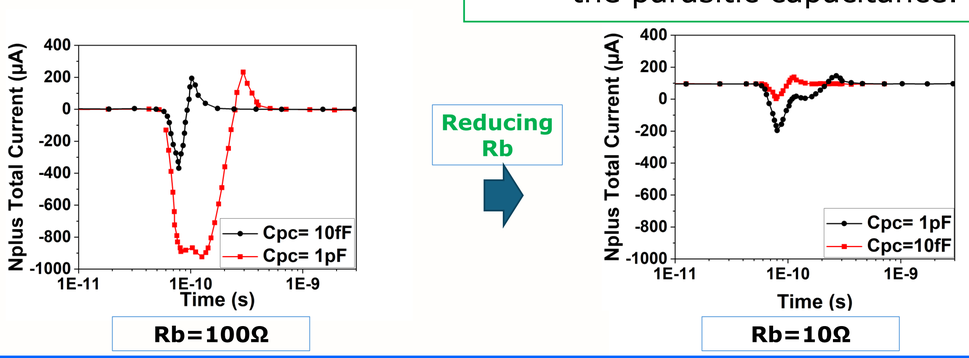
- Injected charge per pulse is affected by **cathode capacitance**
- The **Base resistance** impacts electron detection efficiency
- Voltage drop across base resistance modulates injector bias

Injector Current Pulse Analysis

- Pulse height and duration increase with capacitance and the base resistance.
- Small capacitance leads to small integrated charge.

Proposed Solutions

- Reduce the base parasitic resistance.
- Use integrated resistor to the collector in order to reduce the parasitic capacitance.



Conclusion and perspective

- SEBAT is a promising device enabling the readout of small current signals (e.g., Antenna-coupled FET detectors).
- SEBAT structures were fabricated, but they show poor efficiency due to the base resistance and the parasitic capacitance at the Cathode .
- Issue investigated through TCAD sims and solution identified.
- Design under fabrication to verify the hypothesis of inefficiencies.