DEPFET Sensor with Intrinsic Signal Compression
Developed for Use at the XFEL Free Electron Laser Radiation Source

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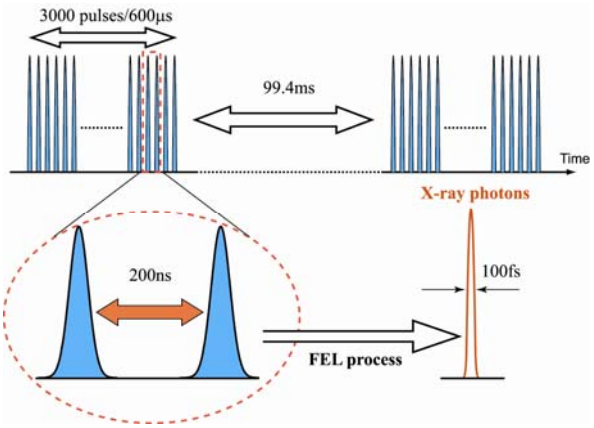
Introduction

Motivation: Requirements of experiments at the future X-Ray Free Electron Laser (XFEL). Detecting **single photons** in some pixels and up to 10000 in some others in the energy range of **500eV to 10keV** at a bunch spacing of **200ns**. This means that the maximum **picture rate is 500 MHz**. DEPFETs have an excellent energy resolution. The large dynamic range requires **signal compression** that is usually performed in readout electronics. The new type of DEPFET described in the following is capable to perform this task, thereby alleviating the task of the external electronics.

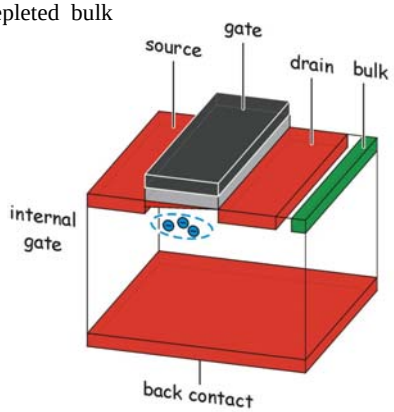


DEPFET (Depleted Field Effect Transistor) **Principle**

Structure: FET on fully depleted bulk

Function:

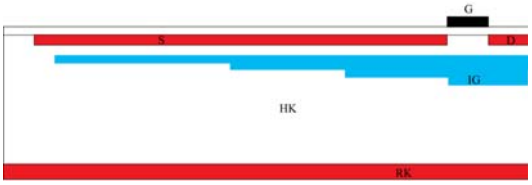
- Signal charge collected in potential minimum (internal gate) below transistor channel steers transistor current
- Clearing by positive pulse on clear electrode



Properties:

- Combined function of sensor, amplifier and memory cell
- Use as readout element in semiconductor detectors and as building block of semiconductor pixel detectors.

DEPFET with Intrinsic Signal Compression



Detector concept:

- Circular DEPFET with large area source
- Internal gate extending below source
- Small signal charge stays below channel
- Large signal charge overflows to the region below the source, steers the current inefficiently
- Very large charge storage capability of int. gate

Device Simulations

along radial direction from centre drain (r=0) to cell rim (r=118µm), wafer thickness 280µm.

Technology simulation (DIOS) providing doping profiles followed by

2-D Device simulation (TESCA) providing potential distribution, electron- and hole concentrations, currents, and further quantities as function of applied voltages and time.

Pixel Cell

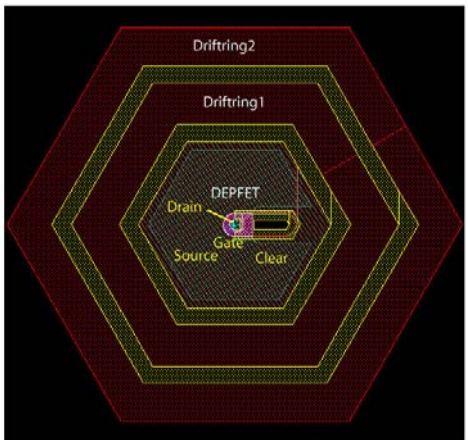
Combine **DEPFET** with **Drift Diode**

DEPFET in centre

hexagonal shape for fast charge collection

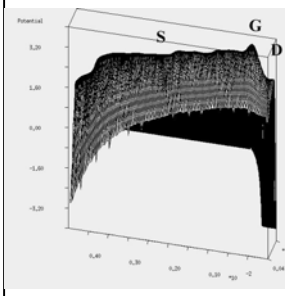
add clear structure

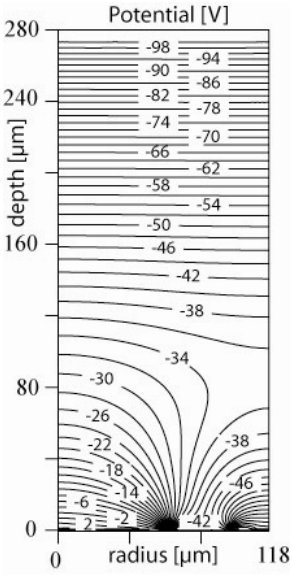
236µm diameter



Static Simulations: Potential

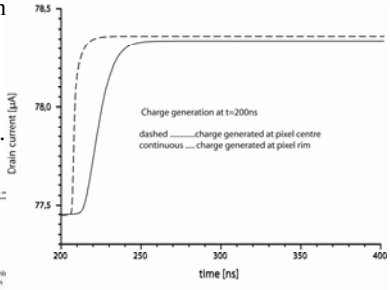
Full simulation region extending from drain centre (r=0) at the left lower corner to the cell rim at r=118µm.

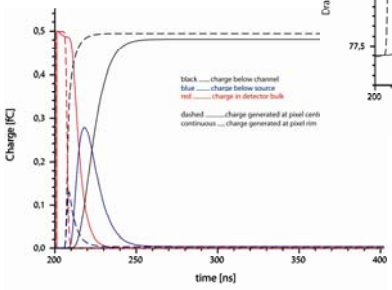




Charge collection and signal response

Charge is transferred to the region below the transistor channel (internal gate) within 60ns in the worst case (generation at the rim).





The drain current follows with insignificant delay. This is true for drain readout configuration.

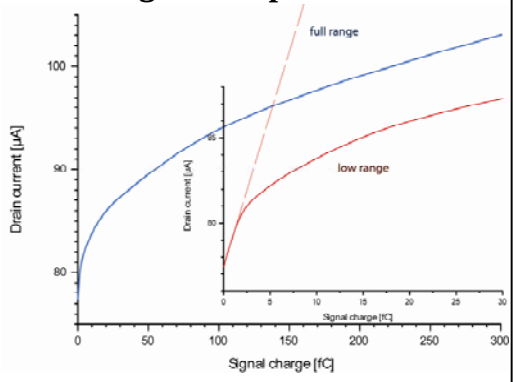
Summary:

The new DEPFET structure provides simultaneously good energy resulution for small signals, signal compression and very high charge handling capacity. Combined with a silicon drift diode it forms the basic cell of a pixel detector to be used at the XFEL Free Electron Laser X-ray radiation source.

The high sensitivity for low signals allows single photon detection and signal compression still keeps the measurement error far below statistical fluctuations in the number of produced photons.

Non-linear response and signal compression

Properties tuned to requirements of XFEL requiring simultaneously single X-ray sensitivity down to500eV energy and the capability to collect 10000 photons per pixel.



A linear region up to ~1.5fC (corresponding to 35 1keV photons) provides high amplification: 1,8 µA/fC corresponding to 77nA/1keV photon. It is followed by a non-linear (signal compression) region. Compared to linear extrapolation from the low signal region, a reduction of a factor 20 in the output signal range is achieved.