Characterization of Proton Irradiated SiC Sensors

Elias Arnqvist (Uppsala University)
CERN Summer Student in EP-DT-DD
Supervisors: Moritz Wiehe (CERN) and Michael Moll (CERN)

Introduction

Detectors play an essential role in experiments at CERN. For instance, semiconductor detectors make it possible to track high-energy particles accurately, resulting in reconstructions of particle paths used for physics analysis. Most semiconductor detectors used today are made from silicon (Si) sensors. However, interest in silicon carbide (SiC) sensors has been sparked by recent developments in fabrication technology. This project aims to study SiC sensors and characterize how they are affected by proton radiation.

Background

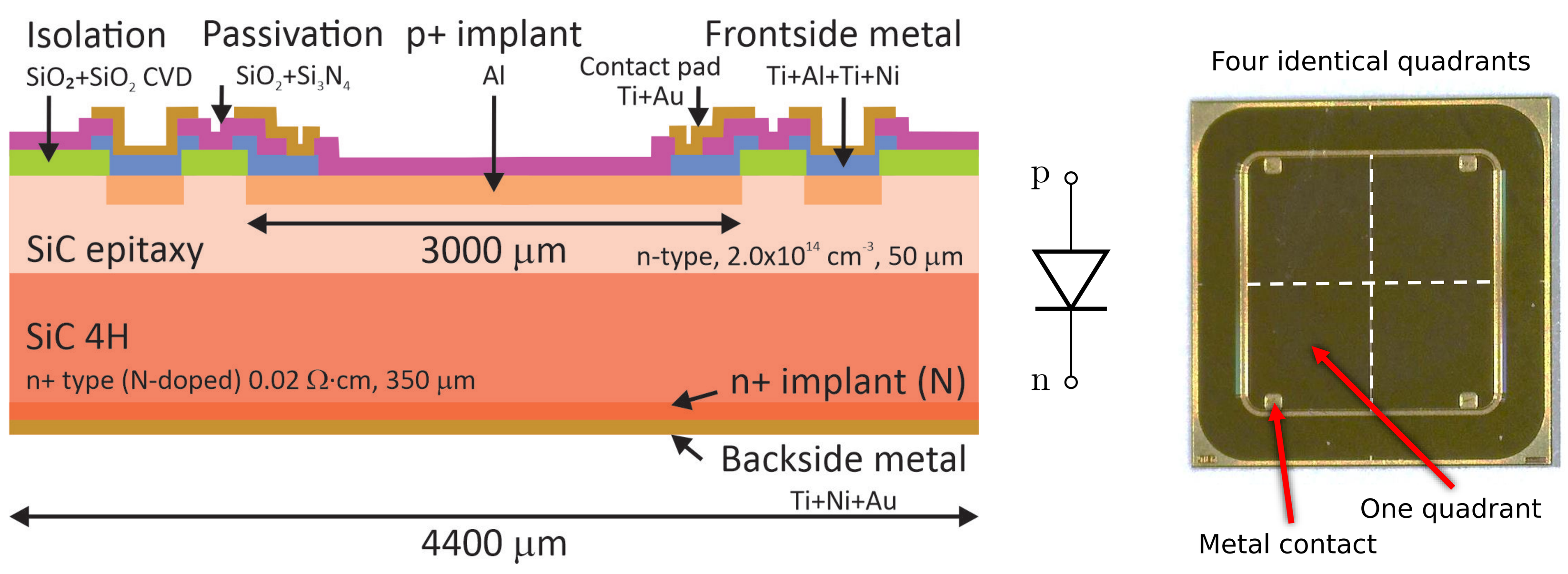
SiC semiconductors have a **larger bandgap** than Si. A beneficial consequence of a large bandgap is a **low leakage current**, resulting in lower power consumption and less signal noise.

Table 1: Selected properties of Si and SiC (at 300 K).

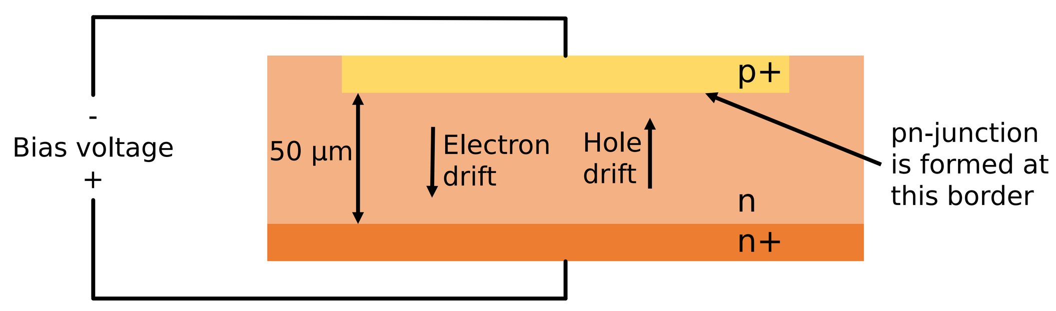
Property	Si	SiC
Bandgap (eV)	1.12	3.27
Threshold displacement energy (eV)	13-15	30-40
Electron saturation velocity (cm/s)	$0.8 \cdot 10^7$	$2 \cdot 10^7$
Breakdown electric field (V/cm)	$3 \cdot 10^5$	$3\text{-}4 \cdot 10^6$
Electron mobility (cm^2/Vs)	1450	800
Hole mobility (cm^2/Vs)	450	115

Method

SiC sensors manufactured by IMB-CNM (Spain) were obtained. Of the sensors, 10 were 5 µm thick and 14 were 50 µm thick. Results for **50 µm thick** sensors with **four quadrants** are discussed here, but the other sensors were also studied.



The sensors consist of a **pn-junction** (a diode). In operation, these sensors are **reverse biased** to create a depletion region (where particles can be detected).



Sensors were irradiated at the **IRRAD facility** at CERN, using 24 GeV/c protons from the proton synchrotron.

Fluences of 10^{13}, 10^{14}, and 10^{15} protons/cm^2 were used.

Outlook and Future Measurements

In the coming weeks, more measurements will be done.

Systematic TCT measurements on sensors will be performed. A new UV laser configuration will be commissioned for the TCT setup.

Defect spectroscopy will also be performed on sensors. This can give information about how radiation damages SiC sensors.

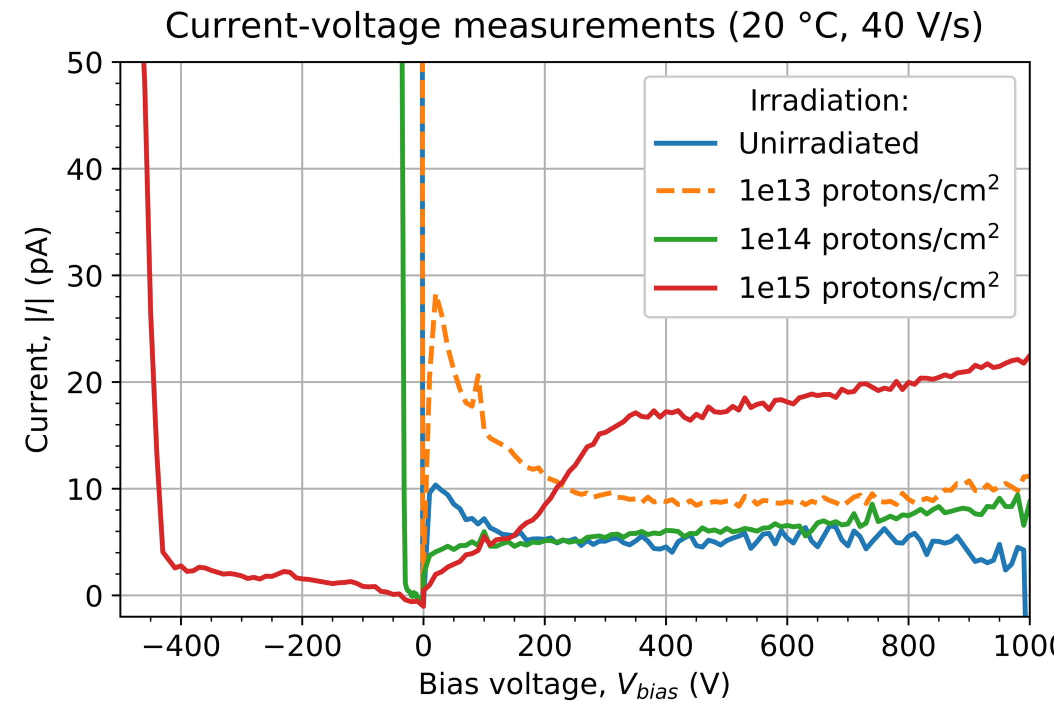
Acknowledgements

I thank Joan Marc Rafí and IMB-CNM for the SiC sensors that were studied in this project. Furthermore, many thanks go to Giuseppe Pezzullo and IRRAD at CERN for the proton irradiation. Finally, I am grateful for the generous support I received from my supervisors and the solid state detector group at CERN.

Current-Voltage and Capacitance-Voltage

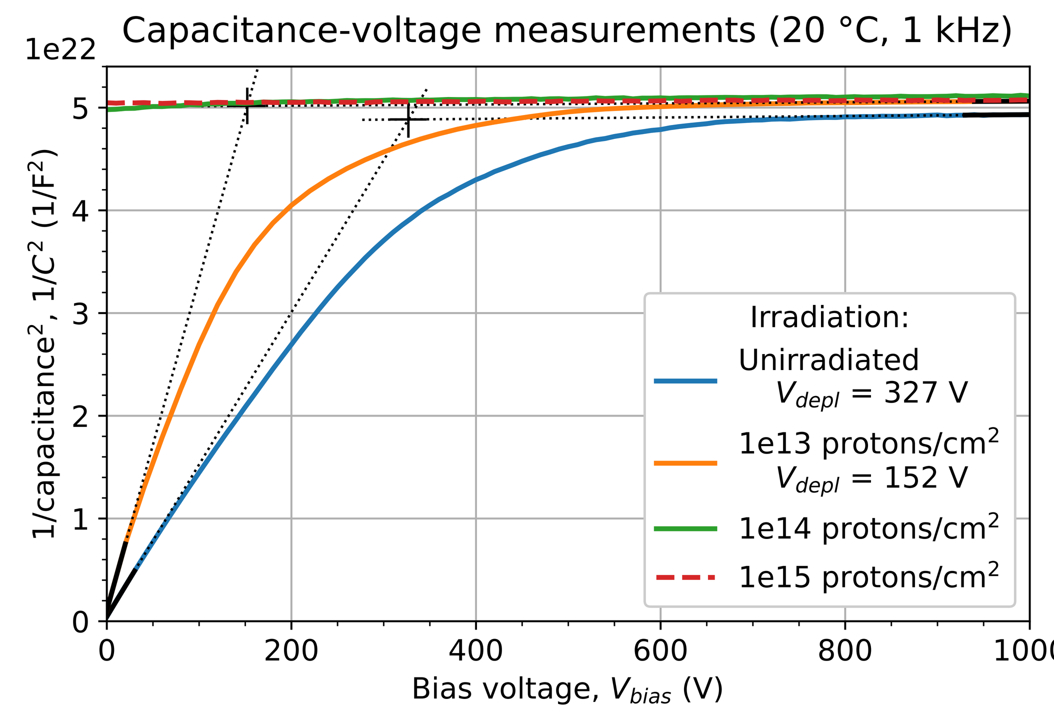
The **current** $|I|$ and **capacitance** C were measured at 20 °C as a function of applied **bias voltage** V_{bias}. Preliminary results are presented below.

- About 20 pA leakage current for fluence of 10^{15} protons/cm^2
- Higher fluences reach larger forward voltages before conduction



In theory, $1/C^2 \tilde{\propto} V_{bias}$. The slope of the curve is determined by the **effective doping concentration**. The voltage at which the curve flattens is the **depletion voltage** V_{depl}.

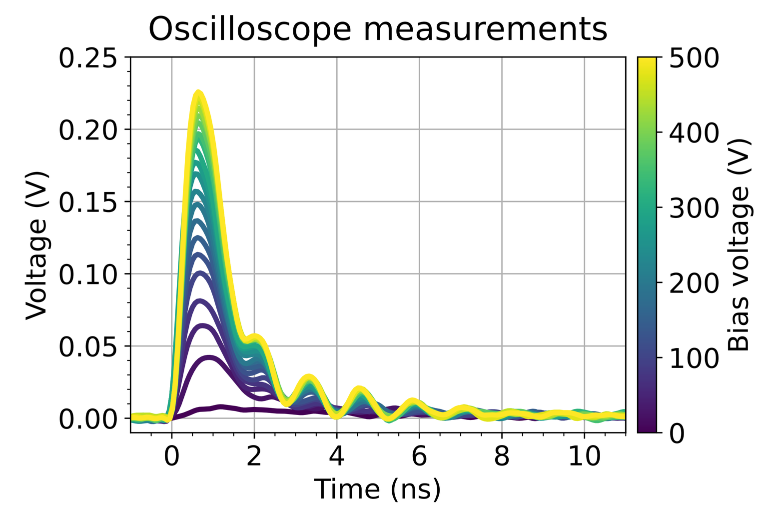
- The depletion voltage is reached for unirradiated and 10^{13} protons/cm^2, and it decreases with irradiation
- For 10^{14} and 10^{15} protons/cm^2 diode properties appear to be lost

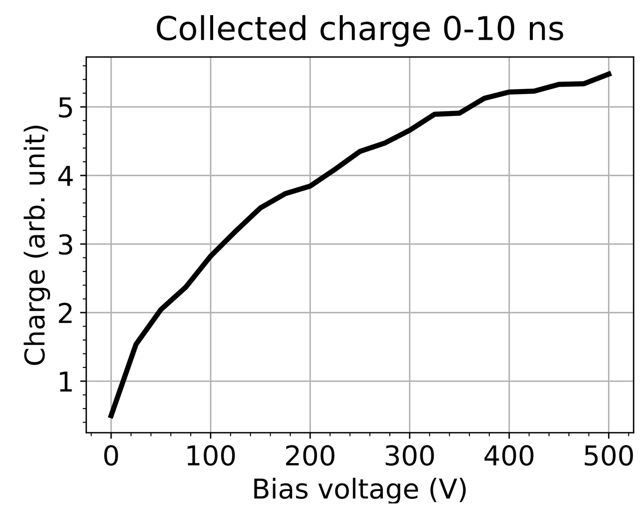


Transient Current Technique

The **transient current technique** (TCT) involves injecting charge at one point on a sensor with a laser pulse and monitoring the resulting signal. Integrating this signal yields the collected charge. Thus, TCT can give information about charge collection efficiency, electric fields, and transport properties of charge carriers.

Using TCT to inject charge at one point gives the results below for an unirradiated sensor.





By moving the laser across the unirradiated sensor, one obtains the collected charge at different positions.