I-V and C-V characterization of Silicon Pad Detectors

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Introduction

Silicon detectors are being used for several applications involving detection and measurement of position and energy of particles, such as alpha particles, fission fragments, heavy ions etc [1]. One of the most important performance requirements of any silicon detector is the dark-state reverse bias leakage current, i.e. dark current. This sets the limit of noise. Limit of the leakage current sets an important parameter for acceptance or rejection of a detector.

The depletion width also increases with the square root of the reverse bias voltage, so increasing the bias voltage will increase the sensitive volume and reduce the capacitance. For a charge particle traversing the detector, this increases the signal charge and reduces the electronic noise; however maximum applied reverse bias is limited. C-V (capacitance versus voltage) profiling is done to characterize threshold voltages [2]. It could also be used to analyze the doping profiles of semiconductor devices since dopant concentration affects the width of depletion region. The fabrication process and the dicing process do not ensure the full quality of the sensors, so the fundamental properties of the detectors have to be evaluated prior to the large scale production and installation of the detector in the experiment. The most important parameters which contribute to the noise at the input of the read-out electronics, are the leakage current of every detector and detector capacitance [3]. The leakage current measurement and capacitance versus voltage profile for 1 cm^2 Si (PIN) pad detector of 300 µm thickness are presented in this paper.

Measurement Setup

Leakage current is measured using Keithley Picoammeter Model 6487 by interfacing the meter to PC through RS232. The methodology used for this purpose is, reverse bias voltage applied to the detector through the Keithley Model 6487 Picoammeter. It was chosen for its voltage supplying capabilities. It can deliver a potential difference across its terminals of up to 505 volts. The Picoammeter is a precision device supplying high voltage whilst measuring current.

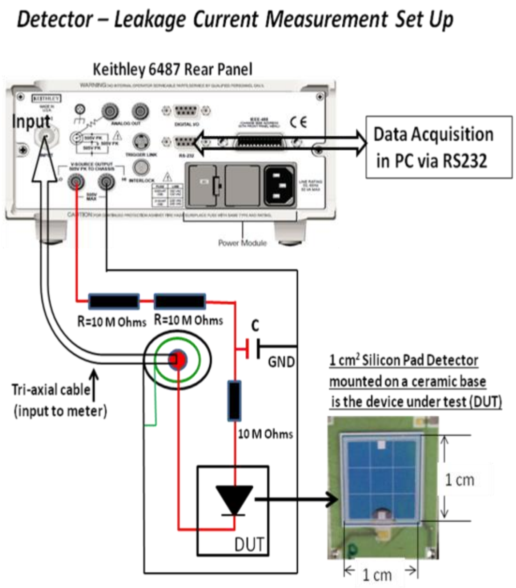

Fig. 1 Measurement setup for the leakage current showing the interface of the Keithley meter with the 1 cm^2 Silicon PAD through a triaxial cable and data transfer to PC through RS232

It measures the current drawn through the device under test (DUT) which is placed across its terminals. The voltage sweep technique is used [4], varied in steps of 5 volts and the leakage current is measured at each step through a tri-axial cable attached to the detector. The detector is kept in a light tight arrangement to avoid any ambient light entering in it. The leakage current continuously fluctuates over a range at a given value of reverse bias, so an arrangement is made in the meter to average out all the fluctuating values of leakage current over few seconds. This averaged value of leakage current is sent out to a PC via RS 232 for storing, plotting and further processing as shown in the Fig.1.

Detector capacitance is also measured using LCR meter (Agilent E4980A) over wide range of frequencies. The procedure for taking C-V measurements involves the application of DC bias voltages across the capacitor (detector) while making the measurements with an AC signal. AC frequencies from about 1kHz to 1MHz are used for this measurement.

Results

Leakage current for 300 µm thick, 1 cm^2 Silicon detector is measured. Fig. 2 shows the typical I-V characteristic of the device under test. At 100 volts reverse bias, leakage current is about 10nA/cm^2, which is in good agreement with the specifications of the manufacturer Bharat Electronics Limited Bangalore. All the measurements are done at the room temperature.

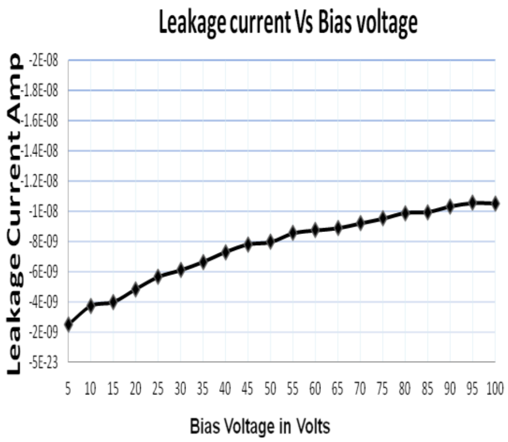

Fig. 2 Typical I-V characteristic curve for 300 µm thick, 1 cm^2 Si (PIN) pad detector.

Detector capacitance is measured with the sweep of bias voltage. The diode capacitance decreases as the reverse bias voltage is raised until the diode is fully depleted, as shown in Fig. 3. As a thumb rule the operational voltage of a silicon detector is about 1.5 times the full depletion voltage [5]. From the derived C-V curve the full depletion voltage is approximated about 50 volts, with an operational voltage of about 75 -80 volts.

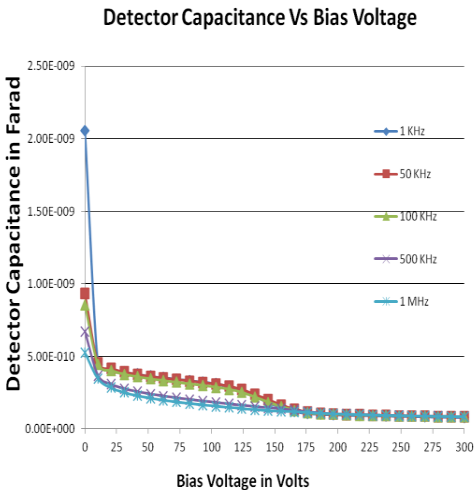

Fig. 3 Typical C-V characteristic curve for 300 µm thick, 1 cm^2 Si (PIN) pad detector, over range of frequencies.

The detailed results will be presented.

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