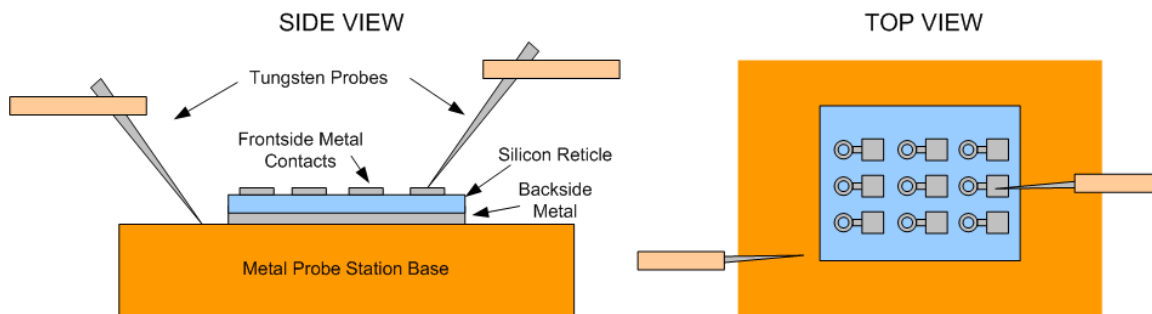


ECEn 555 – Optoelectronics Devices Lab
Week 4
“Photodiode Test”

In this lab you will take the photodiode structures you have been working with in previous weeks and complete their processing by doing some annealing. You will then characterize your diodes by completing electrical only testing as well as testing using optical sources.

Major Objectives

1. Wafer Cleaving. Have a supervisor demonstrate the correct procedure for cleaving silicon wafers (the nick and press method). When you are confident in your cleaving skills, cleave your photodiode wafers so that you have at least one entire photodiode reticle on a piece of silicon. Cleave up at least three of these pieces.
2. Metal Annealing. After the deposition of metal onto a semiconductor surface, typically an annealing step is done. This anneal is done by placing a wafer into a high temperature furnace for a given amount of time, usually with a specific gas environment inside the furnace. The purpose of the anneal is to decrease the contact resistance between the metal and the semiconductor by causing a small amount of metal and semiconductor to go into “solution.” Using the annealing furnace, anneal at least three silicon reticle pieces at different temperatures. Use a nitrogen atmosphere in the tube and anneal each piece for 5 minutes. Choose your different annealing temperatures between the range of 350 and 450C.
3. Diode Measurements. You are now ready to measure the electrical characteristics of your diodes using the probe station in the cleanroom and HP4145 parameter analyzer. Instructions for using the parameter analyzer are available on the cleanroom website. To test your diodes you will need to make contact to the metal pads on your diodes using the probes as illustrated in the diagram below:



These devices should behave like diode so sweep them from a negative voltage to a positive and determine how “diode-like” they are. Measure the reverse bias saturation current or “dark current”. Test photodiodes of different diameters. Does this vary for diodes of different diameters? Should it? The diameters are explained at the end of the lab.

4. Series Resistance and Frequency Response – The series resistance can be determined by forwarding the diode well above “turn on” on measuring the slope of I vs. V to get resistance. Measure the series resistance for the samples that you annealed under different conditions. Use the sample with the lowest series resistance for all further measurements. Using the series resistance, and estimating the diodes capacitance from what you know about its geometry, estimate the frequency response for your photodiodes based on their diameter.

5. Light Intensity – For the next steps you will move to the probe station in the room next to the cleanroom. There you will find several light sources including some LEDs, a laser, and an illuminator used for a microscope. You will use these to illuminate your detectors and determine their responsivity. To do so, you will use a large area commercial silicon photodiode, an oscilloscope, and the HP4156 – a parameter analyzer similar to the HP4145.
The silicon photodiode has been wired up into an optical receiver configuration outlined in the attached datasheet with a feedback resistor of 1000 ohms. Connect this receiver to a power supply and an oscilloscope. Bias the receiver to 10 V. Note that the photodiode you will use is different than the one in the spec sheet. Information about your diode can be found at:
[://www.edmundoptics.com/onlinecatalog/displayproduct.cfm?productID=1305&PageNum=1&StartRow=1](http://www.edmundoptics.com/onlinecatalog/displayproduct.cfm?productID=1305&PageNum=1&StartRow=1) Your diode model is: NT53-372
Place your optical sources above the large area silicon detector the same distance apart that you will use between the sources and your fabricated photodiodes. Measure the change in current through the diode when the source is on. Use the specs on the photodiode to determine its active area and determine how many amps/cm² the detector produces under illumination for each source. It will be necessary to do this because your photodiodes are much smaller than the large area detector and we want to make a fair comparison. For the laser, which has a small beam diameter, you should estimate the beam diameter hitting the detector to get a measure of amps/cm². Given the responsivity of the detector, you should be able to compute the total amount of light emitted by each source.

6. Photodiode Responsivity – Now that you have a good idea of how much current your photodiodes should produce for each of the sources, use the probe station to connect to them as you did in step 3. Illuminate with each of the sources. After measuring the photocurrent divide by the area of the photodiode to determine an amps/cm² number for your photodiode. Was this the same as the large area photodiode? Try some of your photodiodes of different diameter. Are the amps/cm² values the same? If not why not? One hint might be that light beams tend to be Gaussian profiles and are usually brightest in their middles.

Photodiode Diameters.

The photodiodes were originally designed in a set of 25 of varying diameters. The smallest has a diameter of 50 microns and the largest, 500 microns. They increase in size in 18 micron increments from smallest to largest. Why 18 microns? We wanted to make the arithmetic as challenging as possible.

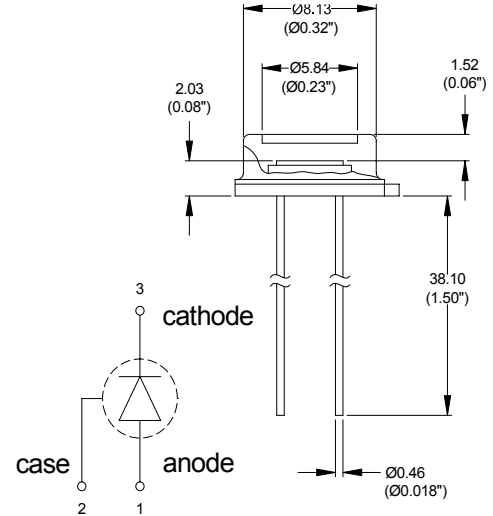
FDS100 Si Photodiode

High Speed
Large Active Area

The FDS100 is a high-speed silicon photodiode with a spectral response from 350nm to over 1100nm. This photodiode has a PIN structure that provides fast rise and fall times with a bias of 20V.

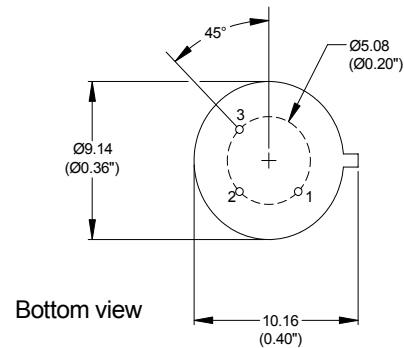
Electrical Characteristics

Spectral Response:	350-1100nm
Active Area:	13.0mm ²
Rise Time (RL=50Ω):	10ns (20V bias)
Fall Time (RL=50Ω):	10ns (20V bias)
NEP@900nm:	1.2 x 10 ⁻¹⁴ W/√Hz (@20V bias)
Dark Current:	20nA max (20V)
Package:	T05, 0.36" can



Maximum Ratings

Damage Threshold CW:	100 mW/cm ²
Damage 10ns Pulse:	500mJ/cm ²
Max Bias Voltage:	25V



Pin Description

1. Laser anode
2. Laser case
3. Laser cathode

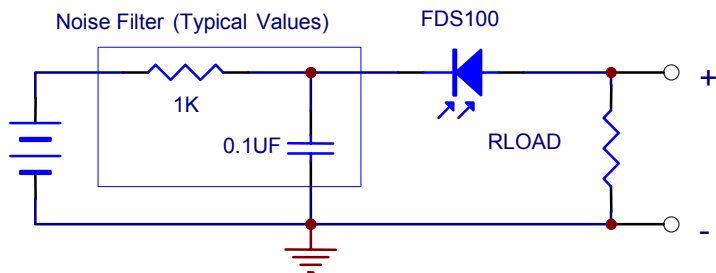
The Thorlabs FDS100 photodiode is ideal for measuring both pulsed and CW light sources, by converting the optical power to an electrical current. The Si detector is housed in a T05 can, with an anode, cathode and case connection. The photodiode anode produces a current, which is a function of the incident light power and the wavelength. The responsivity $\mathfrak{R}(\lambda)$, can be read from **Figure 1** to estimate the amount of photocurrent to expect. This can be converted to a voltage by placing a load resistor (R_{LOAD}) from the photodiode anode to the circuit ground. The output voltage is derived as:

$$V_O = P * \mathfrak{R}(\lambda) * R_{LOAD}$$

The bandwidth, f_{BW} , and the rise time response, t_R , are determined from the diode capacitance, C_J , and the load resistance, R_{LOAD} , as shown below. Placing a bias voltage from the photo diode cathode to the circuit ground can lower the photo diode capacitance.

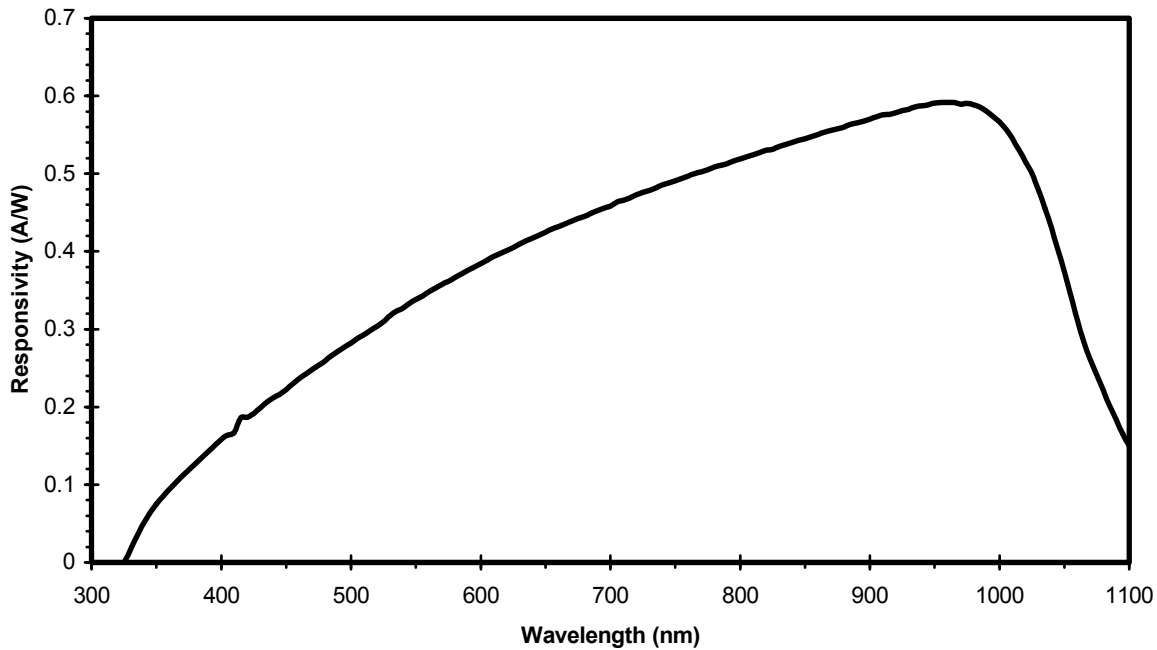
$$f_{BW} = 1/(2\pi * R_{LOAD} * C_J), t_R = 0.35/f_{BW}$$

Typical Circuit Diagram



Typical Plots

Figure 1 - FDS100 Spectral Responsivity Curve



Typical Responsivity Curve using Thorlabs calibration services.