

SLATT UNDERGRADUATE RESEARCH FELLOWSHIP FINAL REPORT

SCHOLAR NAME:	Ruben Torres Gonzalez
FACULTY ADVISOR:	Prof. Patrick Fay
PROJECT PERIOD:	22 of May to 29 of July of 2023
PROJECT TITLE:	Measurement of Wide Band Gap Semiconductor Power Devices
CONNECTION TO ONE OR MORE ENERGY-RELATED RESEARCH AREAS (CHECK ALL THAT APPLY):	<input checked="" type="checkbox"/> Energy Conversion and Efficiency <input type="checkbox"/> Sustainable and Secure Nuclear <input checked="" type="checkbox"/> Smart Storage and Distribution <input type="checkbox"/> Transformation Solar <input type="checkbox"/> Sustainable Bio/Fossil Fuels <input type="checkbox"/> Transformative Wind

MAJOR GOALS AND ACCOMPLISHMENTS

Summarize your research goals and provide a brief statement of your accomplishments (no more than 1-2 sentences). Indicate whether you were able to accomplish your goals by estimating the percentage completed for each one. Use the next page for your written report.

RESEARCH GOALS	ACTUAL PERFORMANCE AND ACCOMPLISHMENTS	% OF GOAL COMPLETED
Found efficient ways to measure each semiconductor.	Different ways of measuring were examined and experimented for. Using two probes with the semiconductor attached to a copper plaque and silver between them two was a step forward.	100
Verify how the length of the used cables impact on the behavior of the conductivity.	Different cable sizes were used to examine the behavior of the current. It was found that the shorter the cable the less the ringing, but then the device was not conducting. It needs to be examined why the device is not conducting with shorter cables.	75
Analyze the behavior of the semiconductors once the reverse bias voltage is applied.	After extent simulations it was found how the device was supposed to behave and what we should expect to see each time it was simulated.	100

RESEARCH OUTPUT

Please provide any output that may have resulted from your research project. You may leave any and all categories blank or check with your faculty advisor if you are unsure how to respond.

CATEGORY	INFORMATION
EXTERNAL PROPOSALS SUBMITTED	(Sponsor, Project Title, PIs, Submission Date, Proposal Amount)
EXTERNAL AWARDS RECEIVED	(Sponsor, Project Title, PIs, Award Date, Award Amount)
JOURNAL ARTICLES IN PROCESS OR PUBLISHED	(Journal Name, Title, Authors, Submission Date, Publication Date, Volume #, Page #s)
BOOKS AND CHAPTERS RELATED TO YOUR RESEARCH	(Book Title, Chapter Title, Authors, Submission Date, Publication Date, Volume #, Page #s)
PUBLIC PRESENTATIONS YOU MADE ABOUT YOUR RESEARCH	(Event, Presentation Title, Presentation Date, Location)
AWARDS OR RECOGNITIONS YOU RECEIVED FOR YOUR RESEARCH PROJECT	(Purpose, Title, Date Received)
INTERNAL COLLABORATIONS FOSTERED	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions)
EXTERNAL COLLABORATIONS FOSTERED	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions)
WEBSITE(S) FEATURING RESEARCH PROJECT	(URL)
OTHER PRODUCTS AND SERVICES (e.g., media reports, databases, software, models, curricula, instruments, education programs, outreach for ND Energy and other groups)	(Please describe each item in detail)

RESEARCH EXPERIENCE

Please let us know what you thought of your research experience: Did this experience meet your expectations? Were lab personnel helpful and responsive to your needs? What else could have been done to improve your experience or achieve additional results?



This was my first research experience of my college life, so I did not know what to expect. Now that this opportunity has ended, I can say I learned a lot through this experience. It has put my expectations high for futures experiences. The people I met throughout this experience were really patience, helpful and nice towards me. The only thing that could have been done to improve my experience was to be able to pass more time with the graduate student that I was assigned to (she needed to leave to another internship three weeks into my research).

FINAL WRITTEN REPORT

(Please use the space below to describe your research project and objectives, any findings and results you can share, and graphs, charts, and other visuals to help us understand what you achieved as a result of this research experience.)

The research project I have been working throughout the summer was "Simulation and Characterization of Wide Band Gap Power Devices". During this research our objectives were to learn how the semiconductors were supposed to behave and base on this look for efficient ways to measure each semiconductor. Through the process we learn that attaching the semiconductor to a copper plaque using silver gave us the option of using two probes instead of one. This gave us more accurate measurement each time a simulation was made. We learn too that the length of the cables was creating a sort of oscillation that could be called ringing. The longer the cable the more the ringing the semiconductor would experiment in each simulation. We then start using shorter cables and the ringing was diminished, but the semiconductor was still experiencing some ringing. This research should be continued to keep looking for ways to eliminate the ringing completely without affecting the conductivity of the semiconductor. This is an important research because semiconductors are used in our daily life devices, so we need them to be the most reliable they can be. This can only be achieved by making sure the semiconductors designed and build are working properly and as expected. As tedious as measuring can be, because is a repetitive process, is really important to be a well-executed process.

Measurement of Wide Band Gap Semiconductor Power Devices

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Abstract

The importance of semiconductors in our daily life is more significant than we often think. Since these devices, put in a simplified way, help conducting the energy that electronic devices need, and do so in an efficient and secure way. These electronic devices range from phones, to computers, to cars, and even to industrial controllers. Nearly every device that uses energy in some way, takes advantages of semiconductor devices for operation. As technology progress and innovates, semiconductors are being designed and created smaller. The reason for this is to have more efficient devices. In this research we are focusing on semiconductors that are power devices based on wide band gap semiconductors. The target application for these devices are for circuits requiring operation at higher voltages and temperatures. In this project, pn junction rectifiers (diodes) based on GaN (Gallium Nitrate) with different areas that range from 35, 70, 160, 325 and 550 um (micrometers) in diameter were measured and assessed in terms of performance. In particular, we have been investigating the reverse recovery transient and charge storage effects in vertical GaN pn junctions. The measurements have been performed using the Keysight B1530 plugin in conjunction with a Keysight B1500 semiconductor parameter analyzer, connected to a probe station for making electrical contact to the devices. We have found that using short cables is essential to minimize ringing or interference that adversely impacts the accuracy of the measurement.

Introduction

Semiconductors have been intensively researched and worked on for a long time. However, for the needs and challenges of today's advancing technology is important to keep on researching and working on semiconductors. That's why during this research we are focusing on the measurement of wide band gap semiconductor power devices. Although these semiconductors are for wide band gap power devices, they are of microscopic scale, because we are trying to conduct as much current as possible through smaller devices. Which will occupy a lot less space inside the components. Deriving in easier ways to maintain a cooling system for the components. As we measure each device conducting capability and behavior the focus is mainly put on how the device behave once a reverse bias voltage is applied. Reverse bias voltage means when a sudden change of voltage occurs. For example, when we turn a lightbulb on and off. In this example we can visualize that when we turn a lightbulb off or a phone off, we expect to turn off and not be going on and off for a few seconds. Instead, we expect it to be an instant change. That's what we want to measure with the semiconductors, that they comply with the capability to stop conducting when we need them to.

Objectives

- Found efficient ways to measure each semiconductor.
- Verify how the length of the used cables impact on the behavior of the conductivity.
- Analyze the behavior of the semiconductors once the reverse bias voltage is applied.

Materials

- Copper
- Aluminum
- GaN based Semiconductors
- Keysight B1530
- Keysight 1500
- Probe Station
- Cables

Procedure

Preparing the Wide Band Gap Semiconductor:

- Apply aluminum on the copper plaque.
- Attach the semiconductor back to the aluminum on the copper plaque.

Prepare the Lab Instruments:

- Connect Keysight B1530 in conjunction with Keysight 1500 to the probe station.
- Introduce the semiconductor attach to the copper plaque to the vacuum chamber of the probe station.
- Move the probes so that one is contacting the semiconductor and the other the copper plaque.

It is important to be careful that the probes aren't damaging the semiconductor or the copper plaque. This will result in bad measurements.

Results

- The use of aluminum to attach the semiconductor to a copper plaque is important, given that improve conductivity.
- The use of two probes is indispensable to take the measurements as it helps in making a more accurate simulation.
- Recovery time of each diameter in the semiconductor is similar.
- Long cables contribute to the ringing or interference effect in the conduction of current.

Next-Steps

- Continue the measurements on the different diameters of the devices with shorter cables.
- Compare the recovery time for the different cable sizes.
- Vary the range of the voltage apply to the simulation to confirm the behavior of the device.
- Using the same parameters and procedure. Apply it to other semiconductors analyze its behavior of conduction.

Conclusion

This research shows us the importance of not only measuring semiconductors devices, but how they need other components to work properly, to their full potential. How the set up and the elements utilize to conduct (such as aluminum and copper) current have an impact in how the semiconductor is going to behave. This is important for futures references and works around this research and topic. Because is not only important to take in consideration if the semiconductor is working how we envisioned, but if the instruments and components used around the semiconductor are the ones needed for it to work on an optimal level. Further, the data collected and the graphs we accomplished through these data. Demonstrate how versatile and efficient the semiconductors are conducting the necessary current.

References

- Y. Irokawa, B. Luo, Jihyun Kim, J. R. LaRoche, F. Ren, K. H. Baik, S. J. Pearson, C.-C. Pan, G.-T. Chen, J.-I. Choi, S. S. Park, Y. J. Park, Current-voltage and reverse recovery characteristics of bulk GaN p-i-n-p-i-n rectifiers. *Appl. Phys. Lett.* 15 September 2003; 83 (11): 2271-2273. <https://doi.org/10.1063/1.1611624>
- Hitachi. (2015, February 12). Ringing phenomenon during recovery of power diodes. https://www.hitachi-power-semiconductors.com/en/products/igbt/pdf/ringing_diode.pdf
- V. Khenka, R. Patel, T.P. Chow, R.J. Gutmann, Design considerations and experimental analysis for silicon carbide power rectifiers, *Solid-State Electronics*, Volume 43, Issue 10, 1999, Pages 1945-1962, ISSN 0038-1101, [https://doi.org/10.1016/S0038-1101\(99\)00155-0](https://doi.org/10.1016/S0038-1101(99)00155-0)

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