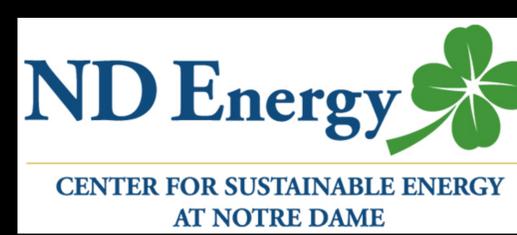




GaN Vertical Junction Field-Effect Transistors for Energy-Efficient Power Conversion



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Problem

It has been estimated that more than 10% of all electricity is lost during power conversion. This loss happens when electricity is converted from one voltage to another, from AC to DC, and from DC to AC.

Research Focus

Transistors made from GaN are being investigated for more efficient high-power applications that can switch 100 A with a maximum operating voltage of 1,200V. This project used Synopsys Sentaurus TCAD to evaluate the performance of different GaN vertical junction field-effect transistors based on device dimensions and doping levels.

Project Overview

The basic cross-section of a vertical junction field-effect transistor (V-JFET) is shown in Figure 1.

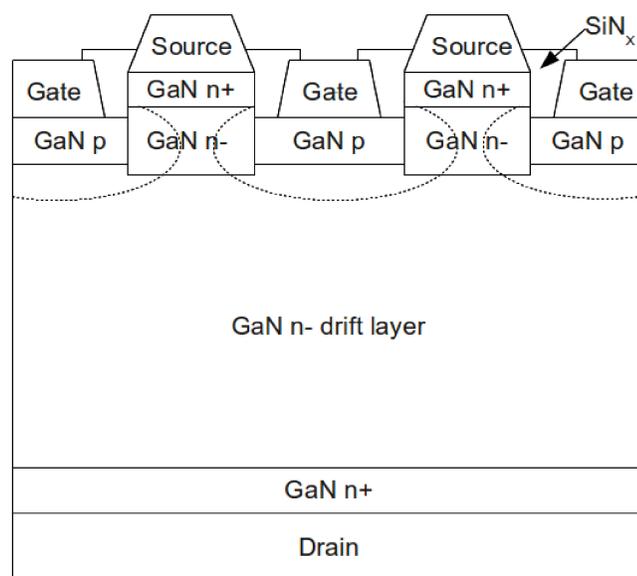


Figure 1 Cross-section of GaN V-JFET

The thickness, length, and doping of each layer was adjusted to optimize the best Id-Vd curve.

Results

The optimized GaN V-JFET using Sentaurus Visual is in Figure 2.

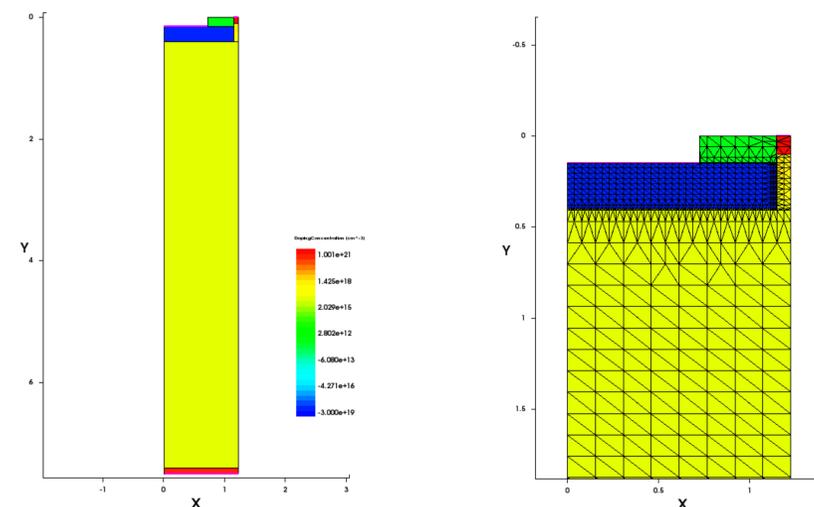


Figure 2 V-JFET doping levels and mesh size are shown.

For this device, the Id-Vg curve for Vd = 1,200V, Vs=0V is shown in Figure 3 and the Id-Vd curves are shown in Figure 4.

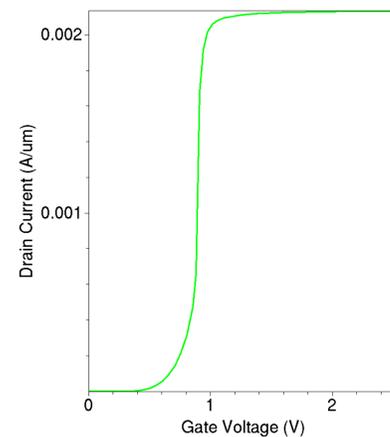


Figure 3 Id-Vg Curve

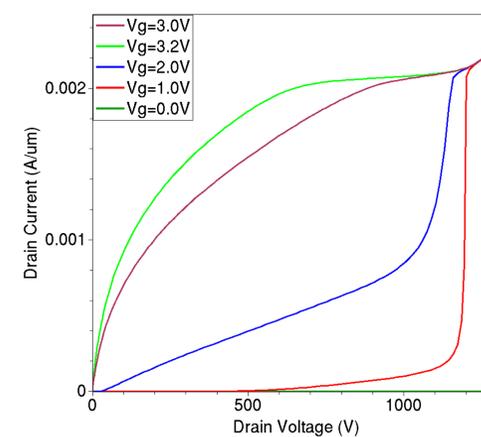


Figure 4 Id-Vd Curves

Id-Vg shows that the threshold voltage is about 0.2V and Id-Vd shows the breakdown voltage happens around 1,200V.

Conclusion

The simulation shows that it is possible to use a GaN V-JFET for high-power switching. More simulation time will be able to fine tune this device to increase Id.

Curricular Connection

This project can be directly connected with the Indiana standards for 7th grade science. Indiana requires their students to understand how energy can be transformed from one form to another and recognize the environmental consequences of obtaining, transforming, and distributing energy.

Energy Conversion Unit

After introducing terminology, students will spend time as a group and individually diagramming the energy entering and leaving various systems. They will apply the concept of energy conservation to each system. They will also discuss the efficiency of the energy transformations as they diagram the energy that is leaving the system in terms of both desired and undesired or waste energy.

Students will also design, build, test, and redesign a rubber band powered car that will convert elastic potential energy to kinetic energy. Students will be given the freedom to explore different designs. Figure 5 shows some of the variety that students will have in their designs.

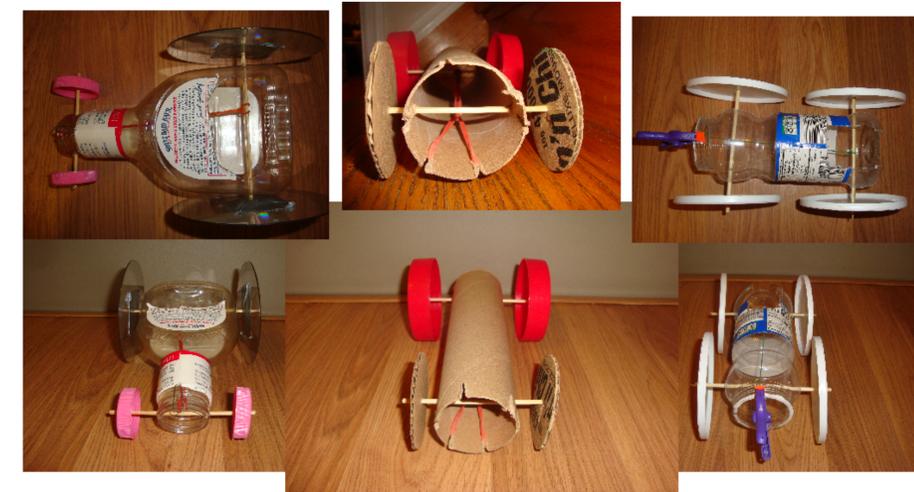


Figure 5

At the end of the activity students will be able to compete against each other to see which design allows the car to travel the furthest distance.

Conclusion

The Energy Conversion Unit teaches students energy related terminology, has students apply these concepts to real world examples, and allows students to actually design and work with energy to perform a specific task. In this way, student have time to deepen their understanding of energy and not only take these concepts with them to the next classroom but beyond the walls of the school building as well.