NDnano
Notre Dame Nanoscience and Technology

NDnano Summer Undergraduate Research
2024 Project Summary

1. Student name & home university:

Daniel Augusto Gonzalez Trujeque
Universidad de las Américas Puebla

2. ND faculty name & department:

Department of Physics and Astronomy

3. Summer project title:

Heterostructure assembly, nanofabrication and characterization of low-dimensional materials

4. Briefly describe new skills you acquired during your summer research:

- Find WSe2 Monolayer via mechanical exfoliation
- Transfer the monolayer to a silicon oxide substrate
- Cut the monolayers and remove the different chunks to isolate them
- Create hBN and couple with WSe2 monolayer
- Create bottom gate and couple it with WSe2 and hBN
- Assisting in developing nanofabrication protocols that lead to a good electrical contact to WSe2 monolayer
- Understanding of equipment such as Glove Box, Transfer stage, Optical microscope, Plasma.
- Teamwork
- Leadership

5. Briefly share a practical application/end use of your research:

WSe2 monolayers can be used to fabricate FETs with excellent electrical properties, including high carrier mobility and an optimal bandgap for transistor applications. When combined with other two-dimensional materials, such as graphene or hexagonal boron nitride (h-BN), these heterostructures can exhibit improved performance characteristics.

6. 50- to 75-word abstract of your project:

Transition metal dichalcogenide (TMD) tungsten diselenide (WSe_2) has emerged as a promising material for advanced semiconductor applications due to its unique electronic and optical properties. This study investigates the synthesis, characterization, and potential applications of WSe_2 monolayers in the semiconductor industry. They hold substantial promise for future semiconductor technologies, offering pathways to miniaturized, high-efficiency electronic and optoelectronic devices.

7. References for papers, posters, or presentations of your research:

Auwärter, W. (2019). Hexagonal boron nitride monolayers on metal supports: Versatile templates for atoms, molecules and nanostructures. *Surface Science Reports*, *74*(1), 1-95. https://doi.org/10.1016/j.surfrep.2018.10.001

Joseph, A., Mahesh, V., Mahesh, V., & Harursampath, D. (2022b). Structural analysis of graphene-based composites. En *Elsevier eBooks* (pp. 91-120). https://doi.org/10.1016/b978-0-12-823789-2.00006-6

Geim, A. K., & Grigorieva, I. (2013). Van der Waals heterostructures. *Nature*, *499*(7459), 419-425. https://doi.org/10.1038/nature12385

In this summer research we work with WSe2, a transition metal dichalcogenides represent a unique class of two-dimensional layered materials that can be exfoliated into single or few atomic layers. Tungsten diselenide (WSe2) is one typical example with p-type semiconductor characteristics. Bulk WSe2 has an indirect band gap (~1.2 eV), which transits into a direct band gap (~1.65 eV) in monolayers. Monolayer WSe2, therefore, is of considerable interest as a new electronic material for functional electronics and optoelectronics (Hailong Zhou, 2015).

In this project I have been working developing devices to utilize new properties of WSe2 monolayer couple with hBN and Graphite, I have been working in the development of this devices, with a manual synthesis using a transfer stage set up, first finding a good WSe2 monolayer at least 10x10 micrometers or more, after that I have to do a transfer from a PDMS substrate to a silicon oxide substrate for me to be able to isolated it, via cutting the expedients with a nano blade, after that removing this expedients with a PC film couple with PDMS, after having my monolayer isolated, I try to find a hBN monolayer in order to start doing my heterostructure device, after finding a good candidate I have to remove the hBN with another PC film with PDMS and picking it up, after having my hBN on the PC film I have to pick my WSe2 monolayer with it in order to couple them, when I am finish with this I have the first part of my heterostructure devices, for the next part I have to create a bottom gate, for the creation of the bottom gate I follow the same steps, just using graphite instead of WSe2 Monolayers.

Also, I work improving the way we get WSe2 monolayers via mechanical exfoliation, finding better ways to collocate WSe2 crystals on the tape to get more monolayers and better quality of them, also exploring other parameters like plasma power, or heating on hot plate, this with the purpose of increase the stickiness of PDMS. I was able to get this device done this this part, and I gave it to, Som Subhra so he could continue with the work and finish it, He will use this device I gave him and make contacts on the clean room, in order to be able to publish this paper, and understand these new properties of WSe2.