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NDnano Summer Undergraduate Research
2021 Project Summary

1. Student name & home university: Brenda Cruz González | Universidad de las Américas Puebla (UDLAP)

2. ND faculty name & department: Professor Prakash D. Nallatamby | Aerospace and Mechanical Engineering (AME)

3. Summer project title: Magneto-silica Nanoparticles (MagSiNs) for Combinatorial Chemotherapeutics and Gene Delivery Against Metastatic Cancers

4. Briefly describe new skills you acquired during your summer research:
In this summer research, I have been developing technical and soft skills in the STEM area. The NDNano program has tools that help you improve some skills that are also important to develop in the science area, we had webinars where they talked about scientific topics that may be interesting in different fields of research, they talked about the Grad School and the programs offered by Notre Dame. And also, we had some social interaction with other Notre Dame programs and with our program, this kind of activities at first seems to be not relevant, but as an undergrad student are useful to grow your network and of course to make friends. Now I have a better understating of how to do quality research for information for a scientific investigation, how to create a poster, how to communicate your research according to the public. In general, the NDNano program offers us integral training in the research area.

5. Briefly share a practical application/end use of your research:
The main objective of our project is to use the Gold Janus Silica Nanoparticles for drug delivery applications. The Janus behavior proves us a noble interaction with the human body since in this research we are using two thiols terminated polymers immiscible between them, PEG and PS, making the nanoparticle more stable and biocompatible. One of those polymers is hydrophilic and the other is hydrophobic making the Nanoparticle is amphiphilic. Since PEG is considered a hydrophilic polymer, this acts as a primer to promote a semi-Silica coating, and hopefully, in the future, we can load this Silica coating, since is a mesoporous material, with a drug for cancer treatments.

6. 50- to 75-word abstract of your project:
Gold-Silica Janus Nanoparticles
Nanotechnology has become one of the most important sciences for innovation in material sciences nowadays and mostly in the medicine field. In this research is reported a Gold Nanoparticles with Janus behavior (Janus AuNPs) as a novel method to do drug delivery to cancer cells. The novelty in this Janus nanoparticle is the immiscible nature of two thiol-derived polymers on the gold surface, Polyethylene glycol (PEG) and Polystyrene (PS), which can self-assemble on the gold in a tunable fashion by varying the size, polymer ratio and temperature, among other experimental parameters [1] but at the same time, one of the two polymers used (PEG) acts as a primer and therefore a partial SiO_2 coating is added to the gold nanoparticle to create a Janus structure [2]. This means that we could improve the biocompatibility and stability in biological environments, such as the human body. Therefore, Janus AuNPs in the future seems to be a promising noble nanoparticle that improve the drug delivery in cancer cells while incorporating multiple modalities.

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

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[2] Fang, L., Wang, W., Liu, Y., Xie, Z., & Chen, L. (2017). Janus nanostructures formed by mesoporous silica coating Au nanorods for near-infrared chemo–photothermal therapy. Journal Of Materials Chemistry B, 5(44), 8833-8838. doi: 10.1039/c7tb02144e

[3] P.G. de Gennes. Soft matter, Science, 256 (5056) (1992), pp. 495-497

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[6] Ross, R., Cole, L., Tilley, J., & Roeder, R. (2014). Effects of Functionalized Gold Nanoparticle Size on X-ray Attenuation and Substrate Binding Affinity. Chemistry Of Materials, 26(2), 1187-1194. doi: 10.1021/cm4035616

[7] K. Kim, J.H. Guo, Z.X. Liang and D.L. Fan. Artificial micro/nanomachines for bioapplications: biochemical delivery and diagnostic sensing. Adv. Funct. Mater., 28 (25) (2018), p. 1705867.

[8] Rodzinski, A., Guduru, R., Liang, P. et al. Targeted and controlled anticancer drug delivery and release with magnetoelectric nanoparticles. Sci Rep 6, 20867 (2016). https://doi.org/10.1038/srep20867

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One-page project summary that describes problem, project goal and your activities / results:

The main goal of this research is the synthesis and characterization of Janus Nanoparticles for biomedical applications. An important challenge in treating cancer in general is to find a technology for a controlled target drug delivery and release to eradicate tumor cells while sparing normal cells [8] and because of this, find the best way to get the drug only be released in the specific cancer cells is needed. One of the complications of cancer is the propagation in the living organs because if we can't control it could be not reversible and the secondary effects that the cancer treatment can bring with them.

The use of nanostructured materials in the biomedical area has been of great interest in recent years thanks to the fact that they have different properties from those of bulk materials, due to the surface area, since the smaller the particle, the greater the surface area, which translates to being more reactive. Research in nanomedicine spans a multitude of areas, including drug delivery, vaccine development, antibacterial, diagnosis and imaging tools, wearable devices, implants, high throughput screening platforms, etc. using biological, nonbiological, biomimetic, or hybrid materials [9]. The interesting thing is that Nanomedicine differs from other types of medicine in that it involves the development and application of materials and technologies with nanometer length scales to function in diagnosing, treating, curing, monitoring, predicting, and preventing [10]. And this is important because now we can think about other approaches to prevent or cure illnesses that could be from an external wound to more complex diseases, such as cancer.

In the Nallathamby group, this summer we were working on the synthesis and characterization of Silica Gold Janus Nanoparticles. The first synthesis that we made was the Gold Nanoparticle (AuNPs) by the citrate reduction method previously reported. With this synthesis, we obtained AuNPs with an average diameter of 15.77 nm. Then, these AuNPs were coated with Polyethylene glycol (PEG) and Polystyrene (PS) that were assembled to the AuNPs surface by chemisorption. This coating provides the Janus behavior in the gold nanoparticle and finally, the Silica coating was made using the core-shell technique but, since the nanoparticle has an amphiphilic behavior, we obtain a semi-Silica coating. Between each step of the process, the characterization of our materials as needed to ensure that the material obtained was the desired one. The UV-vis spectroscopic analysis, Raman + IR, and TEM were used in this research and some of the results that we obtained are the next ones.

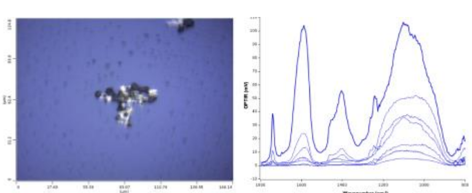

Figure 1. Raman + IR analysis of AuNPs@PEG-PS

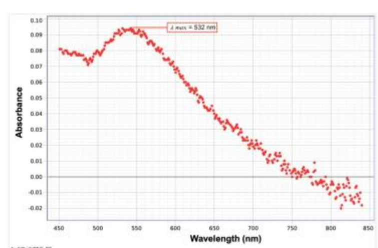

Figure 2. UV-vis spectroscopic analysis of the synthesis of AuNPs@PEG-PS with a λ_{max} at 532 nm

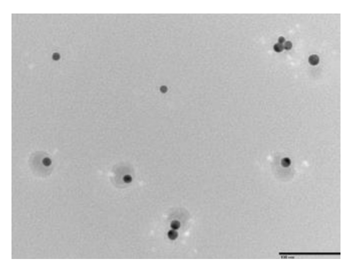

Figure 3. Transmission Electron Microscopy (TEM) of AuNPs@PEG-PS@SiO_2 with an average diameter of (15.77 ± 2.01) nm for the gold nanoparticle and a (15.50 ± 4.58) nm as an average thickness of the Silica coating.

The results of this research indicate that we are very close to achieving the goal since we could obtain the Janus nanoparticle but, there is still work to do with this nanostructure. For the last week, we were working with an Iron Oxide coating instead of the Silica coating since both structures are similar regarding the porosity since the size of the porous in both structures is similar and this property could be useful for drug delivery applications.