ND*nano* Undergraduate Research Fellowship (NURF)
2014 Project Summary

1. Student name: Margaret Best

2. Faculty mentor name: Dr. Ryan Roeder

3. Project title: Nanoparticle contrast agents for spectral (color) X-ray imaging

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

Throughout the summer, I became proficient in using ImageJ software through determining the best plugin to perform spectral unmixing of CT-scanned nanoparticle phantoms. I learned how to make gold nanoparticles in solution and how to conjugate certain groups to their surfaces to make them soluble in different solutions and make them stable upon freeze drying. I also learned how to formulate my own methods of monomer polymerization and adjust them accordingly to each problem that I encountered.

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

My research will provide permanent nanoparticle phantoms that contain known concentrations of nanoparticles. These can be used to determine threshold values for CT imaging and offer a comparison for samples that are imaged in the future. My research regarding ImageJ will provide an insight to the most effective method for spectral unmixing for analyzing X-ray images to give them color. This could eventually be used in imaging to differentiate between different soft tissues, for example in helping detect tumors.

Project Summary:

Nanoparticle contrast agents allow for enhanced X-ray attenuation through their high atomic numbers and can be distinguished on the basis of their K-edge energies. The use of multiple nanoparticles as contrast agents could provide spectral (color) X-ray imaging. Absorption edges occur when the photon energy of X-rays reaches a sufficient level and inner shell electrons from the sample are ejected. The nanoparticles have different absorption edges, giving them different attenuation values at specific photon energies (Figure 1). These absorption edges allows for possible unmixing of attenuation profiles to then merge into one falsely-colored image. The first objective of this project was to determine the best method of spectral unmixing to achieve the colored X-ray images. The second objective was to create phantoms made of nanoparticles dispersed in a polymer that would be permanent for future use.

To accomplish the first project goal, different ImageJ plugins associated with spectral unmixing (designed for use with fluorescent dyes) were tested to determine which would most effectively create a colored X-ray image. Previously scanned phantoms (containing nanoparticles dispersed in water) were used to test the plugins. Three plugins, which used nonnegative matrix factorization to determine the pixels associated with different energy levels, were found to create colored images (Figure 2). The PoissonNMF plugin was determined to be most consistently successful.

The second project goal was accomplished by testing multiple hydrogel and polymer systems and different polymerization methods. A methyl methacrylate (MMA) monomer was considered for photopolymerization or with a poly(methyl methacrylate) (PMMA) powder. Gold nanoparticles (AuNPs) were used in the subsequent experiments with different molecules conjugated to their surfaces. AuNP solutions were mixed with MMA and added to PMMA to polymerize. The method using PMMA powder was very quick polymerization but introduced many air bubbles and was difficult to formulate an official protocol. Using two co-initiators, photopolymerization was performed using oleylamine AuNPs and silica shell AuNPs under a UV light source. The solution was degassed before photopolymerization and was placed in the UV light in a vortex to keep the AuNPs from settling. This allowed for successful polymerization of the MMA with the silica AuNPs permanently suspended in the solution. The photopolymerization of the silica AuNPs in MMA was determined as the best method for the phantoms. However, further experimentation is still necessary to optimize and standardize the polymerization process.

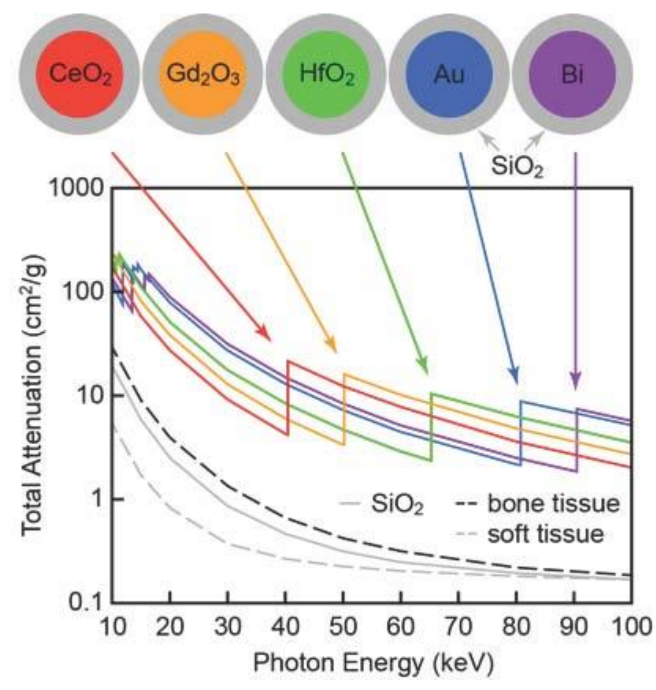

Figure 1. The photon mass attenuation coefficient versus the photon energy for different materials. The K-abosrption edges range from ~40 to 90 keV and the L-absorption edges range from ~10 to 20 keV. This project focused on gadolinium oxide (Gd_2O_3), hafnium oxide (HfO_2), and gold (Au).

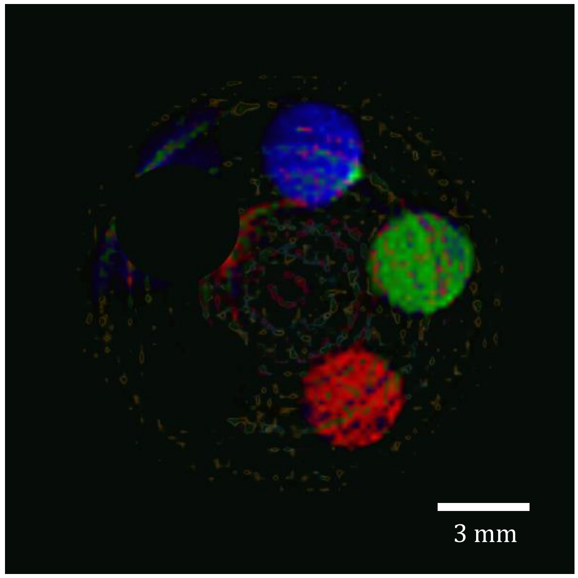

Figure 2. Spectral (color) X-ray image of nanoparticle phantom containing 50 mM of each nanoparticle in small wells. In the image, blue is gold (Au), green is hafnium oxide (HfO_2), and red is gadolinium oxide (Gd_2O_3). This was made using the PoissonNMF plugin in ImageJ.