Synthesis and Characterization of Apatite Nanoparticles for Bioengineering Applications

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Apatite nanoparticles have long been used for their biomimicry and their ability to safely deliver drugs and serve as scaffolds for bone tissue engineering.[1] By synthesizing these particles at physiological pH and recognizing their structure to be typical of bone incorporation, we have used these particles to demonstrate their potential as an augment to biomedical treatment. Previous research has shown that apatite nanoparticles also exhibit an unprecedented effect on bacteriophage *in vitro*. This research has promising implications for phage therapy, a potential alternative to traditional antibiotic treatment.[2]

Apatite nanoparticles, shown in Fig. 1, can also serve as a technology platform for other non-medical fields such as nanoelectronics and nanomanufacturing due to their versatile and tunable material properties. This work demonstrates the synthesis of various doped and un-doped apatite nanoparticles using wet-chemical precipitation mediated by citric acid. The characterization of these particles with UV-Vis spectroscopy of various synthesis recipes is shown in Fig. 2. Doped apatite nanoparticles show unique physical characteristics, such as magnetism, fluorescence, crystal structure, and absorbance, which varies based on synthesis temperature and pH, compared to un-doped hydroxyapatite (HA).[3] This work uses aminoethylphosphate along with other amines to elucidate reliable and generalizable methods for construction of various polymer-nanoparticle composites. Additionally, we explore organic structures cross-linked with nanoparticles for use in bottom-up nanofabrication.

This research explores the use of HA nanoparticles (HANP) to enable a coupled fluorescent-magnetic response. Magnetically sensitive nanoparticles can serve as a novel means of inducing optical modulation with an applied variable magnetic field. The enhanced surface area provided by the HANPs maximize the potential optical interaction, particularly fluorescence, between incident light and resulting optical signatures. Fig. 3 shows far-field reflectivity of europium-containing nanoparticles interrogated with a broad-band ultraviolet light source. The modulation of fluorescent signatures from HANPs in the presence of externally applied magnetic fields will be presented. Various fluorescent doped apatite nanoparticles as well as several supramolecular polymer-nanoparticle aggregates are being used to study this coupled magnetic-fluorescent response.

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[1] Sadat-Shojai, Mehdi, et al. "Synthesis methods for nanosized hydroxyapatite of diverse structures." *Acta biomaterialia* (2013).

[2] Nickel, Amy L. *Synthesis of Nanoparticles and Their Effects on Microbial Processes*. Thesis. Montana Tech of the University of Montana, 2010. AnnArbor: ProQuest, 2010. Print.

[3] "Surface functionalized colloidally stable spheroidal nano-apatites exhibiting intrinsic multi-functionality," United States Patent Application, No. 20130195745.

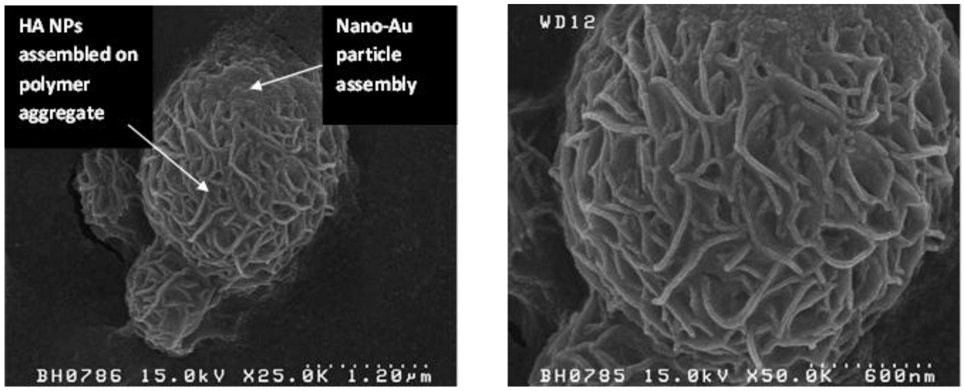

Figure 1: Scanning electron micrographs (SEMs) showing nanostructures made from apatite building blocks on one hemisphere of the sphere and Au-NPs decorating the other hemisphere at low (left) and high (right) magnifications.

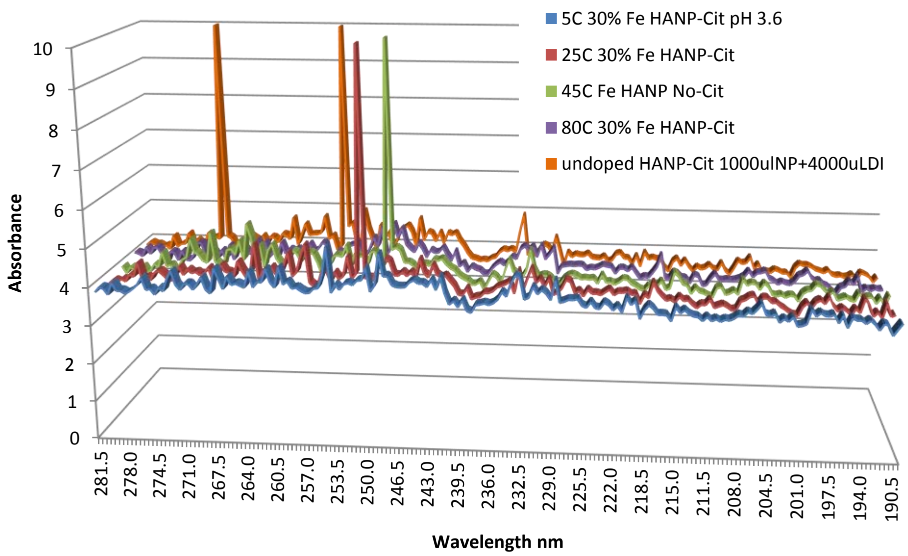

Figure 2: UV-Vis spectroscopy of various apatite nanoparticles. The temperature listed in the legend indicates at what temperature the water bath was kept during particle synthesis, for example “45C” indicates the bath was kept at 45 degrees Celsius. “FeHANP” indicates apatite nanoparticles doped with iron. “-Cit” or “No-Cit” indicate if citrate was added or not. “No-Cit” being no citrate added. Variation of temperature, the presence of iron, and the presence of citrate, all other things being equal, show effects on particle absorption.

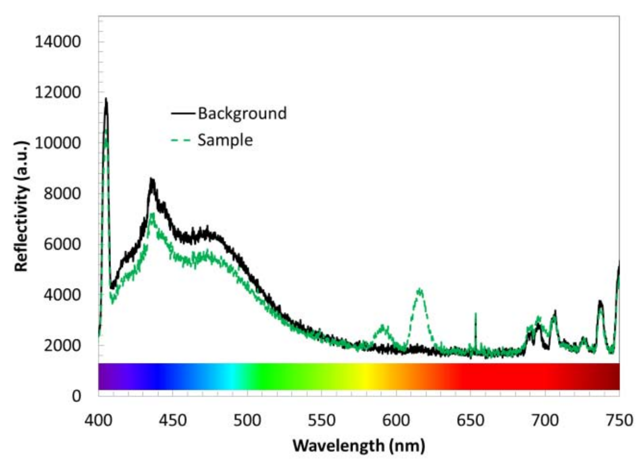

Figure 3: Reflectivity of europium-containing nanoparticles. Fluorescence occurs in the orange range of the visible spectrum with a peak excitation at 615 nm when interrogated with ultraviolet light. Both “Sample” and “Background” spectra are shown.