Formation and Aging of Ferrihydrite Nanoparticles in the Presence of Organics

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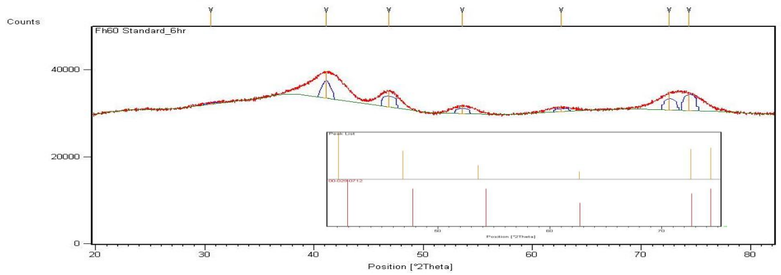
Introduction

The object of this research project is to determine how adding organic compounds during crystal formation affects the physical properties of the ferrihydrite crystals that are formed. Ferrihydrite is a nanomaterial with no bulk counterpart and forms naturally in nature. Through these experiments, we hope to elucidate more details about out how the formation occurs in nature. Once we figure out how the formation occurs, we can manipulate it for various industrial and environmental applications.

Procedure

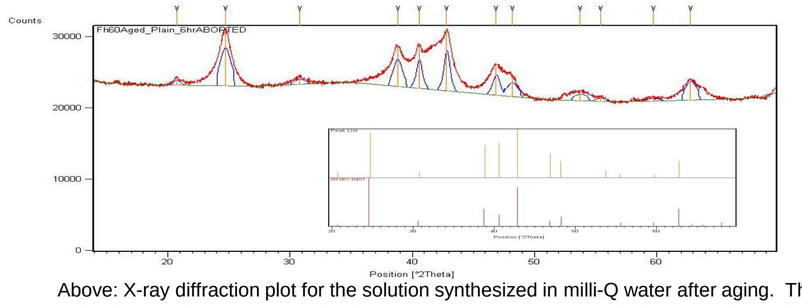
To test how organics affect the formation and aging of ferrihydrite nanocrystals we compared the presence of three different organic molecules at a concentration of 0.1mM - alizarin, alginate, and sugar – against a control of milli-Q water. The syntheses were performed in such a manner that the only variable was the organic molecule present. After synthesizing the ferrihydrite nanoparticles, the suspensions were then dialyzed against milli-Q water for three days. Next, a portion of each suspension was aged in milli-Q water. For the solutions that were synthesized in the organic solutions, they were also diluted and aged in the respective organic to a final concentration of 0.1mM. The remaining portions of the dialyzed suspensions were dried both plain and with sugar. The sugar was added to prevent agglomeration during drying. This will allow the magnetic properties of the solution to be tested later. During aging, samples were prepared for analysis by transmittance electron microscopy (TEM) at 0, 3, 7, 11 days. Once the solutions were aged for 11 days, they were dried by evaporation both plain and with sugar. The samples dried plain analyzed with powder X-ray diffraction. The samples dried with sugar were sent to the Institute of Rock Magnetism at the University of Minnesota for testing. The TEM images will eventually be analyzed to determine the kinetics of the phase transformation of each sample during aging.

*Note: Since Alginate is a polymer we could not determine the molecular weight of Alginate, and thus the exact concentration. To get around this we added the same mass amount of Alginate as we did for Alizarin.



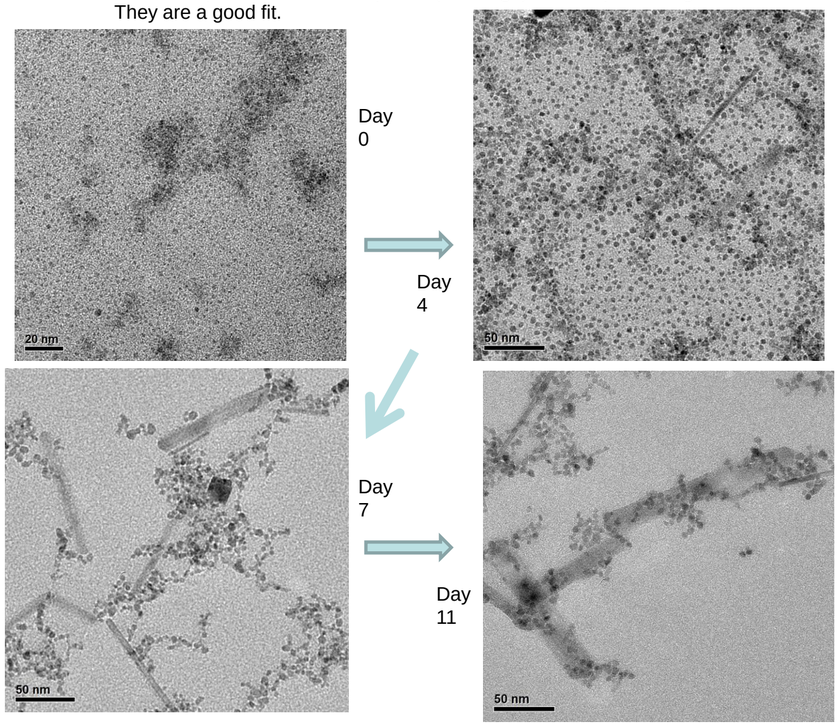
Above: X-ray diffraction plot for the solution synthesized in milli-Q water before aging. The rest of the solutions closely match the same profile before aging. The solution aged in 0.1mM Alizarin also matched this profile.

Inset: The peaks of the above profile (in orange) and the peaks of ferrihydrite standard (in red). They are a good fit.



Above: X-ray diffraction plot for the solution synthesized in milli-Q water after aging. The rest of the solutions closely match the same profile after aging, with the acception of the solution aged in 0.1mM Alizarin.

Inset: The peaks of the above profile (in orange) and the peaks of goethite standard (in red). They are a good fit.



Left: TEM images of the solution synthesized and aged in milli-Q water throughout aging. Most solutions had very similar results, with a few minor differences as far as TEM images can tell.

Right: TEM image for the solution synthesized and aged in 0.1mM Alizarin after aging for 4 days. This is the only solution with noticeable difference from the others. There is no rod formation present.

Results & Conclusions

Before aging, all the syntheses formed ferrihydrite nanoparticles. This leads to the conclusion that adding organics during crystal formation does not affect the identity of the particle. After aging, the mixture aged in 0.1mM alizarin remained ferrihydrite while the others formed into goethite. This leads to the conclusion that alizarin inhibits the ferrihydrite from forming into goethite while the other organics do not affect goethite formation. The magnetism samples are still in the progress of being analyzed at Institute of Rock Magnetism. The magnetic properties of the uncoated and coated ferrihydrite nanoparticle samples will then be further examined and compared. The size of the nanoparticles will affect their magnetic properties because the smaller the particle, the more uncompensated spin there is in antiferromagnetic particles. From looking at the TEM images, it appears that alizarin is the only organic that has a big affect during aging. The sample aged in alizarin did not form any rods. This leads to the conclusion that alizarin hinders rod formation. The data from the images taken with the transmittance electron microscope is in the process of being further analyzed in order to better understand the kinetics of phase transformation during aging. The additional data will improve understanding of the formation of ferrihydrite nanoparticles in nature.

Reference

S. Berquo, Thelma, Jasmine J Erbs, Anna Lindquist, R Lee Penn and Subir K Banerjee. “Effects of magnetic interactions in antiferromagnetic ferrihydrite particles.” *Journal of Physics: Condensed Matter*. (2009).

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