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Colloidal Nano-apatite Particles with Active Luminescent and Magentic Properties for Biotechnology Applications

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COLLOIDAL NANO-APATITE PARTICLES WITH ACTIVE LUMINESCENT AND MAGNETIC PROPERTIES FOR BIOTECHNOLOGY APPLICATIONS, Rajendra Kasinath and Kumar Ganesan, Environmental Engineering, Montana Tech of the University of Montana, 1300 W Park, Butte, MT 59701.

The synthesis of functional nano-materials is a burgeoning field that has produced remarkable and consistent breakthroughs over the last two decades. Individual particles have become smaller and shown potential for well defined functionality. However, there are still unresolved problems, a primary one being the loss of functionality and novelty due to uncontrolled aggregation driven by surface energy considerations. As such the first design criteria to harness the true potential of nanoparticles is to prevent unwanted agglomeration by: (1) improving colloidal stability, and, if possible, (2) controlling aggregation behavior. This requires specific knowledge of the chemistry of the immediate locale of the intended application; especially for biologically relevant applications. The latter criterion is also application driven but should be considered, generally, to diversify the range of functional properties that can be achieved. We have now reason to believe that such a novel system with multifunctional capabilities can be synthesized rather conveniently and have far reaching impact in biotechnology and other applications in the near future. We are presently experimenting with the syntheses of spheroidal, metal-doped, colloidal apatite nanoparticles (~10 nm) for several potential biomedical applications. These include fluorescent probes and MRI contrast agents, for the highly specific and targeted treatment of tumors, and for targeted gene-delivery. We have approached this end from the simple aging of an amorphous precursor to apatite with similar stoichiometry, the only variant being the presence of citric acid groups in the crystallization locale of the nanoparticles. The citric acid groups adsorb onto the nanoparticles and cap the particles preventing growth beyond 10-15 nm. The particles can also be imbued in situ with multi-functional traits by doping with heavy and rare earth metals (such as Fe, Nd and Eu,

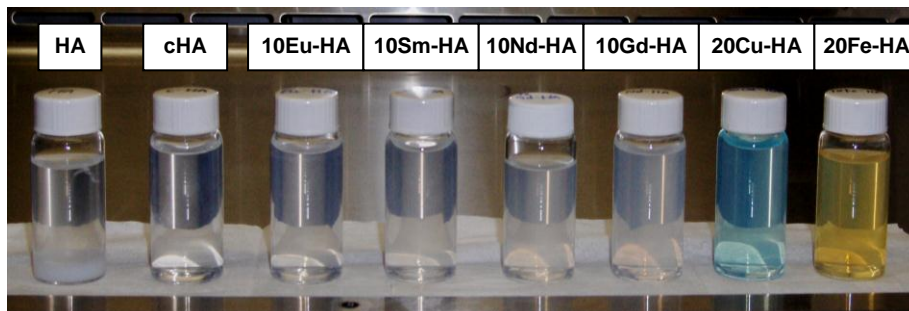


Fig. 1 Various metal doped and dispersed apatite nanoparticles (note the settling of the control HA suspension – far left).



Fig.2 Photograph showing the assembly of complex shapes of Fe doped in HA using the citrate capping synthesis technique.

Fig. 1). With the ability to disperse and dope monocrystalline apatite nanoparticles with a variety of metals, we are now close to a stage where novel properties can be harnessed and tailored for potential biomedical and other applications. We are now

striving to synthesize particles even smaller than 10 nm by optimizing the reaction chemistry using citric acid and at the same time doping the particles with other suitable metals (e.g., Mn and Tr and Ti). The ability to be both fluorescent and magnetic is the type of multi-functionality that we ultimately seek to achieve. Fig. 2 shows the complex macroscopic assembly of Fe-doped nanoapatite

particles (Fig. 3A) when placed under an array of magnets. The magnetically driven assembly is sensitive enough to produce specific shapes as seen from the “writing” of the shape “M T” using a magnetic template placed under a Petri dish containing the Fe-doped nanoparticulate dispersion (Fig. 3). Another characteristic of the Fe-doped nanoapatite particles is its green fluorescence (Fig. 3B) when excited with UV-C radiation. Furthermore, the versatility to which the spectral emission signatures can be varied for rare-earth doped apatites, as seen from published geological data make this work even more exciting and worth investing in. Fig 4 shows combined specific light-absorption and magnetically assisted assembly properties of Neodymium (Nd)-doped nanoapatites. In this case the Nd-doped apatite nanoparticles would likely exhibit: (1) fluorescent behavior at specific excitation wavelengths based on the observed specific absorbance at 580, 745 and 800 nm and (2) super-paramagnetic properties given the 10 nm size and specific and reversible aggregation in the presence/absence of magnetic fields.

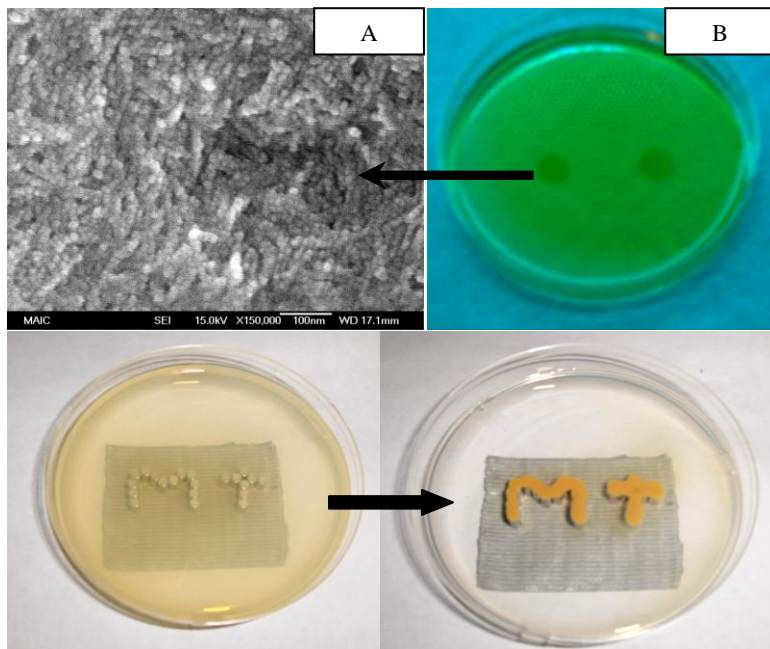


Fig. 3 Controlled assembly of Fe-doped nanoparticles into specific shapes using magnetic templates

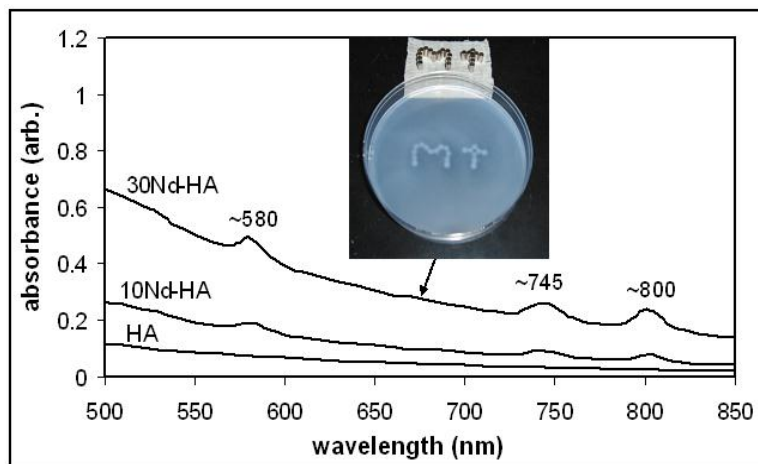


Fig. 4 Nd-doped nanoparticles exhibiting both magnetic and specific light absorption properties.

Currently we are in the process of optimizing the controlled aggregation behavior for these multifunctional nanoparticles. We believe that these nanoparticles, synthesized this way will have immediate application potential, especially in biotechnology, for which we are actively seeking collaboration. We hope to be able to extend this initial work into several application based studies with potential partners within the coming year. This work also coincides with the new bio-engineering thrust in our department, which has seen both infrastructural and informational growth over the last year. When successful, of which we are extremely confident, as seen from our promising preliminary results, we believe that this will revolutionize broad based applications for these non-toxic apatite nano-materials. We aim to, in the process, synthesize a new family of apatite nanoparticles which can exhibit superconducting, superparamagnetic, fluorescent, photo-catalytic, anti-bacterial and perhaps other yet to be revealed properties.