Magneto-motive ultrasound imaging using superparamagnetic ferrite nanoparticles with enhanced saturation magnetization synthesized by a simple coprecipitation method

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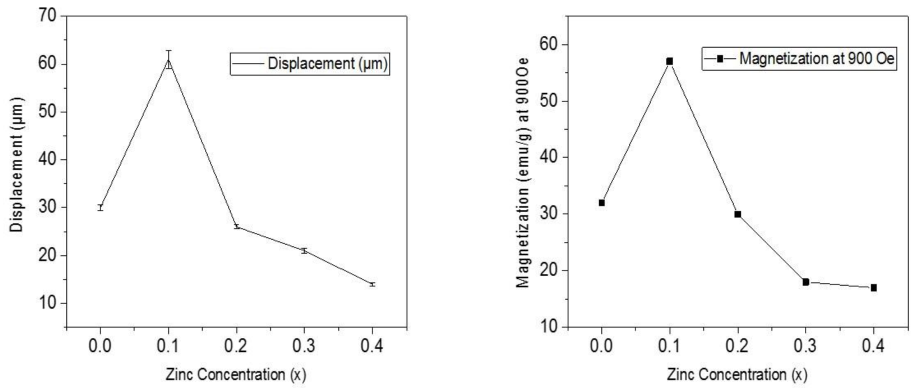
Introduction: Detecting cancer at earlier stages is critical for effective therapeutic procedures and reduction of mortality. Molecular imaging plays a crucial role to improve the early diagnosis of cancer. Magnetomotive ultrasound (MMUS) imaging is a technique developed to improve the detection of magnetic nanoparticles (MNPs) by ultrasound. The advantage of using contrast agents with nanoscale dimensions is their ability to target biologic events at the molecular and cellular levels. In this technique, MNPs are used to label a specific tissue and an induced displacement, due to the interaction of MNPs with an alternating magnetic field, is detected by ultrasound imaging. Therefore, it is desirable to use MNPs with high saturation magnetization to enhance the induced displacements, consequently, improving the visualization of the contrast agent at lower concentrations.

Methods: In this study, five different Zn-substituted magnetite nanoparticles, ZnxFe1-xFe2O4 (x=0.0, 0.1, 0.2, 0.3, 0.4) prepared by a one-pot simple coprecipitation reaction and they were used as contrast agents in MMUS imaging. MMUS images were obtained from five different gelatin phantoms with semi-spheres inclusions of 1 cm in diameter and 0.7 wt% concentration of MNPs. The setup for MMUS consisted of a custom build coil for generating the magnetic field and an ultrasound system (Sonix RP) used for echo signal acquisition, which used a linear ultrasound transducer operating at 9.5 MHz and was positioned opposite the coil. An interface software system developed in MatLab was used for data acquisition and processing.

Results and Discussion: The results showed that all samples were in superparamagnetic state with the size distribution between 30-40 nm. The magnetization of magnetite was enhanced by substituting Zn for Fe in its structure. Prepared MNPs had different magnetization values at the field strength of 900 Oe, the maximum strength for our MMUS setup. All nanoparticles showed good potential to be used in MMUS imaging as a contrast agent and the induced displacement, in the inclusion area, changed according to their magnetization values (see Fig). The highest displacement was 60 µm related to the composition with x=0.1, which had the highest magnetization.



Conclusion: Superparamagnetic nanoparticles of Zn-substituted magnetite nanoparticles were successfully prepared using coprecipitation method. A significant increase was observed with substitution of zinc (at x=0.1) in magnetite structure. This relative high magnetization can lead to use less concentration of nanoparticles in MMUS imaging.