Effect of ionic concentration on dynamic magnetic susceptibility of iron oxide nanoparticles embedded in chitosan hydrogel matrix

M. E. Villamin, and Y. Kitamoto
Department of Material Science & Engineering, Tokyo Institute of Technology, Kanagawa, Japan

Recent interest in ferrogels consisting of iron oxide nanoparticles (FeO_x NPs) attached to a polymer network, such as chitosan hydrogel (CH), is driven by both the desirable properties of FeO_x NPs and CH, which can be useful in many biomedical applications [1-2]. One important potential application is magnetic based biosensing. In this case, it is important to understand how certain chemical stimuli affect the magnetic properties of FeO_x NPs inside the CH polymer. However, actual demonstrations of using chemical stimuli on CH for sensing are limited. In our previous study, we experimentally demonstrate how pH affects the magnetic relaxation of FeO_x NPs embedded in CH under AC field [3]. We observed that as the pH solution decreased, the CH swells and the peak position of the imaginary part (χ'') of the AC susceptibility (ACS) is shifted to higher frequencies. From these results, we inferred that the CH swelling enhances the Brownian relaxation, thus we have demonstrated that chemical stimuli can be magnetically detected. In the present study, we extended our research by using other external stimuli, i.e. ionic concentration, and study its effect on the magnetic relaxation of FeO_x NPs in the CH. Swelling ratio (SR), which is a measure of water absorption of the hydrogel, and ACS were measured after the FeO_x-CH are immersed to different NaCl concentrations. SR results in Fig. 1 show that the swelling of the FeO_x-CH decreases as the ionic concentration increases. When CH is immersed in high NaCl solution, the water inside the CH diffuses outside the CH causing it to shrink. In contrast, in low NaCl solution, the water goes inside the gel resulting to swelling. The inset of Fig. 2 illustrates the frequency dependence of χ'' at different ionic concentrations of FeO_x-CH measured by ACS. From these results, the χ'' peaks are found around 200 Hz. The frequency position of the χ'' peak, f, is generally associated with the magnetic relaxation time, with $\tau \approx 1/f$, where τ is the magnetic relaxation time [4-5]. The χ'' peak frequency values are accurately extracted by fitting the data in the inset of Fig. 2 with a Gaussian function. The χ'' peak values at different NaCl concentration are plotted in Fig. 2. It is evident that χ'' peak frequency positions shift to lower frequencies as the ionic concentration increases. The shift is again expected, since it is inferred that the swelling of the CH enhances the Brownian relaxation. These results, as far as the authors' knowledge, is the first time demonstration of ionic concentration sensing via magnetic detection, which may become useful for magnetic biosensing applications.

References:

1) A. Kaushik, et al Biosens. Bioelectron., **24** (2008), 676-683.
2) J. Cho *et al*., J Food Eng.,**74** (2006), 500-515.
3) M.E. Villamin, & Y. Kitamoto, ICM2018, B10-02.
4) F. Ludwig, *et al.*, IEEE Trans. Magn., **53** (2017), 1-4.
5) S. Bogren, *et al.*, Int J Mol Sci., **16** (2015), 20308-20325

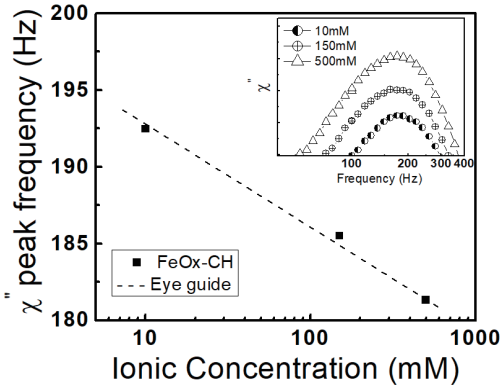

Fig. 2. Measured χ'' peak frequency plotted against varying ionic concentrations. Inset: χ'' frequency dependence of FeOx-CH.

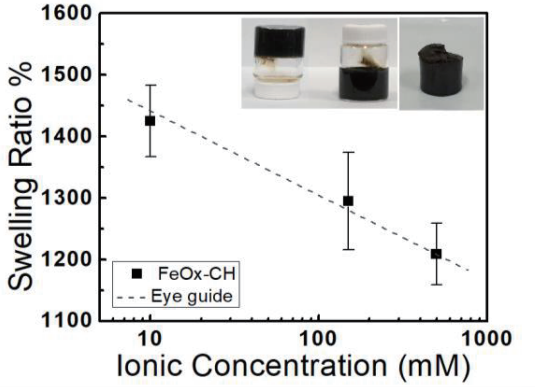

Fig. 1. Swelling ratio plotted against different 10mM, 150mM and 500mM NaCl concentration. Inset: Actual FeOx-CH sample used.