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Magnetic Element Doping of Iron Oxide Nanoparticles for Enhanced Performance in Cancer Thermo-Radiotherapy

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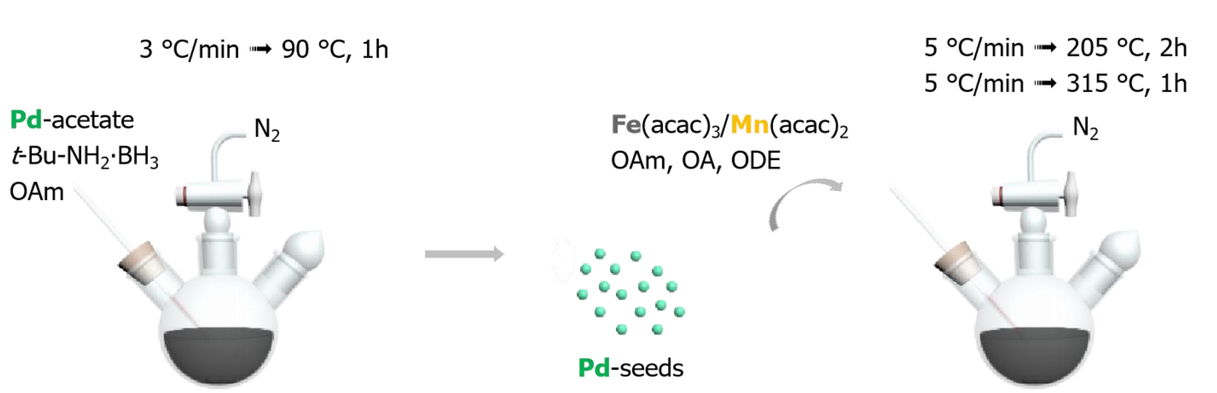
INTRODUCTION & AIM

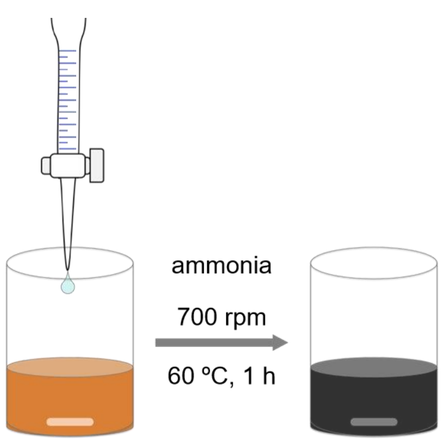
Cancer remains a major challenge to human health. To enhance therapeutic outcomes and minimize side effects, innovative treatments are being developed. One promising method is hyperthermia or thermal ablation using magnetic nanoparticles like iron oxide (Fe_3O_4), which generate localized heat when exposed to an alternating magnetic field. This technique shows even greater potential when combined with traditional treatments such as chemo- or radiotherapy, leading to improved therapeutic results.[1]

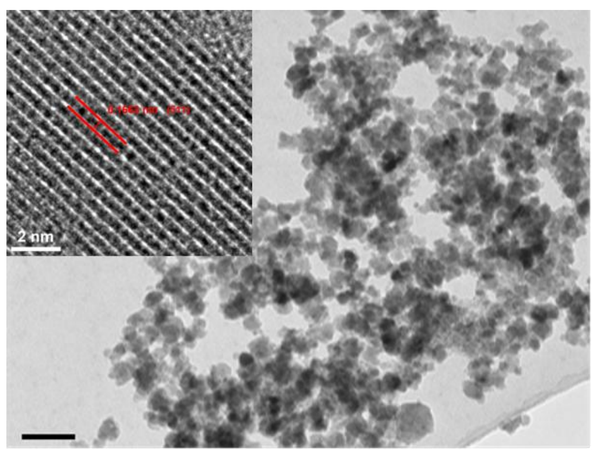
In this work, we investigated iron oxide NPs doped with either paramagnetic Mn(II) or Ho(III) (a lanthanide with the highest magnetic moment), prepared by thermal decomposition and co-precipitation, respectively. The M_S values Mn-doped NPs increased up to 1.7 times with a consequently improved heating efficiency at 346 kHz and 23 mT. In addition, a pronounced Mn(II) outer rim obtained for higher Mn(II)-content NPs allowed the detection of T_1-weighted MRI contrast convenient for monitoring NPs distribution in tissues due to the water exchange at the NP surface. The SLP values of NPs doped with Ho(III) into the Fe-oxide lattice were demonstrated to be depended on both size and Ho-content, with the best performing NPs of 12 nm and 2.5% Ho. Furthermore, the presence of Ho(III) within the Fe-oxide lattice, in addition to higher SLP, offers the possibility of performing radiotherapy using the ^{166}Ho-isotope, a β-emitter (t1/2=26.8h) produced from the stable ^{165}Ho by neutron activation.

METHOD



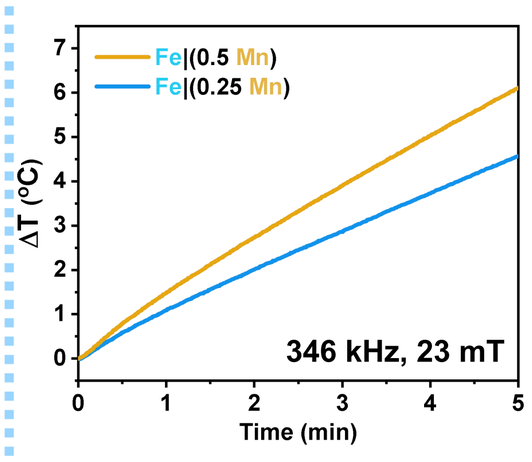
Nanoparticles Fe|(0.25 Mn) and Fe|(0.5 Mn) with a core-shell structure and a size of ±20 nm were obtained through thermal decomposition, and Fe|(2.5% Ho) with size of ±12 nm obtained through co-precipitaiton.





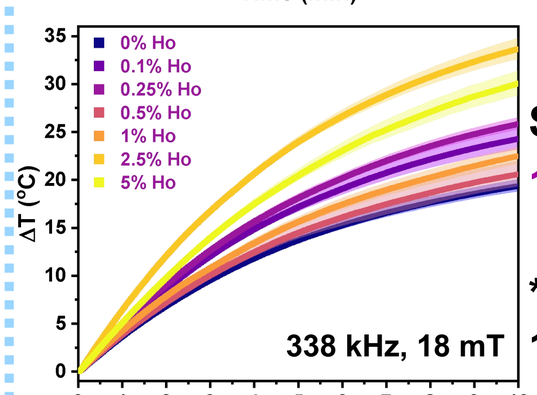
RESULTS & DISCUSSION

Heating effect :



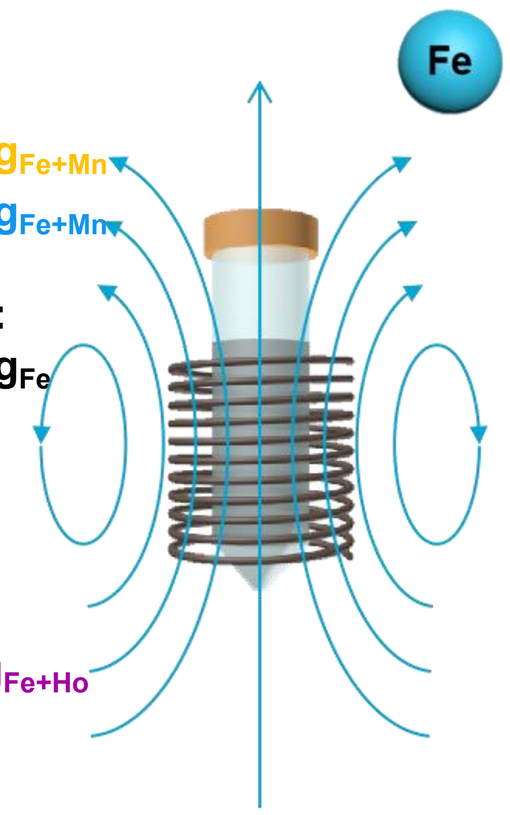
SLP:
386 W/g_{Fe+Mn}
352 W/g_{Fe+Mn}

*for Fe:
233 W/g_{Fe}

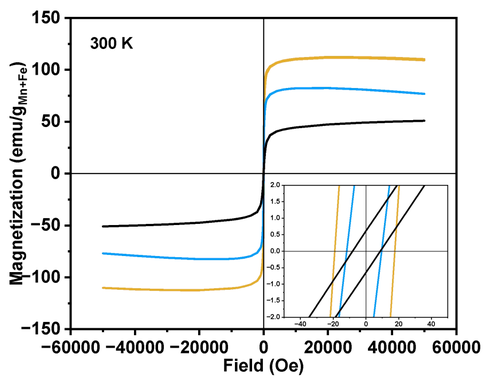


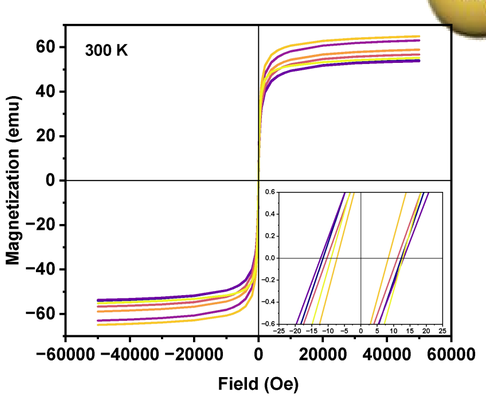
SLP:
176 W/g_{Fe+Ho}

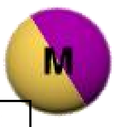
*for Fe:
109 W/g_{Fe}



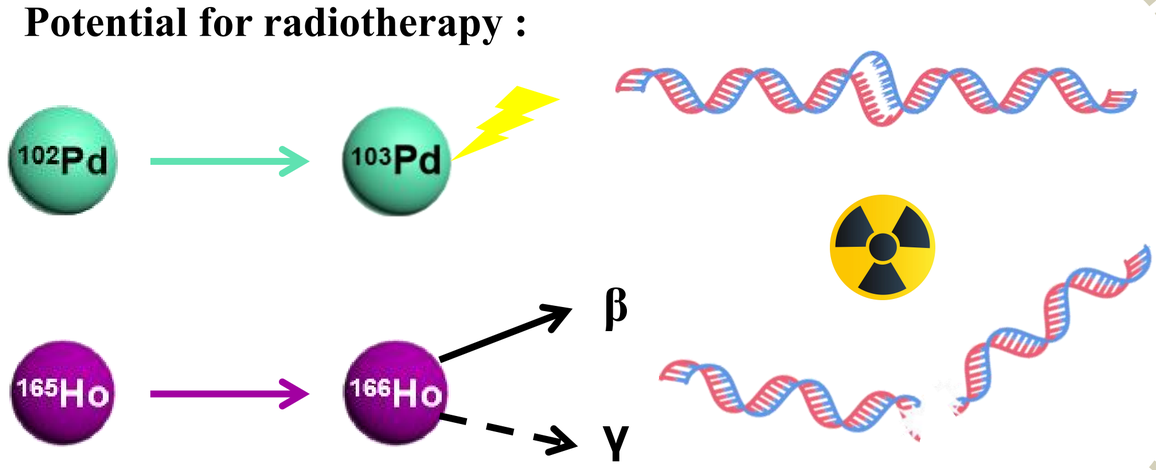
Improvement on magnetic properties :







Potential for radiotherapy :



CONCLUSION

Fe-oxide NPs were successfully doped with Mn^{2+} and Ho^{3+} by thermal decomposition and co-precipitation. Both element doping resulted in SLP and M_S values increased up to 1.7 times for $Mn^{2+}$and 1.6 times for Ho^{3+}. The Pd core can be replaced to ^{103}Pd, and Ho^{3+} can be easily changed to ^{166}Ho for the combination with radiotherapy.

REFERENCES

[1] R. Oossanen, A. Maier, J. Godart, J.-P. Pignol, A.G. Denkova, G.C. van Rhoon, K. Djanashvili. Int. J. Hyperth. 2024, 41, 2299480.