Optimizing magnetic hyperthermia performance under safety limits: role of anisotropy, shape and interactions

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A careful assessment of the heating performance of magnetic nanoparticles (MNPs) under alternating magnetic fields is critical for advancing magnetic hyperthermia as a viable clinical treatment, potentially replacing more invasive cancer therapies such as chemo and radiotherapy [1]. Despite numerous experimental studies, a consensus on standards regarding material properties, dosage, and field parameters remains elusive [2]. Moreover, many interpretations of experimental results rely on theoretical models that fail to capture the essentials of realistic NP ensembles or are based on oversimplified assumptions.

In this talk, we review recent progress in understanding the some of the key factors influencing magnetic hyperthermia performance, from a modeling and simulation perspective. We begin by highlighting the pivotal role of magnetic anisotropy and its relation to nanoparticle shape, in the understanding of the heating properties of MNPs. Our results show that even slight deviations from spherical shape can significantly influence the heating efficiency of MNPs (see Fig. 1a) [3,4]. We identify specific NP size ranges and aspect ratios that optimize heat delivery, constrained by the field amplitude and frequency safety limits required for clinical application. Finally, we address the impact of dipolar interactions in clustered NP ensembles. While such interactions are often considered detrimental, we demonstrate that proper control over spatial distribution and geometric arrangement can mitigate these effects, and that dipolar coupling can even enhance the heating efficiency (see Fig. 1b).

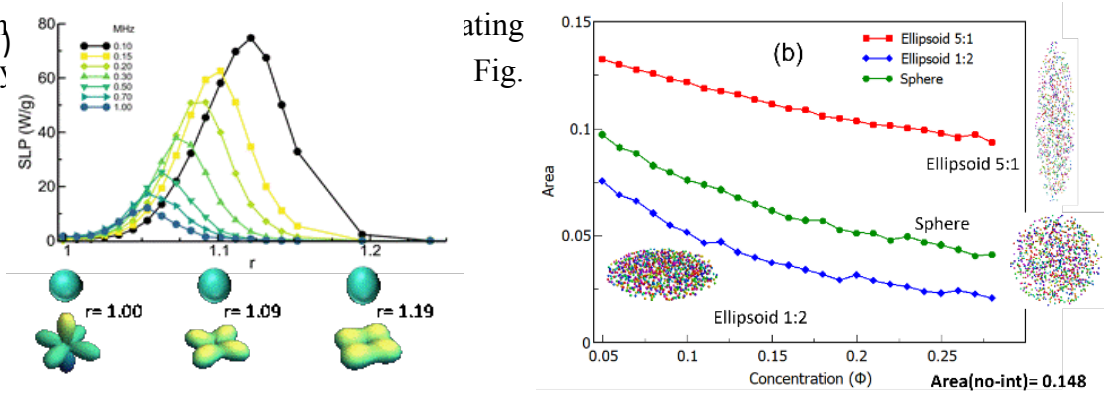

Figure 1: (a) SLP dependence on the aspect ratio (r) of magnetite NP of size D= 25 nm at different frequencies and ac field values complying with the Brezovich criterion. (b) Hysteresis loop area dependence on concentration for disordered NP clusters with different geometries.

References

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