Stability and relaxivity of magnetic particles suspensions improved through a simple structural reorganization

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Ultra-small superparamagnetic iron oxide nanoparticles (USPIO) are a highly valuable tool in the biomedical field for a variety of applications ranging from drug carrier to molecular imaging[1] but also in physics for all the photonic components[2]. They owe this popularity to a number of qualities such as their size (below 50nm), their magnetic and relaxometric properties and their biocompatibility. However, one major challenge is to maintain them stable in solution against their natural tendency of aggregating. This trend is even more accentuated over time with the aging of ferrofluids[3]. A range of chemistries already exists to stabilize these particles such as grafting with hydrophilic ligands, or polymer coating for steric stabilization[4]. Nevertheless, most of these techniques may reveal tedious or costly and definitely time-consuming.

In this work, we developed a simple method to stabilize commercial amino-ferrofluids. The concept relies on electrostatic interactions between the amino groups of the particles and a polymeric dispersant, released by a weakly acidic cation exchange resin. This residual compound seems to lead to structural reorganization of the particles through self-assembly around the dispersant, as can be seen on the TEM of the figure 1. A direct consequence of this reorganization is a net gain in relaxivity for the particles. The intensity of this effect is actually related to a ratio between the number of amino groups on the particles, n_{NH2}, and the number of carboxyl functions on the resin, n_{COOH} (fig.2). In comparison to the original commercial stock, transverse relaxivity values can be increased by a factor twelve (Table1). This is a valuable feature because stronger relaxivity values are seeked for hyperthermia therapy or for biomagnetic imaging in order to detect low concentration of molecular markers. So far, some of the techniques producing higher saturation magnetization imply elaborate syntheses of "hybrid" particles such as Mn-doped iron oxide nanoparticles[5], or also particles with an iron core under a thin layer of iron oxide[6].

In contrast, this study presents the advantage of being technically simple, fast, low cost and in non-denaturing conditions for the particles, while keeping solutions stable for at least six months (Fig.3).

References

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Figures:

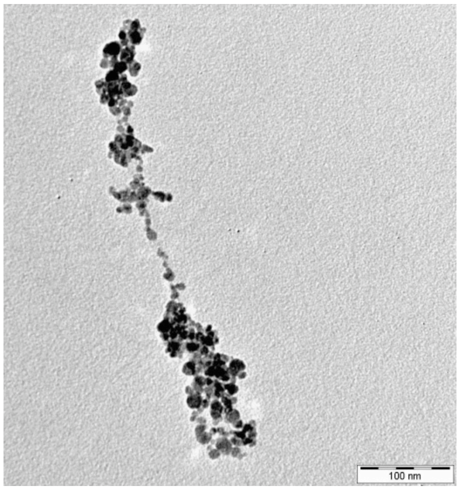

Figure1. TEM of a commercial amino- ferrofluid after interaction with the resin

Names (diam.)	**r_1 ($s^{-1}mM^{-1}$)**	**r_2 ($s^{-1}mM^{-1}$)**
Amino-ferrofluid (50nm) commercial stock	9.5	34.3
Same amino-ferrofluid with resin	39.8	417.8
Clariscan (20nm)	20	35
Sinerem (30nm)	46.9	88.2

Table1. Comparison of relaxivity values with some commercial USPIOs of similar size. (37^{0}C, 0.47T)

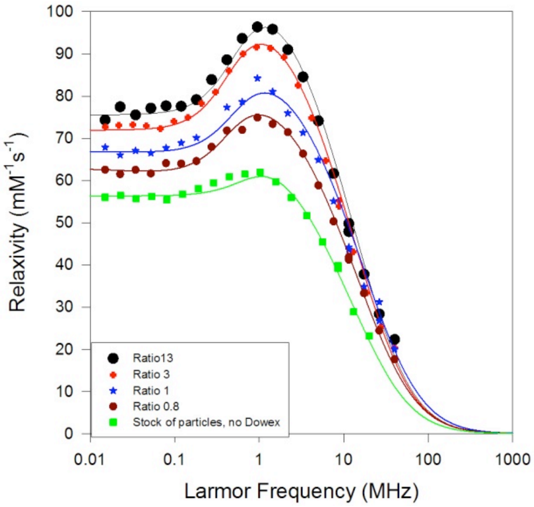

Figure 2. Relaxivity values versus resin equivalents.
Ratio= $n_{NH_2\text{-particles}}/n_{COOH\text{-resin}}$

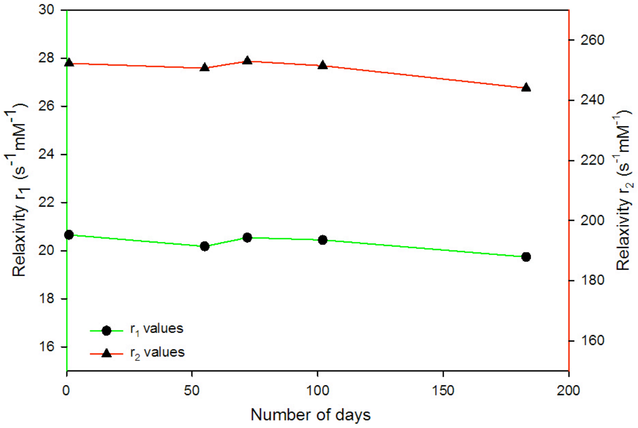

Figure 3. Stability study of an amino-ferrofluid following interaction with the resin