Magnetic, optical and biological studies of ultrasmall Gd_2O_3 and $\text{Eu}:\text{Gd}_2\text{O}_3$ nanocrystals

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Recently, Gd_2O_3 nanoparticles have been shown to have very good proton relaxation properties, which makes Gd_2O_3 a useful candidate for MRI contrast imaging. It is of considerable interest to develop simple and efficient methods, preferably at low temperatures, for the direct synthesis of ultra-small Gd_2O_3 nanoparticles with narrow size distribution.

We present a simple and a rapid microwave-assisted chemical approach to the synthesis of ultra-small undoped and Eu-doped Gd_2O_3 nanoparticles (nanocrystals). The crystallinity and phase purity of the powder synthesised were investigated by XRD. Figure 1 shows XRD pattern of the as-prepared material. The two peaks that can be identified are indicative of very small crystallite size and can be indexed to the (222) and (400) crystal planes of cubic Gd_2O_3 , the most intense peaks of this oxide. The observed peak broadening and low intensity are most likely due to the small size of the crystals.

Figure 1: XRD patterns of as-prepared Gd_2O_3 nanoparticles (a) and after annealing in air at 600 °C (b).

The morphology, microstructure, and crystallinity of as-prepared Gd_2O_3 nanoparticles analysed by TEM and HRTEM imaging is shown in Figure 2. It can be seen that the as-prepared material consists of nearly spherical Gd_2O_3 nanoparticles with sizes well below 10 nm.

Figure 2: TEM micrographs of the as-prepared Gd_2O_3 NP's showing the presence of ultra-small nanoparticles (a, b) with narrow size distribution (c). HRTEM image revealing the single crystalline nature of these individual nanoparticles (d).

The nanoparticles are paramagnetic and show higher relaxation rate than the standard Gadavist used in MRI imaging (Figure 3). Cytotoxicity studies (both concentration- and time-dependent) of the Gd_2O_3 nanocrystals show no adverse effect on cell viability, evidencing their high biological compatibility (Figure 3).

Figure 3: Variation of experimentally measured longitudinal relaxation rate R_1 ($1/T_1$) with the concentration of Gd^{3+} ions in Gd_2O_3 nanocrystals and Gd-DTPA. Effect of Gd_2O_3 nanocrystals on the viability of HEK293 cells.