ABSTRACT

The aim of the research presented in this doctoral dissertation (based on a series of three attached publications) is the experimental verification of theoretical models describing the processes of superparamagnetic relaxation enhancement (SPRE) in solutions of magnetic iron oxide nanoparticles, as well as the analysis of the influence of the diffusion mechanism of solvent molecules on the observed relaxation properties, in the context of a new generation of contrast agents for Magnetic Resonance Imaging (MRI).

As part of the conducted research, extensive experimental data were collected, including proton (^{1}H) spin–lattice relaxation rates measured over resonance frequency ranges from 10 kHz to 10 MHz (P1, P2) and from 10 kHz to 500 MHz (P3), within a temperature range from 263 K to 313 K. The experiments were carried out for aqueous solutions of diamagnetic SiO_2 nanoparticles functionalized with triethoxypropylaminosilane (P1), superparamagnetic H_2N-Fe_3O_4 nanoparticles (P2), and Fe_3O_4 nanoparticles functionalized with carboxylic acid (CA) and polyethylene glycol (PEG) (P3).

In publication P1, the two-dimensional character of the translational diffusion of water molecules within the surface layer of SiO_2 nanoparticles was confirmed on the basis of the characteristic linear dependence of the relaxation rate on the logarithm of the resonance frequency. The determined translational diffusion coefficients were several orders of magnitude lower than those for bulk water.

In publication P2, it was shown that the application of existing SPRE models to the interpretation of experimental data obtained for H_2N-Fe_3O_4 nanoparticles provides satisfactory agreement, although deviations were observed at high frequencies and for slower diffusion processes, indicating limitations of the assumption that electronic relaxation is independent of the magnetic field.

The most comprehensive verification was carried out in publication P3 for the results of relaxation experiments performed on aqueous solutions of Fe_3O_4 nanoparticles over the frequency range from 10 kHz to 500 MHz. It was therefore concluded that the existing theoretical models offer a compromise between an accurate description of relaxation processes in low and high magnetic fields.

The motivation for undertaking this research topic stemmed from the broad applications of superparamagnetic nanoparticles in biology and medicine, including targeted drug delivery, cell separation, and biosensing. Owing to the possibility of surface functionalization with

appropriate ligands, such nanoparticles can be used for the selective labeling of cancer cells, proteins, or nucleic acids, which is of considerable importance in molecular diagnostics and cell biology.