



ELSEVIER

Contents lists available at ScienceDirect

Colloids and Surfaces B: Biointerfaces

journal homepage: www.elsevier.com/locate/colsurfb

Full length article

Tuning magnetic relaxation properties of “hard cores” in core-shell colloids by modification of “soft shell”



Nataliya Shamsutdinova^a, Rustem Zairov^{a,*}, Irek Nizameev^a, Aidar Gubaidullin^a,
 Alsu Mukhametshina^a, Sergey Podyachev^a, Ildus Ismayev^b, Marsil Kadirov^a,
 Alexandra Voloshina^a, Timur Mukhametzyanov^c, Asiya Mustafina^a

^a A.E. Arbuzov Institute of Organic and Physical Chemistry, Kazan Scientific Center, Russian Academy of Sciences, Arbuzov Street 8, Kazan, 420088, Russian Federation

^b A.N. Tupolev Kazan National Research Technical University, 10, K. Marx St., Kazan, 420111, Russian Federation

^c Kazan Federal University, Kremlyovskaya Street 18, 420008, Kazan, Russian Federation

ARTICLE INFO

Article history:

Received 20 July 2017

Accepted 31 October 2017

Available online 11 November 2017

Keywords:

Nuclear magnetic relaxation

Tuning of relaxivity

Gadolinium-based colloids

BSA interaction

Cytotoxicity

Aggregation behavior

Cell viability

ABSTRACT

The present work introduces an impact of polyelectrolyte-based hydrophilic shell on magnetic relaxivity and luminescence of hard cores built from isostructural complexes of Tb(III) and Gd(III) in the core-shell aqueous colloids. Microscopic and scattering techniques reveal “plum pudding” morphology of the colloids, where polyelectrolyte-coated ultrasmall (<5 nm) hard cores form aggregates in aqueous solutions. Interaction of bovine serum albumin (BSA) with the colloids provides a tool to modify the polyelectrolyte-based shell, which is the reason for the improvement in both aggregation behavior of the colloids and their relaxivity. The modification of the hydrophilic polyelectrolyte-based shell enables to tune the longitudinal relaxivity from 5.9 to 23.3 mM⁻¹ s⁻¹ at 0.47 T. This tendency is the reason for significant improvement of contrasting effect of the colloids in T₁- and T₂-weighted images obtained by whole body scanner at 1.5 T. High contrasting effect of the colloids, together with low cytotoxicity towards Wi-38 diploid human cells makes them promising MRI contrast agents.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Nanoparticulate contrast agents (CAs) are a top of current interest today due to great advantage of magnetic resonance imaging (MRI) as a powerful and noninvasive tool in medical diagnostics [1–3]. Gd(III)-based nanoparticles are highlighted in literature as most promising basis of positive contrast agents in MRI [4,5]. Most efforts in a development of nanoparticulate CAs are focused on core-shell morphology, where hard Gd(III)-based cores are stabilized by hydrophilic coating [6,7]. Although no theoretical framework is known for quantitative interpretation of relaxivities in Gd(III)-based colloids, main factors affecting the relaxivity have been highlighted on a qualitative level [8,9]. Restricted molecular motion of Gd(III)-centers in nanoparticles [10–12] as well as lowered toxicity [13,14] are main advantages of nanoparticulate CAs versus their molecular analogues. Nevertheless, size of hard Gd(III)-based cores is confined within 2–5 nm, since greater sizes restrict

an accessibility of Gd(III)-centers to hydration, which in turn is a key reason for enhancing of water proton relaxation [15,16]. Thus, ultrasmall (2–5 nm) Gd(III)-based cores are ideal nanoparticulate CAs with high surface-to-volume ratio to provide an efficient access of water protons to Gd(III) paramagnetic center. In contrast, aggregation of nanoparticles is an unfavorable factor shortening longitudinal relaxivity of water protons due to restricted “active surface” of the nanoparticles, which in turn changes to worse a hydration of Gd(III)-centers at their surface [17]. It is also worth noting that an exchange of Gd(III) inner sphere coordinated water molecules with those in a bulk of solution requires their diffusion through a polymeric shell. The diffusion may be rate-determinative stage for magnetic relaxation in aqueous paramagnetic colloids. The latter tendency is well documented for silica coated Gd(III) complexes, although an effect of soft hydrophilic coating on longitudinal and transverse relaxivities of Gd(III) complex-based cores is not fully recognized [18,19].

Literature data indicate gadolinium oxides and salts, as a common basis for nanoparticulate MRI CAs [16,20,21], although plenty of reports published in recent decades highlight great impact of water insoluble Gd(III) chelates in development of nanoparticulate

* Corresponding author.

E-mail address: rustem02@yandex.ru (R. Zairov).