Size Effect: Effective T2 (T2*) of Gadolinium Silicide (Gd5Si4) Ferromagnetic Nanoparticles for High Magnetic Field (21.1 T) MRI

Hunagund, S.G. (Virginia Commonwealth U., Mechanical & Nuclear Engineering); Rosenberg, J.T. (NHMFL); Gupta, S. Pecharsky, V.K. (Iowa State U., Materials Science & Engineering) and Hadimani, R.L. (Virginia Commonwealth U., Mechanical & Nuclear Engineering)

Introduction

Contrast agents (CA) that are used in MRI today are mostly based on chelated gadolinium compounds for use as T1 CAs or superparamagnetic iron oxides (Fe_3O_4) for use as T2 CAs. Furthermore, these CAs have limited effectiveness at high magnetic fields [1]. However, ferromagnetic CAs are potentially more sensitive as T2 CAs than T1 paramagnetic compounds due to their large magnetic moments. In this study, effect of Gd_5Si_4 nano particles (NPs) of varying sizes and with different concentrations are investigated on T1, T2 and T2* relaxations times using the 21.1 T magnet at the NHMFL.

Experimental

Synthesis process of Gd_5Si_4 is described in detail elsewhere [2, 3]. Ball-milled Gd_5Si_4 NPs are size separated through time sedimentation process that provided four fractions (named S1, S2, S3 and S4) with average sizes of 735 nm, 655 nm, 541 nm and 287 nm respectively, as analyzed from SEM images. For MRI the NPs are diluted in solution with low-temperature 1% agarose with the 1:20 concentration. MR images were acquired using the 21.1 T (900 MHz) magnet at the NHMFL. For T1 measurements, a turbo spin echo (TSE) sequence was used with two rare factors. The echo time (TE) was 8.8 ms and repetition time (TR) of 600 ms were used. T2 relaxation rates were acquired with a multi slice multi echo (MSME) sequence using a TR/TE=5000/71.5 ms. For T2*, a 2D gradient echo (GRE) sequence was used with TR/TE=5000/1.1 ms. Relaxation data were processed in Matlab.

Results and Discussion

Magnetic properties measured in vibrating sample magnetometer (VSM) reveal that the Curie temperature (Tc) decreases for Gd_5Si_4 phase from 315 K for S1 to 305 K for S4. The M-H curves at 300 K exhibits ferromagnetic behavior to more paramagnetic characteristics as we move from S1 to S4 fraction (Fig. 1). MRI results shown in Table 1 indicate that T2*, which is sensitive to local field distortions, increases with increasing particle size as would be expected. Contradictorily, the transverse relaxation (T2), show opposite trends.

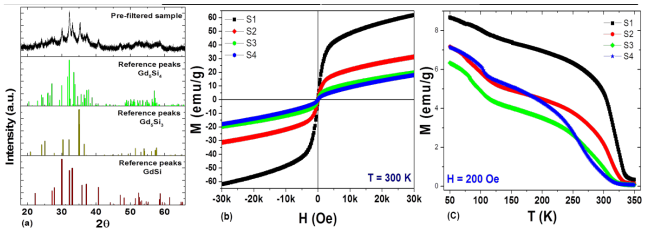

Fig.1a XRD patterns obtained from fractions. Reference peaks of Gd5Si4, Gd5Si3 and GdSi matches with the patterns. (b) M-H curve for all fractions. (c) M-T curve for all fractions.

Sample #	T_1 (ms)	T_2 (ms)	T_2* (ms)
S1	3207.43	38.1704	**1.2187**
S2	3328.76	45.9614	**1.9925**
S3	3173.46	18.1262	**2.28242**
S4	3088.01	19.6214	**3.33331**

Table 1. Relaxation measurements for all 4 fractions of the Gd_5Si_4 particle

Conclusions

The timed sedimentation process provides four distinct fractions of the Gd_5Si_4 particle with different sizes and magnetic properties. The particles show strong T2 and T2* contrast. While T2* relaxation shows decreased relaxation time with increased particle size, T2 relaxation shows opposite trend, which could be due to the ferromagnetic properties of the CA, having different effects on the transverse relaxation. The strong contrast generated should provide excellent cell tracking properties, which is the aim for future work.

Acknowledgements

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