Pore diameter measured using d-PGSE-filtered MRI

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Abstract:
Introduction: Double Pulsed Gradient Spin Echo (d-PGSE) filtered NMR is a powerful multiple scattering technique[1-2]. Recently, we applied it as a filter to an MRI sequence to detect microstructural differences within heterogeneous biological tissue[3]. A similar method was then used to measure pore diameter in radish and spinal cord specimens, and in packed-bead NMR phantoms[4,5]. However, these studies resulted in pore size estimates that were problematic due to the absence of an adequate model of the underlying microstructure and the absence of a well-characterized pore diameter with the NMR phantom. In this study we applied d-PGSE MRI to a well-characterized glass capillary array (GCA) NMR phantom and analyzed the data using a model that accounts for partial volume and all gradients within the d-PGSE MRI sequence.
Materials and Methods: The phantom consists of two water-filled GCA wafers (Photonis); nominal pore diameter=10 μm; thickness=500 μm. d-PGSE-filtered MRIs were performed by applying the two wave vectors sequentially (with no mixing period). The angle between them, ϕ, varied between 0 and 360°. A 7T vertical bore Bruker DRX system was used with δ=3.15ms, Δ=50ms, and G between 0 and 295 mT-m^{-1}. Simulations were performed that account for the shape of the array, partial volume effects, and all finite-width gradient pulses[6].
Results and Discussion: Fig. 1a shows a d-PGSE MRI of the phantom using G=295 mT-m^{-1} and ϕ=180°. Fig. 1b shows the experimental and simulated data for all G and ϕ. The measured pore diameter was the same with and without imaging gradients (between 8.9 and 9.2 μm). Optical microscopic measurements of a similar GCA yielded a pore diameter of 9.3 μm.
Conclusions: d-PGSE filtered MRI is a potentially powerful tool to determine pore diameter. We have demonstrated its application on a highly ordered pack of restricted cylinders with microscopic dimensions, and obtained what we believe are accurate estimates of the pore size by accounting for the effects of free diffusion and all gradients within the pulse sequence.

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a)

b)

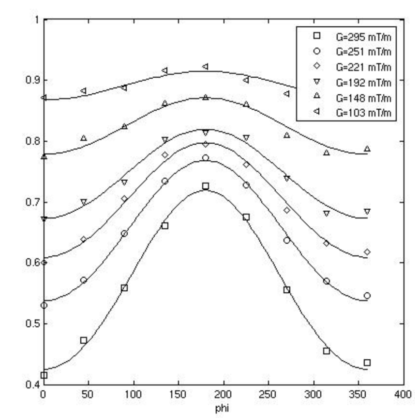

Figure 1a) d-PGSE MRI of GCA phantom at G=295 mT/m and ϕ=180°, 1b) Experimental (symbols) and simulated (solid lines) data vs. ϕ for G = 103, 148, 192, 221, 251 and 295 mT/m.