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Time dependent diffusion studies in partially filled porous glasses using the MAGROFI technique

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1. Introduction

The most popular principle of diffusion measurements by NMR is the attenuation of spin echoes due to incomplete refocusing of coherences as a consequence of incoherent molecular displacements in the diffusion interval of the pulse sequence [0-**Fehler! Verweisquelle konnte nicht gefunden werden.**]. Attenuation of echoes on these grounds arises in the presence of pulsed or steady gradients of the main magnetic flux density B_0 or alternatively of the radio frequency flux density B_1 [**Fehler! Verweisquelle konnte nicht gefunden werden.**]. Moreover, B_1 and B_0 gradients can be applied in mixed form. If suitably matched such mixed combinations of gradients lead to "nutation echoes" [**Fehler! Verweisquelle konnte nicht gefunden werden.**] the diffusive attenuation of which can also be used for molecular displacement studies. Moreover, implementing nutation echoes it is possible to accomplish diffusion measurements with chemical shift resolution in inhomogeneous static magnetic fields [0].

With the techniques mentioned above, a non-equilibrium magnetization distribution is first prepared in the form of a "helix" or as magnetization "grid". Translational diffusion tends then to level the magnetization distribution during the diffusion time. The leveling process is monitored via spin echo attenuation. An alternative method is to directly image the magnetization profile across the sample. A technique for rendering the magnetization profile is the magnetization grid rotating-frame imaging (MAGROFI) pulse sequence [0]. The appealing advantage of the MAGROFI technique in comparison with the rotating frame techniques based on rotary or nutation echoes is that no constant B_1 gradient is required. Moreover, localized diffusion measurements can be performed. The technique is suitable for the simultaneous spatially and spectroscopically resolved acquisition of diffusion, flow, and spin-lattice relaxation data.

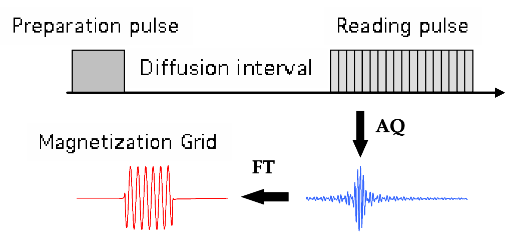

Fig. 1 The MAGROFI technique composed by a preparation pulse, a diffusion interval and a reading pulse. The reading pulse provides a pseudo-FID which, after the Fourier transformation leads to the magnetization grid.

2. Experimental results

In our contribution we show that the MAGROFI technique can be successfully applied to time dependent diffusion measurements of fluids confined in partially filled porous media. A conic coil that generates a spatially rather uniform RF gradient has been designed, and the magnetic field distribution inside that coil has been mapped. The advantages and the reliability of the MAGROFI technique as compared with the spin echo techniques, becomes obvious with measurements of the diffusivities in partially filled porous media with a low filling degree, in which, the short relaxation time T_2, produce a strong attenuation of the signal during the encoding interval in the spin echo technique. The experimental results of this technique are shown in Fig. 2 in comparison to data obtained with the conventional stimulated echo technique (PGSTE).

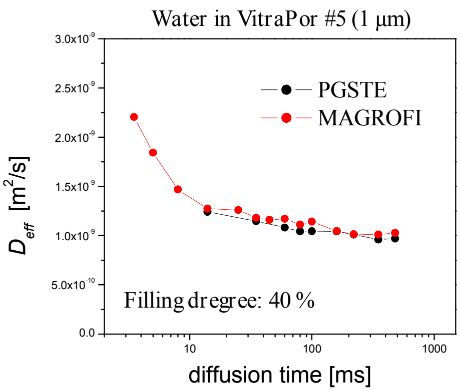

Fig. 2 Comparison of the diffusion coefficients as a function of the diffusion time, measured with PGSTE and MAGROFI techniques.

3. Conclusion

The advantages of the MAGROFI NMR diffusometry technique are: (a) No gradient unit is needed. (b) No constant B_1 gradient is required. (c) Spatially localized diffusion measurements can be performed. (d) The diffusivity can be measured in very short diffusion times.

Diffusion in solvents in partially filled porous glasses is characterized by strongly time dependent diffusivities reflecting the onset of restrictions and contributions by the vapor phase upon molecular exchange between the liquid and gaseous phases [7]. Data measured with the PGSTE and MAGROFI techniques coincide. This demonstrates the reliability of the techniques.

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