An investigation of the pipeline materials for continuous hyperpolarized ^{129}Xe gas imaging

M. SAITO[1], T. HIRAGA[1], M. HATTORI[1], T. NAKAI[1]

[1]National Institute of Advanced Industrial Science and Technology, Ikeda, Osaka, Japan

Introduction

The continuous hyperpolarized xenon-129 (HP-^{129}Xe) gas delivery system with high polarization rate has many potential applications such as fluid imaging or diffusion imaging with higher signal intensity. However, there is a problem: HP-^{129}Xe gas is easily drops to the equilibrium state due to the wall-relaxation phenomenon, and the MR signal thus declines [1]. This relaxation is caused by the interaction between the HP-^{129}Xe gas and the surface of the gas chamber. To minimize the signal loss by wall-relaxation, Pyrex glass has been widely used. The disadvantage of Pyrex glass is fragility. The purpose of this study was to investigate a substitute for Pyrex glass to serve the HP-^{129}Xe gas to the MR imaging systems with minimum signal loss.

Materials & Methods

Stainless steel tubes (ST) prepared with five different passivation processes on the inner surface were investigated. A Pyrex glass tube (PT) was employed as a reference. By combining these STs with inner tubes (IT) made of Pyrex glass, the effect of the surface area size of passive film was evaluated (Fig.1). When a shorter IT was inserted into the ST, more surface area with passive film was exposed. As ITs, thin Pyrex glass tubes (50, 75, 100, 120 and 150mm in lengths) were prepared. All STs were 9.5 mm in outer diameter, 7.4 mm in inner diameter and 150 mm in length. The signal intensities of the HP-^{129}Xe gas, which passed through the tube with the above preparation, were monitored.

^{129}Xe gas was polarized using the spin-exchange method with laser-polarized rubidium under the fringe field (1-2 Gauss) of a 0.3 T permanent magnet (SSMC) of a homebuilt MR system [2]. The mixture gas consisted of naturally abundant Xe (including 26.4 % of ^{129}Xe, flow rate 5.50 ml/min) and N_2 (flow rate 0.65 - 1.00 ml/min). Polarization was performed under atmospheric pressure (760 Torr), and the signals from the HP-^{129}Xe gas were detected at ambient temperature (22.5 °C). The signal intensities were calculated by extrapolation of each real FID. For the comparison of the signal changes between ST and PT, the MR signal intensity of the effective length 0 mm ST, i.e., no area of passivated film was exposed, was normalized. Six recordings were obtained for each ST and the PT. The statistical differences were evaluated using ANOVA.

Results

Fig.2 shows the correlation analysis between the effective lengths of the ST and the MR signal intensities for each ST and PT. The inclination of the signal decline was calculated by linear regression to compare the extent of signal loss. The signal decline was smaller with FP (-0.026, passive film: FeF_2), diX-C (-0.027, poly-para-xylylene) or EP (- 0.037, Cr_2O_3). Among these three, the passive film of iron fluoride (FP) maintained higher signal strength, which was next to that with Pyrex glass (-0.017). The signal intensity was strongly reduced with the other two types of tube, CRP (-0.206, Cr_2O_3) and GEPW (-0.095, Cr_2O_3).

Discussion and Conclusion

The MR signal intensity of HP-^{129}Xe gas could be best maintained by iron fluoride film passivated in the FP process, and most lost by Cr_2O_3 film passivated in the CRP and GEPW processes. When the inner surface area of passivated film increases, the volume of the pipeline also increases and the velocity of the HP-^{129}Xe gas decreases. The longer residence time of HP gas in the pipeline also promotes the T_1 relaxation and it may be responsible for the MR signal decline of PT, which was made of Pyrex glass as was IT. However, the extent of signal loss induced by the wall-relaxation depended more on the material of the passivated film.

Our results suggested that the stainless steeling tube with appropriate passive film may retain the life time of HP-^{129}Xe gas, although the MR signal decline level was slightly larger compared to that of Pyrex glass in the present study. To practically apply a continuous HP gas delivery system to an MR imaging system, stainless steel tubes may be one of the appropriate material as a gas pipeline in terms of the robustness, flexible workability and cost. The use of a thicker tube may give less contact between the gas and the surface, although the residence time of the gas becomes longer. Further investigation of the chemical characteristics and surface treatments will achieve ideal stainless steel tubes for the HP-^{129}Xe gas pipeline.

References

1. Zeng X, et al., *Phys. Lett.* 1983; **96A**: 191-194.
2. Happer W. *Rev. Mod. Phys.* 1972; **44**: 169-249

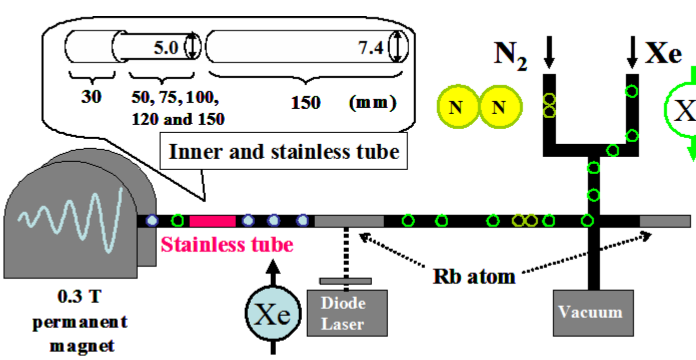

Fig.1 The hyperpolarized ^{129}Xe gas flow system

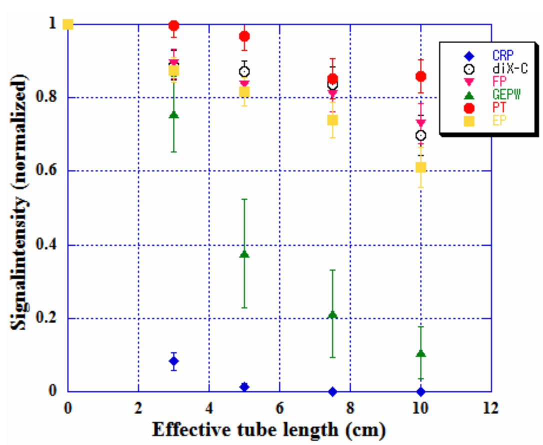

Fig.2 Correlation analysis of the effective lengths of the ST and the signal intensities