VESSEL FOR RARE GAS FILLING, AND METHOD FOR POLARIZATION OF RARE GAS ATOMIC NUCLEUS USING SAID VESSEL

TECHNICAL FIELD

The present invention relates to a vessel for rare-gas filling, and a method for polarization of rare-gas nucleus using the vessel.

BACKGROUND

Magnetic resonance imaging (MRI) diagnostic apparatuses have been put into practical use as a method of examining an internal structure of an object to be measured without injury. At present, many such apparatuses are being operated at general hospitals in local communities and so on, playing an active role on site in medical image diagnostics along with X-ray CT. The MRI exploits the interaction between an atomic nucleus spin (nuclear spin) and an electromagnetic field, which is called as nuclear magnetic resonance (NMR). The resonance energy may be frequencywise converted into a frequency of several tens of megahertz (the frequency band used for FM radio transmission). In the MRI, therefore, the electromagnetic energy irradiated to a test body is fairly low as compared with visible light and X-rays, and is less invasive. However, the low interaction energy for NMR/MRI leads to a related disadvantage, i.e. low detection sensitivity, in theory. In reality, although the MRI diagnostic has become widely used, its resolution is lower than that of X-ray CT. Moreover, since MRI is directed to the hydrogen nucleus (proton, 1H), which has the largest interaction energy among atomic nuclei, it visualizes the density of hydrogen atoms in water, or lipid of a living tissue. Therefore, MRI has found few applications on organs having a low hydrogen density such as the lung. To address such problems, research has been conducted into improving the detection sensitivity of MRI, including application of a very high magnetic field and high coil efficiency. Each attempt at improvement, however, seems to have reached a plateau. In order to achieve an even higher sensitivity, it will be necessary to introduce an innovative technology which studies in depth the principle of NMR. Practical examples of research which has been achieving a success in fulfilling the above described demands include an introduction of a rare gas having a high nuclear spin polarization.

Gases having no sensitivity to MRI at a normal pressure will drastically change the characteristics of MRI when the polarization of nuclear spin of the gases are increased. The nuclear spin polarization of rare gases have been studied for application to the basic science. A method increasing nuclear spin polarization in a rare gas is as follows. The rare gas is filled in a vessel together with an alkali metal such as rubidium or the like. The contents of the vessel are then irradiated with circularly polarized light. Matching the wavelength of the light to the D1 resonance of the alkali metal atom results in a polarization of electron spin of the alkali metal atom due to D1 resonance absorption. The polarized alkali atom collides with the rare gas atom. Through a hyperfine interaction between the electron spin and the rare-gas nuclear spin upon collision, the electron spin polarization is transferred to the nuclear spin polarization. The nuclear spin polarization of the rare gas obtained through this method is very high as compared with a nuclear spin polarization in the conventional MRI. When such a polarization is applied to MRI, the sensitivity will increase by a factor of several tens of thousands to obtain a magnetic resonance signal stronger by not less than 1000 times that of the same volume of water, so that such a rare gas has come to be used for MRI.

In the application to MRI, a polarized rare gas is supplied to a test body in two ways. One way involves a method in which the rare gas is stored together with an alkali metal vapor in a vessel under a static magnetic field. The vessel is irradiated with a laser light to polarize the atomic nucleus of the rare gas through the laser light irradiation, and the rare gas is then supplied to the test body. The other way involves (1) a method in which a mixed gas of the rare gas and the alkali metal vapor is passed through a laser light irradiating part in a static magnetic field to continually polarize the rare gas, and the rare gas is supplied to the test body, or (2) a method using a flow-type polarization vessel conducting the polarization while flowing the mixed gas. The sensitivity of MRI is determined by (1) the energy of the interaction between the nuclear spin and the electromagnetic field, and (2) the product of a square of the nuclear spin polarization and the number of polarized nuclei. This latter product provides a figure of merit for optimization that depends on various parameters. These parameters include, but are not limited to, intensity and circular polarization of laser light in the D1 resonance, a spin exchange rate between the electron spin and the nuclear spin, a spin relaxation time, a pressure of the rare gas, a pressure of nitrogen gas or 4He gas added thereto, and so on. The intensity and circular polarization of the laser light are preferably comparatively high. The spin exchange rate is determined by a combination of a rare gas and an alkali metal and the alkali-metal atomic number density, and the value of the spin exchange rate is preferably comparatively high. The alkali atomic number density is dependent on a temperature. The spin relaxation times of the electron and the nucleus depend on the alkali atomic number density, gas pressure, vessel wall and so on, in which the relaxation time is preferably comparatively long. Taking into consideration all of the above, conditions most suitable for a polarization vessel are as follows:

(1) the light incident part of the vessel should not impair the intensity of the laser light generating D1 resonance;

(2) a more completely circularly polarized light in the vessel should be realized in order to promote a high nuclear spin polarization;

(3) paramagnetic impurities should be decreased on the surface of the vessel as far as possible in order to obtain a long relaxation time;

(4) the vessel should have a high alkali resistance;

(5) the vessel should have a high pressure resistance because a higher gas pressure in the vessel, for example not less than several atmospheric pressure, is preferable; and

(6) when the vessel is used for the polarization of 3He, the vessel should have no permeability for 3He.

Further, when the vessel is applied to basic science, especially when it is used in precision experiments and the like, it is required to have an certain accuracy, so that

(7) the thickness and material of the vessel are preferably uniform; and when the vessel is used in an neutron scattering experiment,

(8) the material of the vessel must have a transparency for neutrons.

JP-A-11-309126 describes an apparatus for producing a polarized rare gas. A flow-type polarization vessel of a coaxial, multi-cylindrical configuration is created by combining outer and inner cylinders, each made of silica glass with a clearance of 0.5 mm. A mixed gas of a rare gas and a vapor of an alkali metal, such as rubidium, is caused to flow in one direction into the clearance. An excited light is irradiated into