MICRO-CELL FOR NMR GYROSCOPE

BACKGROUND

This application relates generally to nuclear magnetic resonance (NMR) gyroscopes and atomic clocks, and in particular to fabrication, coating, and sealing of alkali vapor cells suitable for both applications.

Atomic clocks and NMR gyroscopes (gyros) utilize generally glass cells containing alkali metal, alkali metal vapor and various other gases. The alkali metal is optically pumped to an excited state. For the optimum operation of either the clock or gyro, interaction of the alkali vapor with the walls must be minimized. One way is to use a buffer gas to reduce the number of collisions with the walls. The other way is to minimize the interaction with the walls when a collision does occur. Various coatings have been utilized to minimize interaction. For atomic clocks, paraffin has been used. For NMR gyros, certain hydrides have been used.

Thus, a need exists for a cell having a high transmissivity at wavelengths of interest while minimizing undesired cell wall interactions.

SUMMARY

The invention in one implementation encompasses a cell. The cell comprises an alkali metal and a coating of parylene on an interior surface of the cell.

Another implementation of the invention encompasses a method. The method comprises the steps of forming a cell from an optically transmissive material having an opening therethrough, attaching top and bottom covers to the optically transmissive material, forming an opening in one of the top or bottom covers to provide a fill hole for the cell, depositing a coating of parylene on an interior surface of the cell, and placing an alkali metal within the cell.

DESCRIPTION OF THE DRAWINGS

Features of exemplary implementations of the invention will become apparent from the description, the claims, and the accompanying drawings in which:

FIG. **1** is a top plan view of a cell of the prior art.

FIG. **2** is a side elevational view of the cell of FIG. **1**.

FIG. **3** depicts a cell arrangement suitable for an atomic clock implementation.

FIG. **4** illustrates a cell configuration for an NMR gyro.

FIG. **5** is a top plan view of a cell in accordance with one embodiment of the present invention.

FIG. **6** is a side elevational view of the cell of FIG. **5**.

FIG. **7** is a top plan view of a cell illustrating heater placement.

FIG. **8** is a side elevational view of a cell illustrating creation of a cold spot.

DETAILED DESCRIPTION

Cells made using MEMS (micro-electromechanical systems) technology have been developed for chip-scale atomic clocks. FIGS. **1** and **2** illustrate the basic principle. The cell **100** uses a standard pyrex-silicon-pyrex wafer sandwich, in which relatively transparent pyrex wafers **101** are bonded to an open silicon structure **202** to form a cell. Generally, the wafers **101** are bonded to the silicon **202** by anodic bonding. A mirrored surface **102** may or may not be included. Naturally, the mirrored surface **102** would be included in a double-pass arrangement where the detector would be on the same side of the cell as the light source **201**. FIG. **3** depicts a cell arrangement suitable for an atomic clock, in which the detector **301** is oppositely disposed from the light source **201**. In FIGS. **1-3**, the light source **201** is a VCSEL (Vertical Channel Surface Emitting Laser). Much better performance can be obtained for a gyro implementation by utilizing the arrangement shown in FIG. **4**, which exhibits light transparency (high transmissivity) in the near infrared (IR) on two orthogonal axes.

Both atomic clocks and NMR gyros use optically pumped alkali atoms. In a clock, the hyperfine splitting of the ground state gives the time-stable frequency required in a precise clock. In a gyro, the spin moment of the Zeeman levels are transferred via collision to the nuclei of noble gas atoms. The subsequent precession of these moments about an applied magnetic field is observed by their effect on the alkali atoms and detected as modulation of a light beam. By comparing the precession frequencies of two noble gas systems, desired rotation effects can be extracted. The basic operation of a gyro system is described in detail in U.S. Pat. No. 4,157,495, the disclosure of which is fully incorporated by reference thereto as though fully set forth herein.

Since both atomic clocks and NMR gyros employ alkali metals optically pumped from their ground state, a competitive advantage could be obtained by designing an instrument that contains both clock and gyro functionality. It would require adding a number of features to the clock, including the need for a transverse interrogation beam to obtain gyro precession signals, more uniform and directed magnetic field, and perhaps separate light sources for gyro signals. Virtually all small inertial navigation systems currently envisioned need both gyro and clock functions. However, although each individual instrument would be more complicated, the sum would be both smaller and less costly than having dedicated instruments for each function.

FIGS. **5** and **6** illustrate the design and fabrication processes and sequence for NMR gyro cells. The cells **500** are filled at the wafer level, and then sealed at the wafer level under an atmosphere of the required gases (like Xe and Kr or selected isotopes thereof). First, a cell opening **601** is cut into the pyrex wafer **603**. Top and bottom silicon covers **602** are anodically bonded to the pyrex wafer **603**, one at a time, with one of the top or bottom covers **602** having a fill hole **501** provided therein. The interior of the cell **601** is then coated with parylene.

Parylene is an extremely inert polymer film. It is deposited in vacuum and is completely conformal. It has a wide working temperature range from −200 to +200 deg C. The films can be optically transparent as required for either atomic clock or NMR gyro applications. It performs as a coating like paraffin, but is much more uniformly deposited and has a much larger working temperature range. The monomer deposits as a film inside the cell with only a small fill hole (**501** in FIG. **5**). Cells are then sealed by melting a film of parylene over the fill hole.

It is anticipated that parylene will manifest spin lifetime enhancing properties similar to paraffin. It is known that an NMR gyro utilizes two kinds of spins. One is the spin of orbital electrons of the alkali metal. This state is obtained by optical pumping. Both clock and gyro use this state. This state normally has a lifetime of the order of a millisecond. Paraffin has been shown to increase this lifetime substantially, perhaps up to one second. Since parylene is also a hydrocarbon, it should be similarly effective, and certainly performs better than bare glass cell walls.

The other kind of spin is the nuclear spin. Xe129 and Xe131, both of which occur in natural Xenon, can be caused