NMR GYROSCOPE

BACKGROUND

This application relates generally to nuclear magnetic resonance (NMR) gyroscopes, and in particular to an exemplary architecture and implementation.

Known implementations of NMR gyroscopes (gyros) have inconveniently large packages and undesirably high power consumption. Additionally, known gyro structures mix technologies, requiring process steps and procedures that are inconsistent with efficient batch processing during manufacture.

Thus, a need exists for an NMR gyro in a relatively small package with reduced power consumption. Further, there is a need for an architecture that allows efficient batch processing during manufacture.

SUMMARY

The invention in one implementation encompasses an NMR gyro. The NMR gyro comprises a support structure affixed within an enclosure, an NMR cell affixed to the support structure, a plurality of permanent magnets disposed about the NMR cell to produce a magnetic field within the cell, and a field coil disposed proximate the cell to produce a modulated magnetic field transverse to the magnetic field produced by the permanent magnets.

In one implementation, the NMR gyro is fabricated in a batch process with a wafer structure comprising a centrally disposed micro NMR cell wafer disposed between top and bottom lid wafers, a detector wafer adjacent the NMR cell wafer, an electronics wafer including detection and signal processing electronics adjacent the detector wafer, a polarizer wafer adjacent the NMR cell wafer on a side opposite the detector wafer, an optics wafer adjacent the polarizer wafer, a laser wafer including readout and pump VCSELs adjacent the optics wafer, and a source control electronics wafer adjacent the laser wafer.

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 an NMR gyro assembly in accordance with the present invention.

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

FIG. **3** is a perspective view of the NMR gyro of FIG. **1**, with the cover shown in outline.

FIG. **4** is a stylized view of a wafer organization of an alternative embodiment of an NMR gyro in accordance with the present invention.

FIG. **5** is an alternative depiction of the wafer organization of FIG. **4**.

DETAILED DESCRIPTION

FIGS. **1-3** illustrate a compact, generally circular NMR gyro package **100**. In one embodiment of the invention, the case **108** is about 16 mm in diameter and 6 mm tall. Of course, the exact shape and aspect ratio of the package could be modified after detailed consideration of magnetic field and field uniformity.

The cell **101** containing the alkali metal, gases with desired nuclear spins, such as, but not limited to, isotopes of

Xe or Kr and potential buffer gas is located at or near the center of the case **108**. In one embodiment of the invention, the cell **101** must be maintained at a temperature of roughly 100 deg C. The cell **101** is equipped with a heater, although this is not illustrated in the drawings. To provide a gyro with the lowest possible operating power, the cell **101** must be suspended in vacuum to minimize thermal loss. It is suspended in vacuum by the support **106**. In one embodiment of the invention, the support is made from a material with a high strength to thermal conductivity ratio to minimize thermal conduction down the legs. Also on the support is a pump VCSEL **103** (Vertical Channel Surface Emitting Laser). The light output from the pump VCSEL **103** is directed along the direction about which the rotation is being measured, depicted by arrow A. Depending on the final implementation, the VCSEL chip may also be required to contain a photodetector to monitor the light reflected from a mirror deposited on the opposite face of the cell **101**. The light from the pump laser must be circularly polarized. This is accomplished by inserting a quarter wave plate **109** between the pump VCSEL **103** and the cell **101**.

Also on the support **106** is a VCSEL **102** with a photodetector on the chip to act as a sensor. On the cell face opposite this VCSEL **102** is a deposited mirror. The support **106** also has electrical conducting traces **104** to carry heater power and signals between the electronics and the VCSEL/cell cluster. These traces may be on any or all legs of the support, and may be on either top or bottom of the support, or on both sides.

The wavelength of the light output from the VCSELs must be tuned to the exact absorption wavelength of the alkali line. This is accomplished by adjusting the temperature of the VCSEL cavity. This in turn can be adjusted by changing the VCSEL current or by providing a heater on the VCSEL so that the optical power out of the VCSEL can be independently controlled.

The operation of the gyro requires a magnetic field along the rotation axis, depicted by arrow A. To avoid using electrical power to generate this magnetic field, permanent magnets **105** are used to generate a uniform magnetic field, in the range from about 0.1 to 10 Gauss, within the internal volume of the cell **101**. The design of magnets to accomplish this is covered in U.S. Pat. No. 5,469,256, the disclosure of which is fully incorporated by reference thereto as though fully set forth herein.

The case **108** contains four support mounts **202** to which the support **106** is attached. On the floor of the case is a custom ceramic circuit board **204** that surrounds the magnets **105**. The circuit board **204** contains all the electronics for control of the gyro. Much of the electronics will be contained in a single ASIC chip. There may be an innovative method for having the support mounts also make electrical interconnections between the traces on the support and traces on the ceramic circuit board **204**. In the alternative, connections may be made by conventional wire bonds.

In one embodiment of the invention, the case **108** itself is made of annealed HyMu 80 to achieve maximum shielding. HyMu 80 alloy is an unoriented, 80% nickel-iron-molybdenum alloy that offers extremely high initial permeability as well as maximum permeability with minimum hysteresis loss. There is flexibility in the location of the joint **201** between the top and bottom of the case **108**. The design shown for the joint is intended to be illustrative of measures to be taken to insure that external magnetic lines do not penetrate through the joint **201**. In the base of the case are a number of feedthroughs **203** that are arranged in a circle reasonably close to the outside diameter of the case **108**. The