Torsional Oscillator for the Study of the Two Dimensional Superfluid $^3$He

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Abstract

One of the most important characteristics of the superfluid helium, $^3$He, is the existence of two phases; the A (axial) and B (isotropic) phases. They have similar free energy and are separated by a surface of first order transition in the space of pressure, temperature and magnetic field. Theoretical work predicts unexpected phase transitions for the two dimensional superfluid $^3$He as compared to the transitions in the bulk superfluid $^3$He [1, 2]. In order to study the phase transitions in the two dimensional $^3$He, we have developed a torsional oscillator in which the superfluid helium is constrained to a 500 nm thick layer.

Summary of Research

The superfluid helium is constrained to a thin film in a doughnut shaped cell with a diameter of 1 cm and a depth of 500 nm. In order to create the cell, a 3 $\mu$m thermal oxide is grown on a 3 mm thick silicon wafer followed by patterning and etching the oxide. A second thermal oxidation consumes different amounts of silicon in the etched and non-etched regions. The cell is then ultrasonically drilled to create the helium fill-channel and the mounting point for the torsional rod. The wafer is then diced into square pieces with the fill-line in the center, followed by removal of the remaining oxide layer (Figure 1). The final step is to anodically bond the silicon to a 3 mm thick SD2 Hoya glass with the same size as the diced silicon pieces.

The cell is then epoxied to a torsional rod made of coin silver with magnesium wings. The torsional rod has been drilled through in advance to create the fill-line for the cell. The wings are capacitively coupled to the driving and detection electrodes. In order to achieve better thermal conductivity for the assembly, a 2 $\mu$m silver film is sputtered on the cell and the epoxy joint. The final assembly of the oscillator is shown on Figure 2.
The quality of the bond between the silicon and the glass has been tested by cooling the whole oscillator to liquid nitrogen temperature and pressurizing it to 20 psi with helium while looking with a leak detector for escaping helium gas. A separate cell with a different geometry (rectangle with width 7 mm and length 10 mm) has been tested at liquid helium temperatures for the quality of the bond. In both cases the cells were leak tight.

Since the distinction between the A and B phases of the superfluid $^3$He is done by measuring the ratio between normal and superfluid fractions in the respective phases, we need to know precisely how much of the normal fraction is coupled to the oscillator. Casey, et al [3], have observed the slip of thin slabs of normal $^3$He in a torsional oscillator. Prior to the measurement of the A and B transitions, we will characterize the slip amount in our cell for different temperatures and pressures.

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**References**

