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PHYSICA B

Diffusion Welds Between Copper and Silver Alloys

J. V. Porto and J. M. Parpia
Department of Physics, Cornell University
Ithaca, New York, 14853, USA

We describe the diffusion weld process we use to construct a torsional oscillator cell, designed to cool saturated mixture films of ^{3}He and ^{4}He. We intend to look for the proximity effect across the ^{3}He-dilute solution boundary.

1. MOTIVATION

The cell described in this paper was designed for experiments on ~1000Å films of ^{3}He-^{4}He mixtures. The design tries to address the problems of cooling the films and mass sensitivity. A diffusion weld provides good thermal contact between the various parts of the cell, essential since the films will be cooled entirely through the weld. The interior geometry of the cell is preserved by the weld, and after joining the parts can be machined.

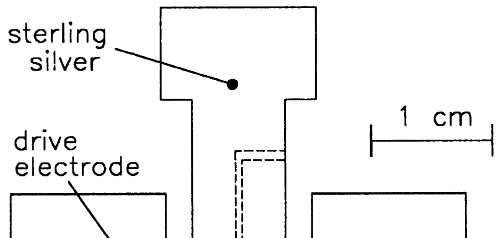

Figure 1. Double oscillator with drive and detect electrodes.

2. DESIGN AND FABRICATION

To minimize the mass of the small cell, the device is a double oscillator, with the drive and detect electrodes attached to the second, more massive moment of inertia (fig 1). The oscillator body was made of sterling silver to ensure good thermal conductivity down the torsion rod [1], and because sterling silver welds well to copper, the bottom cap of the cell was made of copper. The copper could be reasonably well polished down to 0.05 μm alumina powder.

Only the interior cup of the cell and the fill lines were machined into the 1/2 inch sterling rod before the diffusion weld was made. The cup was machined .006 inches deep by .440 inches in diameter, leaving a flat rim to which the copper cap was joined. After welding, the copper cap was faced off to a thickness of .020 inches and the two torsion rods were machined into the silver. The electrodes were epoxied to the second moment as the last step.

3. DIFFUSION WELD RECIPE

Four factors were varied in the search for the correct diffusion weld recipe: pressure across the joint, surface preparation, temperature and time. All of the welds were done under vacuum.

3.1. PRESSURE

Diffusion welds were tried with pressures ranging from 25 to 350 lbs/in^2, applied by stacking stainless steel weights on top of a jig. The relatively high pressures were easily obtained because of the small area of contact (~ 4-8 mm^2) between the copper cap and the silver cell.

A high pressure is critical if the surfaces to be joined do not match exactly. All of the lower pressure welds were successful in *joining* the copper and silver pieces, but the joints leaked. The high pressure did cause deformation of the silver rod, but this was small (~ 1 % in diameter of the rod) and the piece was machined after the weld.

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3.2. SURFACE PREPARATION

Successful diffusion welds require that the surfaces to be joined must be clean of oxides, grease and other contaminants. The easiest way to clean the surfaces was to rinse them in propanol and then polish them with 0000 grit dry emery paper. The copper was polished and soaked in acetic acid.

Leak tightness also required a good match between surfaces. The top and bottom of the copper cap were machined to be parallel to each other. The top was carefully polished to maintain the geometry. Care was also taken to ensure the squareness of the rim and cap while applying pressure during the weld.

3.3. TEMPERATURE AND TIME

The copper/silver eutectic temperature is 780 C. The temperatures tried ranged from 550 C to 760 C. Time at temperature varied from 2 hours to 30 minutes. In general for the highest temperatures long times were not needed. For temperatures between 650 and 700 C the metals were joined but not leak tight, and welds done at 700 C for an hour were not consistently leak tight. The recipe that reproducibly succeeded required a pressure of 350 lbs/in^2 at 755 C for 40 minutes.

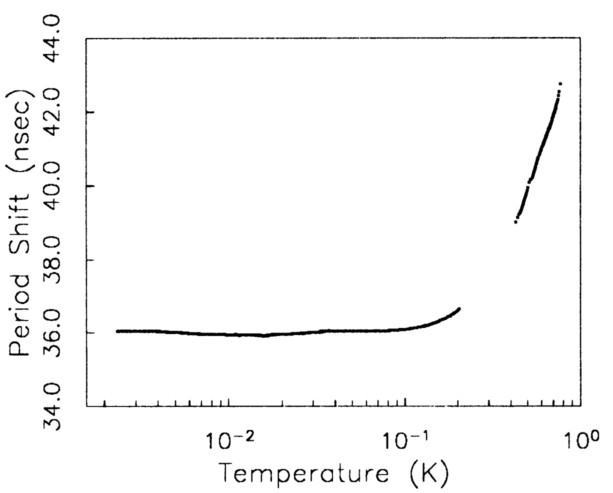

Figure 2. The empty cell background period shift of the sterling silver torsional oscillator.

4. CELL PERFORMANCE

The cell was leak tight against superfluid ^4He. The antisymmetric mode had a resonant frequency of ~1700 Hz, and a Q of ~ 5 x 10^5. The empty cell background period shift was measured from .8 K to 2 mK.(fig 2) Sterling silver has a smaller temperature dependence to its elastic constant than beryllium copper. For the oscillator described in this paper we find a temperature variation of ~0.1 nsec below 100 mK, an order of magnitude smaller than that of comparable BeCu oscillators. Past experience has shown that a post machining anneal can further reduce the temperature dependence of the background while enhancing the Q. With the present design we require a period stability of 1 part in 10^9 to resolve the mass of ^3He in a 2500 Å dilute mixture film to 1%. Currently we are a factor of 10 from this goal, with phase noise in the feedback loop and interacting parasitic modes being the dominant component to the period variation. Stability of a part in 10^9 has been achieved in the past.[2]

5. ACKNOWLEDGMENTS

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