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Torsional oscillator measurements on superfluid ^{3}He in 99.5% porous aerogel

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Abstract

We used a torsional oscillator to investigate the properties of ^{3}He confined in a 99.5% porosity aerogel. We measured both the period and amplitude of the oscillations over a range of pressures and temperatures. The supression of the superfluid fraction and the reduction in T_c relative to bulk are less pronounced than in the denser aerogels previously studied.

Keywords: Aerogel; ^{3}He superfluid in aerogel; Phase transition

The superfluid transition in bulk ^{3}He is well understood both experimentally and theoretically [1]. Superfluidity of ^{3}He in silica aerogel has opened new paths for investigation. The aerogel provides correlated structural disorder which affects the phase transition into the superfluid state; the interactions between the aerogel and the ^{3}He quasiparticles have been observed to suppress both the transition temperature and the superfluid density [2]. We have constructed a torsional oscillator cell filled with a very low-density silica aerogel in order to investigate the role of the microstructure of the disorder in shifting the phase diagram of ^{3}He.

We used a BeCu torsional oscillator with a resonant frequency of 483 Hz. The quality factor for this torsional mode was 20 000 at helium temperature. The oscillator was driven in a self-resonant loop which provided a period stability of better than 5 parts in 10^7. We monitored the amplitude of the oscillations at constant drive to obtain information about dissipation in the cell.

The aerogel used for this experiment was grown into the pores of a 100 μm silver sinter. The aerogel had a nominal 99.5% porosity which, by extrapolating from previous measurements, leads to correlated disorder on length scales from 30 to 2000 Å with a geometrical mean free path of over 10 000 Å. We measured the temperature using a LCMN susceptibility thermometer sharing a common ^{3}He reservoir with the cell. The LCMN was calibrated using the heat capacity anomaly at the bulk superfluid transition. The warming rate was kept to 25 μK/h, which led to a thermal offset of 15 μK between the cell and the thermometer.

We were able to observe a superfluid transition in ^{3}He in a 99.5% porosity aerogel at pressures ranging from 2.5 to 25 bar (Fig. 1). We identified the critical temperature in aerogel (T_{ca}) by associating the superfluid transition with a sharp change in the period of the oscillator. The suppression of the aerogel transition temperature is largest at low pressures (longer coherence lengths) and decreases with increasing pressure (see inset to Fig. 1). The pairing mechanism of the ^{3}He quasiparticles is more sensitive to the presence of the aerogel at low pressures because the Cooper pairs interact with the nonuniform disorder background over a wider range of length scales. At higher pressures, where the coherence length drops to 150 Å, the Cooper pairs are less sensitive to the longer length scales in the aerogel.

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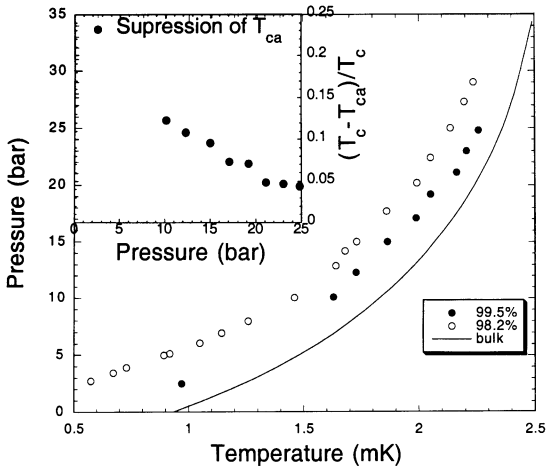

Fig. 1. The superfluid transition temperature for various pressures. The full circles are for the 99.5% aerogel; the empty circles are for previous measurements on 98.2% aerogel. The inset shows the suppression of T_{ca} relative to T_c, ranging from 25% at the lowest pressure to 5% at higher pressures.

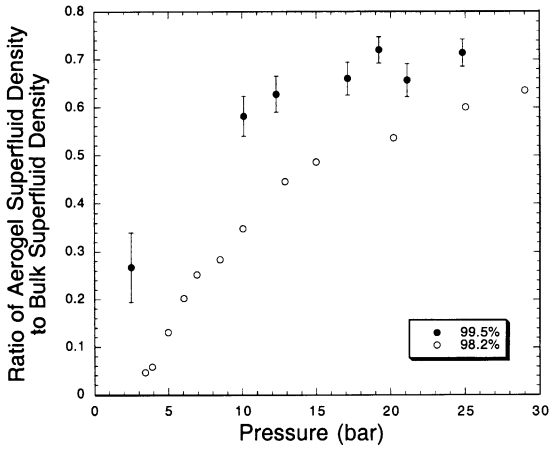

Fig. 2. Superfluid density of ^{3}He in aerogel at $0.8T_{ca}$. The vertical axis is ρ_{sa}/ρ_{s0} at $0.8T_c$. The full circles are data for a 99.5% aerogel; the open circles are for a 98.2% aerogel. Error bars for the 99.5% aerogel arises from subtracting off the bulk contribution.

The aerogel also affects the development of the superfluid density (ρ_{sa}). We obtain ρ_{sa} at each temperature by comparing the period shift below the transition temperature to the period shift measured upon filling the empty cell with ^{3}He, correcting for a small amount of bulk liquid present in the cell. The normal component of the ^{3}He is clamped inside the pores and the superfluid component couples into the oscillator only through the tortuosity of the sinter and aerogel. The 99.5% porosity aerogel is a weaker perturbation to ρ_s than the 98.2% aerogel, especially at lower pressures (Fig. 2).

We have investigated a new region of the disorder–pressure–temperature phase space for the ^{3}He in aerogel system. The results are qualitatively similar to previous measurements, although the behaviour of the ^{3}He is closer to the bulk behaviour than was observed in the denser aerogels.

Acknowledgement

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