

Acoustic Spectroscopy of Superfluid ^3He in Aerogel

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Abstract: We have designed an experiment to study the role of global anisotropic quasiparticle scattering on the dirty aerogel superfluid ^3He system. We observe significant regions of two stable phases at temperatures below the superfluid transition at a pressure of 25 bar for a 98% aerogel.

Keywords: Superfluidity, Helium 3, Aerogel

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INTRODUCTION

Ultrasonic spectroscopy has proven to be a powerful tool in the study of ^3He . The acoustic impedance for transverse sound exhibits anomalies at phase transitions that mark the superfluid phase diagram of ^3He in 98% porosity silica aerogel [1]. The scattering of ^3He quasiparticles from the silica aerogel strands suppresses T_c and stabilizes the B -phase. An A -like phase is found to be metastable in zero field with large supercooling [1]. This is consistent with NMR [2] and low-frequency sound velocity measurements [3].

More recent acoustic tracking experiments by Vicente *et al.* [4] and NMR by Osheroff *et al.* [5] (99.3% aerogel) reveal that the A -like phase is in fact stable in a small temperature window near T_c at high pressure. Vicente *et al.* suggest that this stabilization is due to the *local* anisotropic scattering from the aerogel strands. Furthermore, they propose introducing *global* anisotropy by uniaxial compression of the aerogel to study the effect.

THEORY

Sauls [6] and Thuneberg *et al.* [7] have shown that local anisotropy can stabilize the axial state of superfluid ^3He within aerogel. The relative stability of the axial (A) and isotropic (B) phases can be expressed as the difference between the beta parameters. The beta parameters are the coefficients of the fourth order terms in the Ginzburg-Landau expansion of the free energy in powers of the order parameter and are

proportional to the difference in the heat capacity jumps.

Sauls also noted [6] that large length scale correlations, or global anisotropy, in the aerogel might also favor phases with the orbital wavefunction perpendicular to the anisotropy axis, namely the planar or axial phases.

EXPERIMENT

In order to study the role of anisotropy, one needs a probe that is both directional and extremely sensitive to phase transitions in the ^3He . Transverse acoustic impedance has been shown to give a clear signature of all phase transitions in ^3He [1]. The magnetic field dependence of the phase diagram allows us to assign which phases are equal spin pairing (ESP), like the A -phase or non-ESP, like the B -phase.

We designed and built a cell to compress a pair of aerogel samples that sandwich an *ac*-cut quartz acoustic transducer, as shown in Fig. 1. The electrical impedance was measured with a continuous wave impedance bridge [8]. A melting curve thermometer (MCT) was used as the primary thermometer based on the Greywall temperature scale [9].

The 98.2% aerogel in this experiment was grown at Northwestern using a two-step synthesis with rapid supercritical extraction (RSCE); and $\sim 10\%$ shrinkage was observed. Similar aerogels were studied by small-angle x-ray scattering (SAXS) as a function of compression [10]. Anisotropy increases systematically with uniaxial compression.

Additionally, there is evidence of some intrinsic anisotropy [10].

In our preliminary work, we performed temperature sweeps, Fig. 2, to determine how the ^3He might be affected by this aerogel before removing the spacers and compressing the samples; this is the data that we present here.

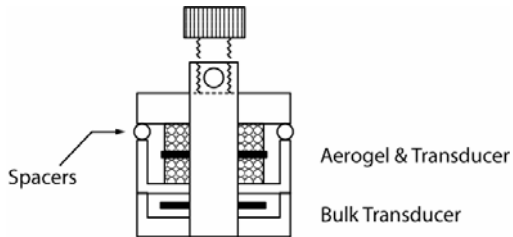


FIGURE 1. Compression cell. Spacers ensure transducer contact to the nominally uncompressed aerogel.

DATA AND RESULTS

At a pressure of 25 bar the bulk transition is at 2.36 mK, and is indicated by a separate bulk-transducer, Fig. 1. This trace is not shown in Fig. 2. We see no evidence for a bulk transition with the aerogel-sample transducer. In addition, the superfluid transition temperature in aerogel is less suppressed than previously observed by Gervais for a comparable porosity aerogel [1] ($T_{ca} = 1.91$ mK). The transition from normal to superfluid appears to be in two parts, the superposition of a broad transition and a narrow transition. At lower temperatures there are also two distinct features in the acoustic impedance. On warming one of these is exceedingly sharp ($\Delta T \approx 2$ μK) and it exhibits a small hysteresis that can be associated with a first order transition. All of these features have been reproduced on multiple temperature sweeps.

The double transitions can most naturally be associated with there being two, non-identical, aerogel samples with which the transducer is in contact. Tentatively we associate the two low temperature features as transitions from B to A -like phases on warming, based on: a) previous studies of transverse impedance experiments [1], and b) their supercooling. The stability of the A -like phase might be a consequence of intrinsic global anisotropy [10], or possibly anisotropy introduced by nominal strain from the sample holder. Further work at different pressures and as a function of compression and magnetic field should help to clarify this situation.

CONCLUSIONS

Preliminary studies of ^3He at 25 bar in 98% aerogel grown at Northwestern suggest that an A -like phase can be stabilized, likely due to global anisotropy induced in the aerogel sample.

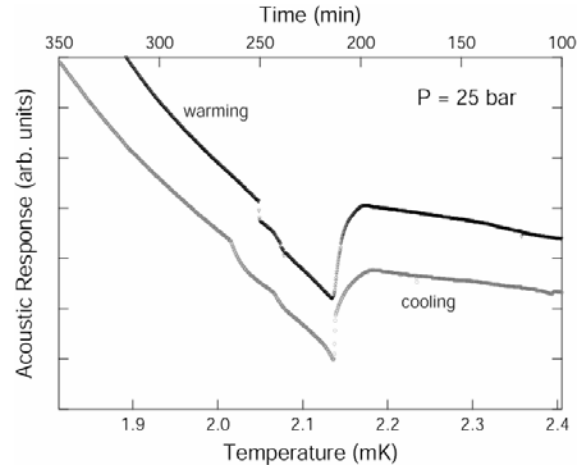


FIGURE 2. Acoustic impedance measurements of phase transitions for ^3He within a 98.2% aerogel. The major feature is the transition to superfluid in aerogel; smaller features are discussed in the text.

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