OBSERVATION OF A HIGH FIELD PHASE IN SUPERFLUID $^3$He IN 98% POROSITY SILICA AEROGEL

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Introduction

Superfluid $^3$He in high porosity aerogel is the system in which the effects of static disorder on a p-wave superfluid can be investigated in a systemic manner. The nano-meter scale structure of high porosity aerogel provides a self-sustaining matrix of dilute static impurity which interferes with the formation of Cooper pairs in superfluid $^3$He. The fragile nature of the p-wave Cooper pairs against impurities was clearly demonstrated by the significant depression of the superfluid transition. To date, two distinct superfluid phases have been observed in this system in moderate magnetic fields ($< 8$ kG). We report our finding of the third superfluid phase in 98% porosity aerogel which appears only in the presence of strong magnetic fields [1].

Experimental

We performed continuous wave shear acoustic impedance measurements on both bulk liquid (pure) and liquid in aerogel(dirty) in the presence of magnetic fields up to 15 T at 28.4 and 33.5 bar using the High B/T Facility. In brief, we detect the change in electrical impedance of an ac-cut quartz transducer in contact with both pure and dirty liquid. The acoustic measurement is performed at 8.7 MHz. Temperature is determined by the $^3$He melting pressure thermometer attached right below to the main sample cell made out of pure silver and titanium. In high magnetic fields ($3 T < H < 14.5$ T), the recent calibration by a University of Tsukuba group was employed [3].

Results and Discussion

Figure 1 shows the field dependent transition temperatures at 28.4 bar. Open (closed) circles are for bulk (aerogel) transitions. The transition features are identified as distinct steps (bulk) and slope changes (aerogel) in the acoustic trace. The single transition feature at zero field splits into two transitions in magnetic fields inducing a new phase appearing inside the wedge. The size of the splitting is linear in field as demonstrated in the figure. The high field phase in bulk has been identified as the A1-phase in which only the spin up component participates in forming Cooper pairs. Similar behavior is observed for 33.5 bar. We could not resolve or identify the splitting in aerogel below 3 T. This might suggest antiferromagnetic exchange between the localized $^3$He adsorbed on the aerogel surface and mobile $^3$He spins in liquid.

Conclusions

We observed the superfluid transition in 98% aerogel split into two transitions in the presence of magnetic fields above 3 T at 28.4 and 33.5 bar. The field dependence of each transition is consistent with that of the A1-phase observed in pure liquid.

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References