Measurements of longitudinal and transverse magnetic relaxation in superfluid ^{3}He confined to aerogel

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Abstract

We present results of pulsed NMR measurements of magnetic relaxation in liquid ^{3}He in aerogel. It was found that both longitudinal and transverse relaxation starts to change below the temperature of the superfluid transition of ^{3}He in aerogel. Below T_c^a the longitudinal relaxation depends on the initial tipping angle.

Key words: superfluid ^{3}He; aerogel; NMR

1. Introduction

Previous studies of superfluid ^{3}He in aerogel (see e.g. [1–4]) resulted in establishing the superfluid phase diagram and also raised several new questions. In particular, the origin of a negative frequency shift in supercooled A-phase is not yet well understood. In the B-phase the width and the form of the NMR line shows that the texture of the order parameter is not defined by the walls of the experimental cell, but probably by local spatial inhomogeneities inside the aerogel. The texture is found to be quite rigid, so even large tipping pulse does not cause the textural transition into the Brinkman-Smith configuration [5]. The magnetic relaxation in superfluid ^{3}He in aerogel was not yet systematically studied but it is clear that it should depend on these textural inhomogeneities. Here we present the results of our pulsed NMR studies of the magnetic relaxation in superfluid B-phase of ^{3}He in aerogel. The experiments have been done for the case of aerogel preplated with a few monolayers of ^4He as well as for pure ^3He in aerogel.

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2. Experiments

Experiments were made at pressure of 20.5 and 25.5 bar in magnetic fields from 142 Oe up to 1.06 kOe (corresponding NMR frequencies are 461 kHz and 3.45 MHz). The obtained results are found to be qualitatively the same for all used NMR frequencies. The aerogel sample (porosity is about 98%) had a form of a cylinder (diameter = length = 5 mm) with the axis oriented along the external magnetic field. The sample was situated inside an epoxy cell so that there were small gaps (0.15 mm) between aerogel and internal surfaces of the cell. The NMR coil was wound outside of the cell and was thermally attached to the mixing chamber of a dilution refrigerator. Standard pulsed NMR technique was used. To measure transverse relaxation we have applied a single radiofrequency (RF-) pulse which deflected the magnetization on a small angle ($\beta \leq 15^\circ$) and free induction decay signal (FIDS) has been recorded. The longitudinal magnetic relaxation was measured by the application of a set of pairs of RF-pulses with different time delay between pulses in the pair.

The superfluid transition temperature of ^{3}He in aerogel was found to be $T_c^a \approx 0.76\,T_c$ at 25.5 bars (T_c is

the superfluid transition temperature in the bulk ^{3}He). The amplitude of the FIDS signal for small ($\leq 15^\circ$) tipping angles is well described by the exponential law $A = A_0 exp(-t/T_2)$, where effective transverse relaxation time T_2 slowly increases with increasing the temperature. Such a behavior is obviously due to the presence of solid ^{3}He layer on aerogel strands. We have found that $T_2 \approx 1.8$ ms at $T = T_c^a$ for both used pressures and for the field of 284 Oe. Below T_c^a the duration of the FIDS decreases and the dependence of its amplitude on time is not described by the exponential low. Surely it is due to the superfluid transition of ^{3}He in aerogel and the textural broadening of the NMR line as it was found earlier in CW NMR experiments. In the case of ^{4}He preplated aerogel the results are qualitatively similar, however above T_c^a the transverse relaxation time is much larger and we were not able to directly measure it due to the residual inhomogeneity of the external magnetic field (about 5×10^{-5} in our experiments).

Above T_c^a the longitudinal relaxation time (T_1) depended on whether we have ^{4}He preplated sample or not (e.g. at $T = T_c^a$ and H=284 Oe $T_1 \approx 2$ s in the case of ^{4}He preplated aerogel and $T_1 \approx 40$ ms for the pure ^{3}He sample). This difference is due to the surface magnetic relaxation on solid ^{3}He on aerogel strands [6]. The recovery of longitudinal magnetization was found to be exponential in both (pure ^{3}He and ^{4}He preplated aerogel) cases.

Below T_c^a the recovery is not exponential and T_1 (defined as the best exponential fit) rapidly decreases with the decrease of the temperature (Fig.1). Moreover, we have found that T_1 starts to depend on the tipping angle (Fig.1 and Fig.2).

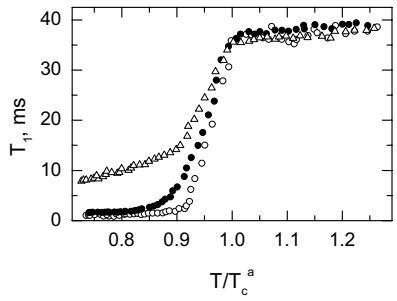

Fig. 1. Effective longitudinal relaxation time versus the temperature for pure ^{3}He in aerogel. H=284 Oe, P=25.5 bar. Open circles: $\beta = 50^\circ$, solid circles: $\beta = 65^\circ$, triangles: $\beta = 110^\circ$

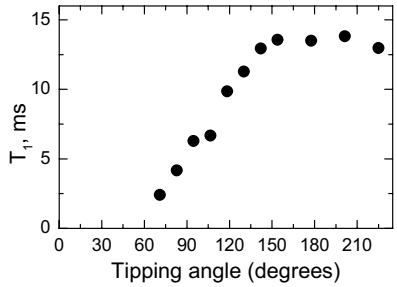

Fig. 2. Effective longitudinal relaxation time versus the tipping angle for pure ^{3}He in aerogel. H=284 Oe, $T = 0.82 T_c^a$, P=20.5 bar.

3. Discussion

It is known that the magnetic relaxation in the bulk superfluid ^{3}He-B is rather complex and depends on many factors e.g. on the gradient of the external magnetic field, inhomogeneity of the spatial distribution of the magnetization, geometry of the sample etc. [7,8]. In particular, spin supercurrents in B-phase can form a homogeneously precessing domain (HPD), which is characterized by quite slow relaxation due to the absence of large spatial inhomogeneity [8]. Recent CW NMR experiments shows that the homogeneously precessing state with slow relaxation can be also created in B-phase of ^{3}He in aerogel [9]. However, in the case of pulsed NMR (when the HPD is not formed), textural inhomogeneities probably play the main role in relaxation processes. The fact that the effective T_1 depends on the tipping angle points out that spin supercurrents should be also taken into account in order to explain the results.

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