Torsional Oscillator Study for Solid ^{4}He Growth on Graphite and Graphene from the Superfluid

September 2013

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Thesis Abstract

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Thesis Title

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Thesis Summary

Helium-4 (^{4}He) exhibits various intriguing quantum phenomena at low temperature such as superfluidity. Systems containing superfluid and solid ^{4}He are ideal for clarifying theories of solid formation and have been studied in detail. The growth of solid ^{4}He on graphite from the superfluid phase is known to occur with the number of adsorbed layers increasing with pressure. The solid is thought to undergo step-like growth below 1.3 K. Experiments in search of these layering transitions have seen that the solid grows layer-by-layer below 1.3 K, and possibly in a two-stage layer-by-layer fashion below 0.95 K. The two-stage layer-by-layer growth has, to our knowledge, never been confirmed and its cause is still unclear.

This thesis presents experiments for solid ^{4}He growth adsorbed on graphite and graphene from the superfluid phase at temperatures between 1.65 K and 0.1 K. Shifts and discontinuities in the oscillation frequency and patterns of energy dissipation have been observed at constant temperatures.

The measurements on graphite show layer-by-layer growth that is mostly continuous and confirm the two-stage growth seen previously. Measurements down to 0.1 K have revealed that there is less solid on the substrate at low temperature. These observations lead us to believe that the exfoliated graphite samples (grafoil), used here and in all previous studies, are not ideal substrates and severely influence the growth of the adsorbed ^{4}He. The average platelet diameters are on the nanometer order and the substrate has a tortuous pore structure.

We have also employed a graphene sample with average platelet diameters on the micrometer order and observed the growth of a single ^{4}He layer to be a series of discontinuous steps. This suggests that solid ^{4}He growth on graphene does not occur in a simple layer-by-layer fashion. We propose that the uppermost solid ^{4}He layer grows via a succession of two dimensional phase transitions through various commensurate and incommensurate phases. Additionally, each discontinuity is preceded by a dip and overshoot that become larger at low temperature.