H.099 EXCITATIONS OBSERVED IN THIN ^{4}He FILMS.*

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Using a technique developed by Hall and Reppy[1] we have used third sound to investigate thin ^{4}He films adsorbed on Vycor glass.

The cavity (shown in Fig. 1) consists of a piece of Vycor glass potted in STYCAST 1266 epoxy and supported by a drill rod suspension. The cavity is driven by a capacitor on one end and its motion is detected by a microphone. The frequency of oscillation of the cavity is varied and third sound resonances were observed as sharp peaks in the velocity of oscillation.

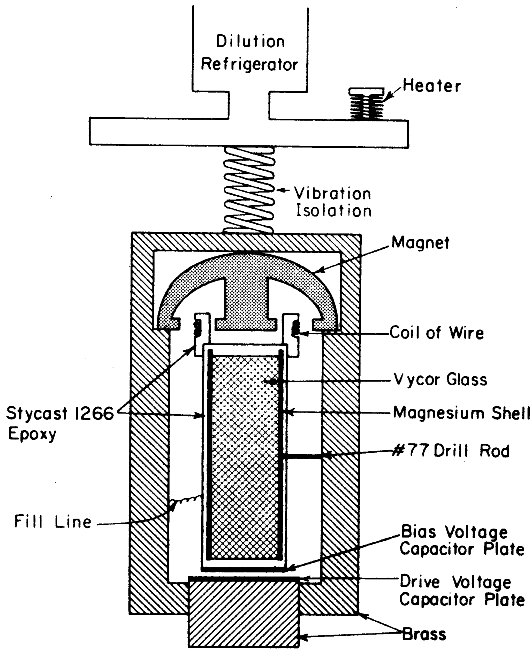

Figure 1. Schematic drawing of cavity. The piece of Vycor is 1.5 cm long.

Third sound resonances were observed for coverages ranging from 1.51 atomic layers to 2.7 atomic layers at temperatures ranging from 0.23°K to 1.25°K.

By analyzing the motion of the cavity we were able to calculate directly the actual superfluid masses of the thin ^{4}He films. The second figure shows the superfluid masses plotted against coverage. Extrapolation of the data suggests that at a non-zero coverage (1.41 atomic layers) the superfluid mass is zero. This is further evidence of a "frozen out layer" of ^4He which does not participate in superfluidity but provides a favorable substrate for superflow.

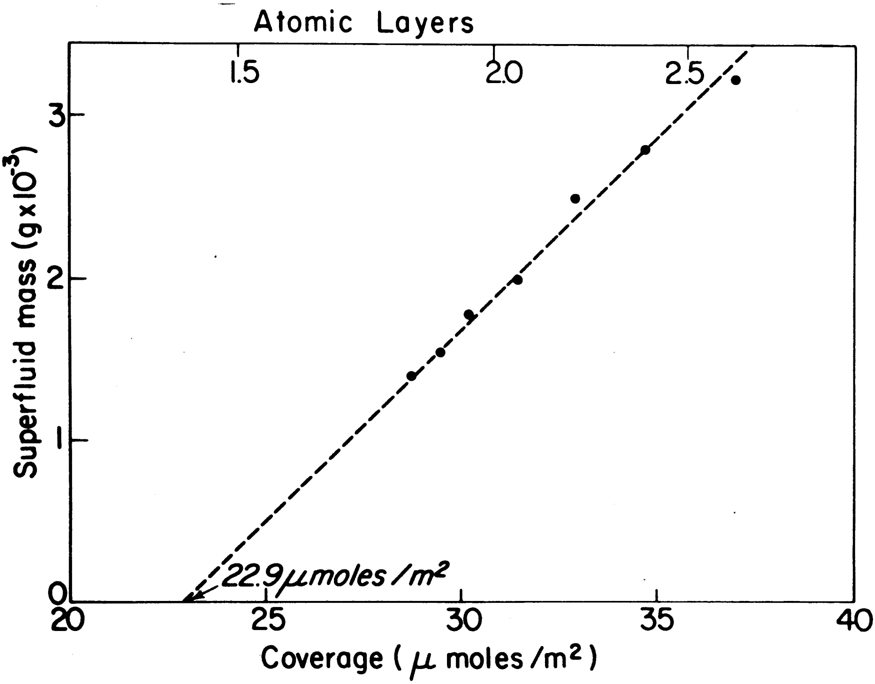

Figure 2. Plot of superfluid mass vs. coverage. The intercept corresponds to 1.41 atomic layers of ^4He.

Using the relation:

$$\rho_s(T)/\rho = (C_3(T)/C_3(0))^2$$

we have calculated ρ_s/ρ vs. T for our thin films. The low temperature regions were found to be phonon dominated with a T^2 temperature dependence. The observed T^2 dependence (Fig.3) is what one would expect for phonons in cylindrical channels,[2,3] which is a plausible model for Vycor glass. The fourth sound (full pore) data is also shown in Fig. 3 and as predicted[2,3] it also shows a T^2 phonon dominated regime.

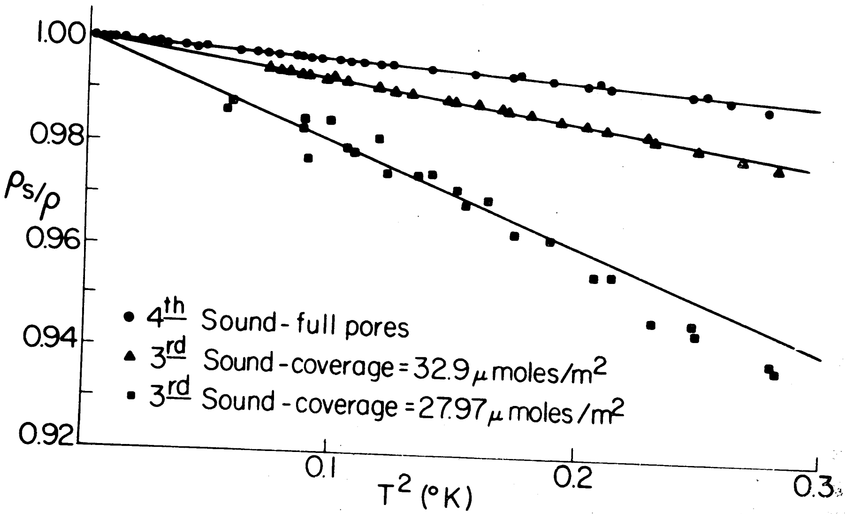

Figure 3. ρ_s/ρ vs. T^2 at low temperatures. This graph shows the low temperature behavior of ρ_s/ρ for films and filled pores in Vycor glass.

At high temperatures the departure from a T^2 dependence was treated as a roton type excitation. By taking our ρ_s/ρ data and subtracting off the phonon contribution we were able to fit the remainder to obtain roton energy gaps. Our data gave energy gaps for all coverages in the range 4-6°K. These values are in rough agreement with those calculated by Padmore[4] using a Feynmann-Cohen technique. These values are approximately the same as that obtained for the full pore case (5.85°K) but are substantially lower than the values obtained for bulk Helium (8.65°K) at saturated vapor pressure. Within experimental error the roton energy gaps appear to be independent of film thickness supporting Padmore's contention that there exist two dimensional rotons which dominate the behavior of ρ_s/ρ in the pores in this temperature region.

In Fig. 4 we show our data for the entire temperature range investigated. The theoretical curves are calculated using a combination of a T^2 phonon term and a roton term. At higher temperatures quasiparticle interactions which have been ignored presumably become important and worsen the agreement with the data.

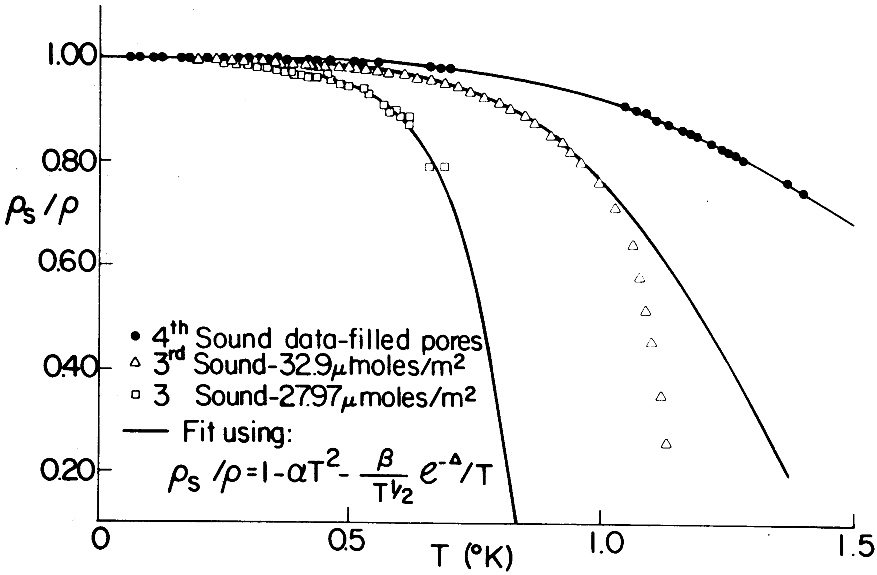

Figure 4. ρ_s/ρ vs. T for the entire temperature range.

In summary we have observed third sound in Vycor glass using a new technique. Our data supports the idea of a "frozen out layer" of ^4He which forms a favorable substrate for superflow and the existence of phonon and roton excitations in the thin ^4He films, but with a roton gap changed by the influence of the walls.

References:

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4. T. C. Padmore, Phys. Rev. Letters 32. 826 (1974).