

Specific Heat of ^4He Confined to 9869\AA Planar Geometry.

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Abstract

We report new data for ^4He confined between two silicon wafers spaced 9869\AA apart. This spacing complements a series of previous measurements which now span a factor of 20 between the smallest and largest confinements. These new data allow us to further check scaling predictions. We find, as reported with previous data, that the present data scale well except near the heat capacity maximum, and below into the superfluid region.

Keywords: helium; scaling; specific heat; 2D crossover

A system which exhibits a second order phase transition has its behavior governed by the distance over which the system becomes correlated. This *correlation length* is a function of the system's temperature, growing as the system approaches the transition temperature. As this length becomes comparable to the size of the smallest dimension in the system, *finite-size effects* are seen. These effects are evident in all systems, since even bulk systems are finite in dimension. However, the temperature where these effects are manifest occur so close to the transition as to be unmeasurable. If one constructs a system with a dimension much smaller than what may be considered a typical bulk system, these effects may be seen in thermodynamic properties such as heat capacity or, in the case of ^4He , the superfluid density. Scaling theories describe how a system, confined in this manner, behaves as it approaches a critical point.[1]

There are two key elements to our experiment, the construction of the cell used to confine the helium and the actual measurement of the confined system in the presence of a much larger amount of helium. We have reported on these aspects elsewhere.[2] The helium is confined between two silicon wafers. One wafer has SiO_2 grown on it, and is then etched to provide an open volume with posts. A second wafer is then bonded[3] to the first and these posts separate the two wafers uniformly without subtracting significantly from the open planar volume. This provides the means to restrict the system in one dimension while the other dimensions, 4.2 cm in our case, may be considered infinite. The technique used to measure the system's heat capacity is an AC calorimetric measurement in which the cell is heated from the bottom while its average temperature is held constant. The corresponding temperature oscillations in the cell are detected by thermometers placed upon the top of the cell. These temperature oscillations are inversely pro-

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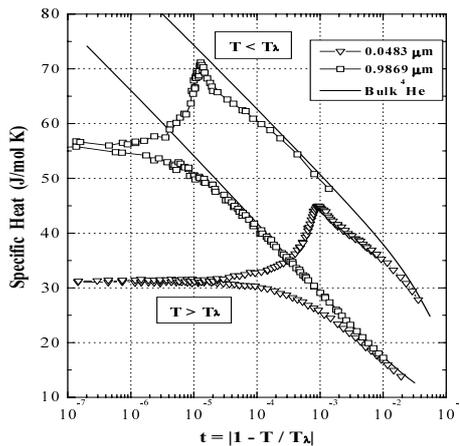


Fig. 1. Plot contrasting the specific heat of the 483Å and 9869Å planar confinements.

portional to the heat capacity.

Fig. 1 shows the analyzed heat capacity data on a semi-log plot as a function of the reduced temperature $t = |1 - T/T_\lambda|$. T_λ is the transition temperature of the bulk system. We now have data for six different confinement sizes ranging from $L = 0.0483\mu\text{m}$ to $0.9869\mu\text{m}$. [2] We show here data for the largest and smallest confinements. These data may be scaled using the following equation [2]

$$[C(t, \infty) - C(t, L)]t^\alpha = (tL^{1/\nu})^\alpha f_2(tL^{1/\nu}) \quad (1)$$

where α and ν are the heat capacity and correlation length critical exponents. Data for $T < T_\lambda$, scaled using Eq. 1, are shown in Fig. 2. The data $T > T_\lambda$, which are not shown on this plot, scale very well. The data below T_λ but above the heat capacity maximum also scale well. However, there is a systematic lack of scaling in the region of the maximum (seen here as a minimum in the difference plot). We believe this lack of scaling is attributed to the system crossing into a two-dimensional (2D) behavior. This lack of scaling also persists into the region below the maximum and confirms a previous conjecture. [4] This is also consistent with a preliminary result for confinement at $57\mu\text{m}$. [5]

More precise work remains to be done to examine geometries for 1D [6]; and new experiments for 0D crossover are needed. This would verify that

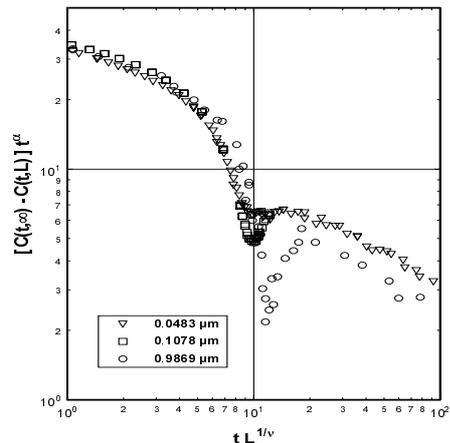


Fig. 2. Difference plot showing the collapse of the data above the heat capacity maximum and the lack of scaling near and below it. The data above the bulk transition (not shown here) also scale very well.

the lack of scaling we observe is a reflection of the 2D lower dimension.

Work supported by the NFS, DMR9623831 and DMR9972287. SiO₂ lithography done at the NNF, Cornell University, Proj. 526-94.

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