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Wetting Behavior of Superfluid ^{4}He Droplets on Cs

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The temperature dependence of the dynamical behavior of ^{4}He droplets inpinging on cesiated surfaces is investigated. Using surface plasmon microscopy pronounced differences in the structure of the droplets and the developing film are observed, which can be related to the wetting phase diagram.*

1. INTRODUCTION

After the prediction that ^{4}He does not wet a cesium surface [1] it is now established that ^{4}He undergoes a first order wetting transition [2]. Detailed information about the phase diagram has been obtained using heat flow, third sound and quartz microbalance techniques. However, little was known so far about the dynamics of ^{4}He on Cs. In order to study this behavior we have recorded the propagation of He droplets on a tilted Cs surface in the various regimes of the wetting phase diagram.

2. EXPERIMENT

In our measurements the Cs (approximately 10 monolayers) was evaporated in situ at 4.2 K onto a 33 nm thick silver film. During the preparation a shutter was placed in front of the lower area of the sample leading to a non-cesiated area for comparison. We used surface plasmon microscopy to monitor the thickness of the He film on this surface with high spatial and temporal resolution [3]. For this purpose the sample was illuminated by an expanded light beam and the reflected light was image onto a CCD camera. The angle of incidence was adjusted such that surface plasmons were excited resonantly in the cesiated area leading to a reduction in the reflectivity. In the pictures (Fig.1 and 2) this area therefore appears dark, while the bare silver part appears somewhat brighter. Liquid He covering the substrate causes a shift of the resonance angle, which gives rise to an increase (decrease) of the reflectivity in the upper (lower) area. The change in the intensity of the recorded light is thus a measure of the thickness of the He film.

3. RESULTS and DISCUSSION

After evaporating the cesium the temperature is lowered to the region of interest in the phase diagram and then He is supplied to the sample cell through a capillary from outside. The gas condenses in the capillary and from its end droplets fall onto the substrate. For different temperatures in the cell one observes various characteristic structures of the droplets and the developing films:

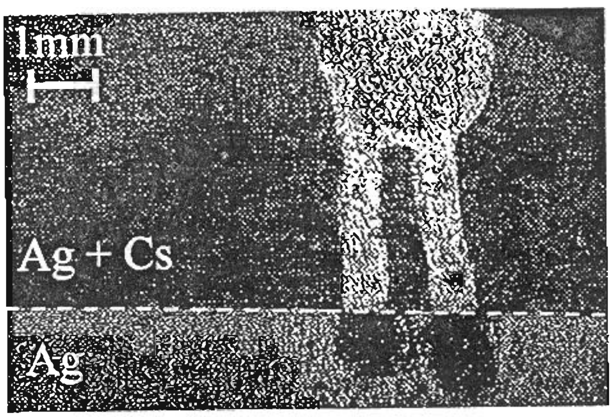

Figure 1: ^{4}He droplet on a tilted Cs substrate at 1.5 K showing the finger-like structure.

i) At 1.5 K, far below the wetting temperature (in our case we determined $T_W \approx 1.8$ K) the droplets

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do not have a compact form while flowing down, but finger-like structures are observed (Fig.1). This indicates that the surface is not completely wetted by He. The contact lines perpendicular to the flow direction (and also between the fingers) are immobile, which is also indicative of incomplete wetting. The flow velocity of the liquid in the fingers is in the range of 2 ± 0.5 cm/s.

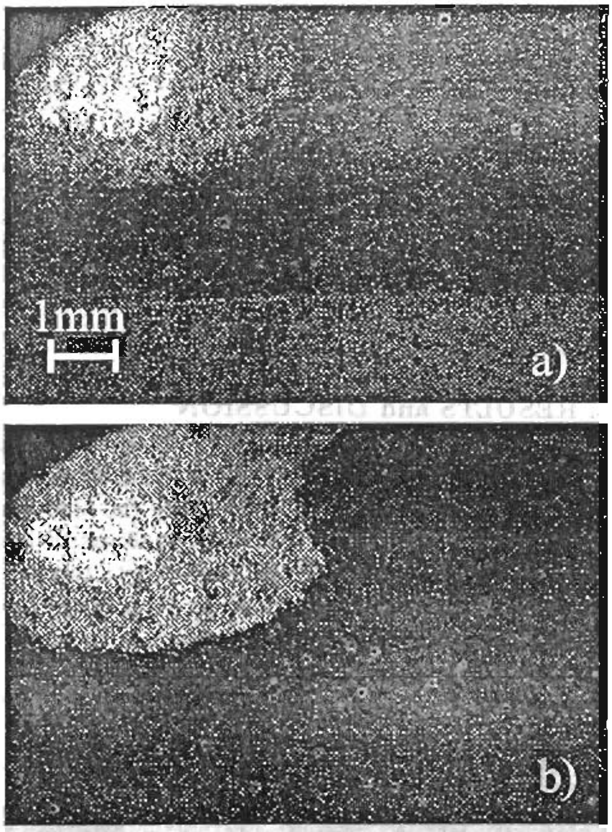

Figure 2: ^{4}He droplet spreading on a tilted Cs substrate at 1.85 K (just below the prewetting transition). The bright spot (2 mm in diameter) is bulk He, the surrounding area a $\approx$ 30 nm superfluid film.
a) immediatly after the droplet hit the substrate
b) 60 ms later

ii) When the temperature is raised up to 1.85 K (where the Cs surface, which is not quite at liquid-gas coexistence, is still below the prewetting transition and is hence only covered with a very thin He film), a distinctly different structure of the droplets appears (Fig.2). Instead of forming fingers the superfluid droplets now flow down the substrate in a compact form without changing their shape. In addition they are surrounded by a "halo" of a He film with 30 nm thickness, which starts to spread with a velocity of 0.55 cm/s immediatly after the droplet touches the surface. Both the boundaries between the bulk He droplet to the 30 nm film and from there to the prewetting region are quite sharp.

iii) Well above T_W, but still below the phase transition into the normalfluid phase (e.g. at 2 K) the whole substrate is covered by a saturated superfluid film of $\approx$ 30 nm thickness already before a droplet hits the surface. The droplet profile in this case shows a continuous variation from the bulk value in the droplet center to the superfluid film thickness far outside.

Just below T_λ at 2.15 K one observes that the superfluid He film can be removed by the heat input due to the illuminating light beam. He droplets falling onto the substrate then display again the formation of a superfluid film halo with nearly the same thickness and spreading velocity as for crossing the prewetting line (ii).

iv) Normalfluid droplets at $T > T_\lambda$ flow down the Cs surface in a compact form, somewhat similar to ii), but with a velocity which is one order of magnitude smaller than in the superfluid case. The formation of a film halo surrounding the droplet is not observed, which is in agreement with expectation due to the viscosity of the He in this range.

4. CONCLUSIONS

The observations presented here give a qualitative overview of the behavior of droplet flow and film spreading in various regions of the phase diagram. Although more detailed experiments are required to define the thermodynamic path of the data more accurately, we believe that the results clearly show the basic features of the dynamics of ^{4}He droplets on Cs.

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[3] for a more detailed description of the technique see G. Mistura, D. Reinelt, S. Herminghaus and P. Leiderer, J. Low Temp. Phys. 101 (1995) 211