Comment on "Observation of Unusual Mass Transport in Solid hcp ^{4}He"

Thanks to a clever experimental setup, Ray and Hallock (RH) [1] have observed mass flow through solid helium samples. In their discussion, they "interpret the absence of flow for samples warmed to or created at 800 mK to likely rule out liquid channels as the conduction mechanism." However, we show that liquid channels (LCs) could explain the results of Ref. [1], and propose experimental tests to decide this issue.

Sasaki *et al.* (SCB) [2] have shown that LCs exist where GBs meet walls (not "at the interface between crystal faces and the surface of the sample cell" as stated by RH) and that the LC width is inversely proportional to the departure $P_S - P_{eq}$ from the equilibrium pressure $P_{eq} = 2.53$ MPa. SCB later explained [3] that, between grains, there are also LCs whose cross section is a curved triangle with angles 2θ (Fig. 1) and an area

$$S = R^2\left[2\sqrt{3}\sin\phi\sin\left(\phi + \frac{\pi}{3}\right) - 3\phi\right], \qquad (1)$$

where $R = [\rho_S/(\rho_S - \rho_L)]\sigma_{LS}/(P_S - P_{eq})$ is the radius of curvature of the liquid-solid interface whose energy is σ_{LS}, and $\phi = \pi/6 - \theta \approx \pi/12$. ρ_L and ρ_S are the liquid and solid densities, respectively.

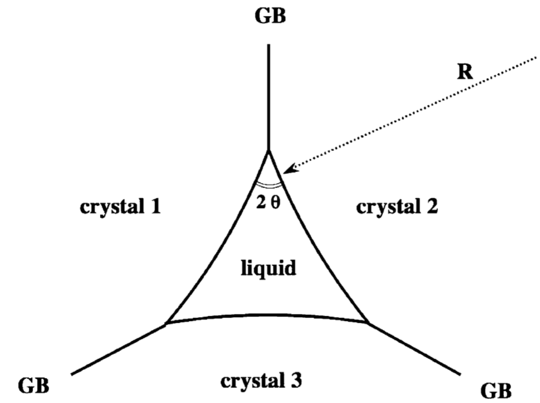

FIG. 1. The intersection of grain boundaries (GBs) leads to the formation of liquid channels (LCs) with a triangular section.

The maximum pressure at which RH observed mass flow is 2.68 MPa with their sample A which could thus contain LCs with $S = 12$ nm^2. If we take the same critical velocity as RH, 2 ms^{-1}, the flow rate in sample A could be explained by 340 LCs. Since the sample cross section area is 32 mm^2, this would correspond to grain diameters of about 0.35 mm. Some of RH's samples showing flow were grown from the superfluid but they should be single crystalline only if kept at P_{eq}. Any pressurization beyond P_{eq} (as in sample A) is likely to create inhomogeneous stresses and a large density of defects. RH observed flow only through samples close to P_{eq} where LCs are open and could contribute to mass flow.

The problem with the LC scenario is that the LC superfluid temperature is expected to be around 1.7 K, the same as for bulk liquid at the same pressure, while RH observe no flow above 800 mK [1]. However, the absence of flow at 800 mK could be due to some kind of annealing, for example, the unpinning of GBs above about 600 mK leading to the disconnection of LCs. This disconnection should be irreversible, as actually observed by RH in most of their samples. To disprove the LC scenario, RH should find samples showing flow at 400 mK, no flow when warmed up to 800 mK, and flow reappearance when cooled back to 400 mK without pressure changes which could modify the connection between defects. This would establish that the critical temperature of the structures responsible for the flow is between 400 and 800 mK. Only one of RH's samples might have behaved this way (sf1-3b_sh7 mentioned in their supplementary material) but, unfortunately, RH do not show its relaxation curves.

In addition, one would need to carefully check if, for samples showing flow, the pressures $P1$ and $P2$ on both sides of the cell relax to the same equilibrium pressure. If not, it would mean that the structures initially responsible for mass flow disconnect and cease to conduct mass. This disconnection could be due to the motion of the structures. The measurement shown in Fig. 1 of Ref. [1] did not reach equilibrium. In fact, its irregular relaxation indicates that the structures responsible for mass flow do move, even at low temperature, so that disconnection of LCs may happen as a consequence of any temperature or pressure change. This is reminiscent of the irregularities observed by our group at 40 mK (but at P_{eq}) for the pressure measured at the end of a capillary connected to the bottom of a cell full of solid helium [4]. When the solid in the cell was brought to P_{eq}, the pressure relaxed irregularly, and did not reach P_{eq}. Further studies are needed to establish the nature of the structures that conduct flow in RH experiments.

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