§4. Behaviors of He II in Two-dimensional Channels Filled with He II

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Two-dimensional channels composed of the good conductor are common in a He II cooled apparatus. In the 2D-channels, the heat transfer from to He II below the λ-point pressure P_λ is largely influenced by the superheating in He II (^{S}He II). So far, we have reported that the heated surface of a heated conductor is partially insulated with the superheated He I (^{S}He I) in He II below the λ-point pressure P_λ [1]. That is, ^{S}He I appears forming an intermediate state in heat transfer characteristics such that the transition at Q_λ is gradual like in the pressurized He II. In the present paper, we confirm that the intermediate state consists of the superheated phases. The appearance of the intermediate state gives a considerable margin for the stabilization of the He II cooled apparatus.

The experiment was performed by the use of a copper disk with the radius of 10 mm with the thickness of 5 mm. An insulator disk was placed in parallel to a plane surface of the copper disk as shown in Fig. 1. The heat flux Q was applied from a thermo-foil in a vacuum can. To measure the temperature of helium in the channel, chip-resistors $T_{1\sim6}$ were arrayed on the insulator disk at intervals of 2 mm. The temperature of the copper disk T_C was measured with thermometer T_C. Pressures in the channel P_c and in the bath P_b were measured with in-situ pressure gauges. To measure the stability of superheated states, a pendulum with a metal ball was prepared to disturb the cryostat mechanically. The threshold potential energy E_M of the pendulum to break the metastability phases was taken as an index of the stability.

It is estimated from Fig. 2 that not the bubble but ^{S}He I nucleates in the hottest area on the heated surface covered with ^{S}He II, when T_1 crosses the λ-line extended below P_λ. The small heat conduction of ^{S}He I drives a part of Q downstream through the conductor without the sharp transition at Q_λ. T_1 increases over T_λ on an isobar without boiling until Q_n reaches as shown in Fig. 2b, that is, $\Delta P = 0$, where $\Delta P = P_c - P_b$. When Q is decreased from above Q_n, T_1 jumps beyond T_λ at a critical heat flux of recovery Q_r. Both the isobaric behaviors up to Q_n and the sudden changes in ΔP at Q_n and at Q_r suggest that the boiling does not occur in the intermediate state. This also means that ^{S}He II layer surrounds coaxially the ^{S}He I layer in the intermediate state.

The disturbance with E_M breaks momentarily superheated states. E_M can be an indirect index of the metastability. However, the metastable phases, ^{S}He II and ^{S}He I reappear in a second after the transient collapse (the inset of Fig. 3). That is, ^{S}He I and ^{S}He II are apparently stabilized such that they return immediately after a mechanical shock disrupts them. The stability decreases with increasing Q.

The intermediate state where ^{S}He I coexists with ^{S}He II is succeeded by the mixed state where the alternation of superheating and boiling is sustained. Above P_λ, by contrast, the temperature of the conductor in 2D-channel rises steadily due to the stable and viscous subcooled He I.

1). Kobayashi H. et al. Proc ICEC21 2006:389-392

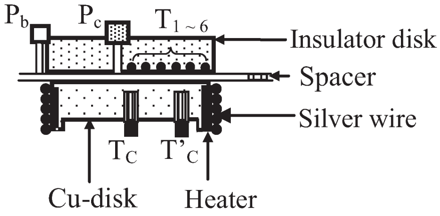

Fig. 1. Schematics of tested 2D-channel
The 2D-channel is formed between the insulator disk and the copper disk. $T_{1\sim6}$, T_C: the thermometer, T'_C: the spare. P_c, P_b: In-situ pressure gauges. The thermo-foil is fastened to the wall of the copper disk with the silver wire.

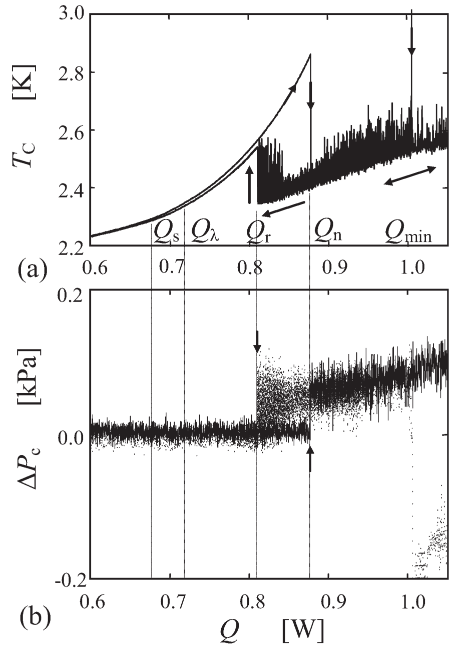

Fig. 2. Heat transfer characteristics and the pressure change
(a) T_C -Q, (b) ΔP-Q, $\Delta P = P_c - P_b$
T_b =1.95 K, P_b = 4.50 kPa, gap distance: 0.15 mm

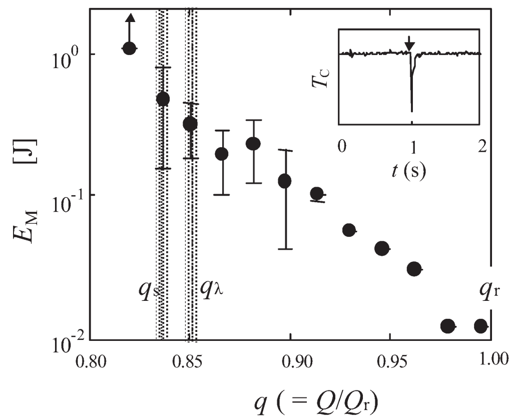

Fig. 3. The threshold energy vs. heat flux
E_M: the threshold potential energy to breaks the superheated states. The heat flux is normalized with Q_r. The arrow mark in the inset: the moment of hitting, the bars: standard errors, T_b = 1.95 K, P_b = 4.25 kPa, Q_λ = 0.68 W, the gap distance: 0.15 mm