§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 \( P_\lambda \) is largely influenced by the superheating in He II \( ^3\text{He} \). So far, we have reported that the heated surface of a heated conductor is partially insulated with the superheated He I \( ^3\text{He} \) in He II below the λ-point pressure \( P_\lambda \). That is, \(^3\text{He} \) appears forming an intermediate state in heat transfer characteristics such that the transition at \( Q \) 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 \( T_{1-6} \) 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 metastable phases was taken as an index of the stability.

It is estimated from Fig. 2 that not the bubble but \(^3\text{He} \) nucleates in the hottest area on the heated surface covered with \(^3\text{He} \), when \( T_C \) crosses the \( \lambda \)-line extended below \( P_C \). The small heat conduction of \(^3\text{He} \) drives a part of \( Q \) downstream through the conductor without the sharp transition at \( Q \). \( T \) increases over \( T_C \) on an isobar without boiling until \( Q \) reaches as shown in Fig. 2, that is, \( \Delta P = 0 \), where \( \Delta P = P_C - P_B \). When \( Q \) is decreased from above \( Q \), \( T \) jumps beyond \( T_C \) at a critical heat flux of recovery \( Q \). Both the isobaric behaviors up to \( Q \) and the sudden changes in \( \Delta P \) at \( Q \) suggest that the boiling does not occur in the intermediate state. This also means that \(^3\text{He} \) layer surrounds coaxially the \(^3\text{He} \) layer in the intermediate state.

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

The intermediate state where \(^3\text{He} \) coexists with \(^3\text{He} \) is succeeded by the mixed state where the alternation of superheating and boiling is sustained. Above \( P_c \), by contrast, the temperature of the conductor in 2D-channel rises steadily due to the stable and viscous subcooled He I.