

Chapter 7

EFFECT OF SUPER THERMAL CONDUCTION ON He II CONDENSATION

7.1 Introduction

The x-t diagram for He II condensation process in the present experimental cell is illustrated in Fig.7.1. Highly transient He II condensation is caused by an evaporation wave impingement onto a He II free surface from the vapor phase as indicated by the *arrow C1*. Some portion of the impinging evaporation wave is reflected (*arrow C2*) from the free surface, and a second sound thermal pulse (*arrow C3*) and a first sound wave (*arrow C4*) are generated from a He II free surface and propagate downward through He II. There have been many experimental studies of condensation phenomena induced by a gasdynamic shock wave impingement for the conventional substances. The condensation phenomenon induced by a gasdynamic shock wave impingement onto the end wall of a shock tube was experimentally investigated for methanol, acetic acid and carbontetrachloride by Fujukawa[62]. For He II, as described in Sec.1.4, in a number of experimental studies[21], [22], [25] the reflection and the transmission of a pressure wave impinging onto a He II free surface from the vapor. In the present study, the phenomena induced by the impingement of an evaporation wave is treated from the point of view of condensation

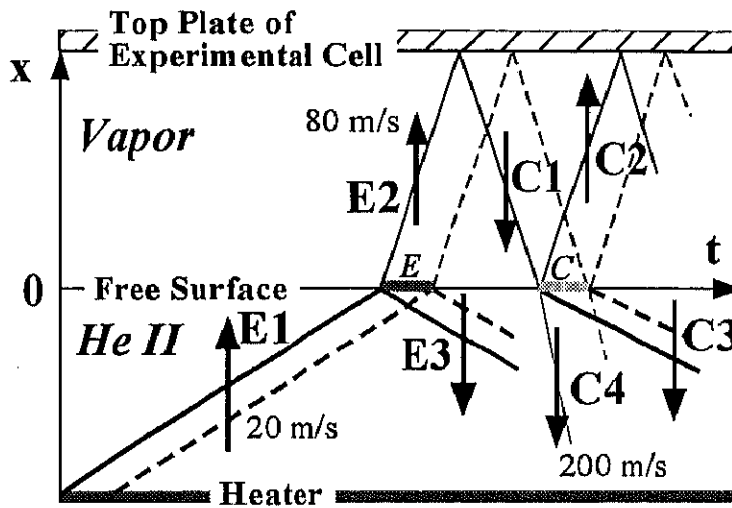


Fig. 7.1: The $x-t$ diagram of He II condensation experiment. The solid and broken lines indicate the wave front and its tail. $E1$: the impinging thermal pulse, $C3$: the reflected thermal pulse, $E2$: the evaporation wave, $C1$: the impinging evaporation wave, $C2$: the reflected evaporation wave, $C3$: the generated thermal pulse, $C4$: the generated first sound, E : the evaporation, C : the condensation.

phenomena. It is a characteristics of He II condensation that the effect of the super thermal conduction appears. It is described in Sec. 5.2 that the condensation coefficient of He II may be effected by the super thermal conduction. But, this effect was not experimentally verified. Here, the present experimental process of He II condensation induced by an evaporation wave impingement onto a He II free surface is qualitatively similar to the process that helium atoms in vapor phase condense to He II phase as shown in Fig. 7.2. This similarity means that the effect of super thermal conduction on the condensation coefficient of He II can be confirmed by the experimental result of He II condensation. It is, therefore, the main objective of the present He II condensation experiment that to experimentally investigate the effect of super thermal conduction on the He II condensation coefficient. The effect of super thermal conduction on the He II condensation is investigated by comparing the experimental result of the pressure behind a reflection wave from a rigid wall covered with superfluid

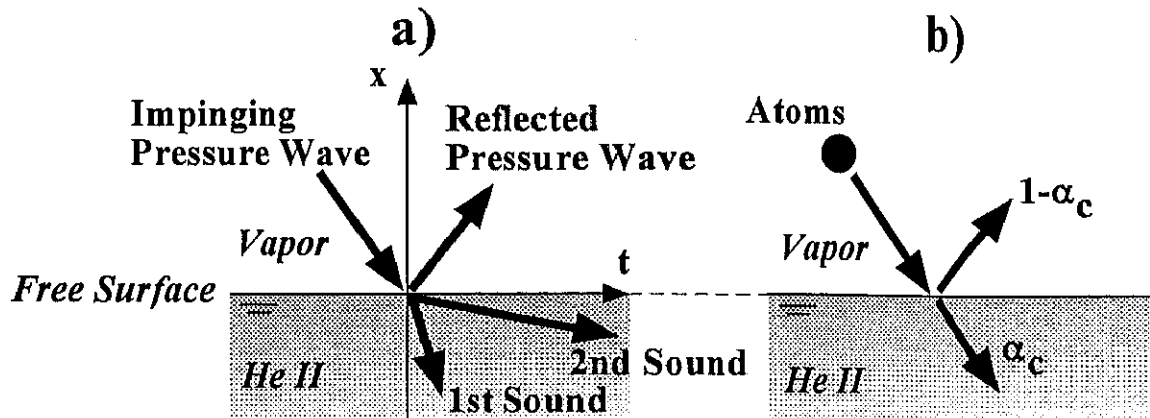


Fig. 7.2: The condensation processes onto a He II free surface. a): the x - t diagram of He II condensation experiment induced by a pressure wave impingement, b): the schematic drawing of the definition of condensation coefficient indicated by Eq. (1.2), the number of $(1 - \alpha_c)\%$ atoms within the total number of incident helium atoms is reflected from a He II free surface.

thin film with that from a He II free surface and it is also investigated by direct measuring the temperature dependence of the pressure amplitude reflection coefficient R_{GG} . The absolute pressure is measured with both a wall mount type pressure transducer on the top plate of the experimental cell and a miniature type transducer on the side of the experimental cell in the present experiment.

7.2 Effect of Super Thermal Conduction

The pressure, $P_{r,rigid}$, behind the reflected evaporation wave from the top plate is measured with a wall mounted-type pressure transducer. And the pressure, $P_{r,free}$, behind the reflected evaporation wave from a free surface is measured with a miniature type pressure transducer. The pressure measurement results of $P_{r,rigid}$ and $P_{r,free}$ normalized by P_0 are plotted against the shock strength P_e/P_0 in Fig. 7.3. It is seen at the temperature $T_0 = 1.74 K$ that the experimental result of $P_{r,free}/P_0$ indicated by solid circles is smaller than that of $P_{r,rigid}/P_0$ indicated by solid triangles. It is

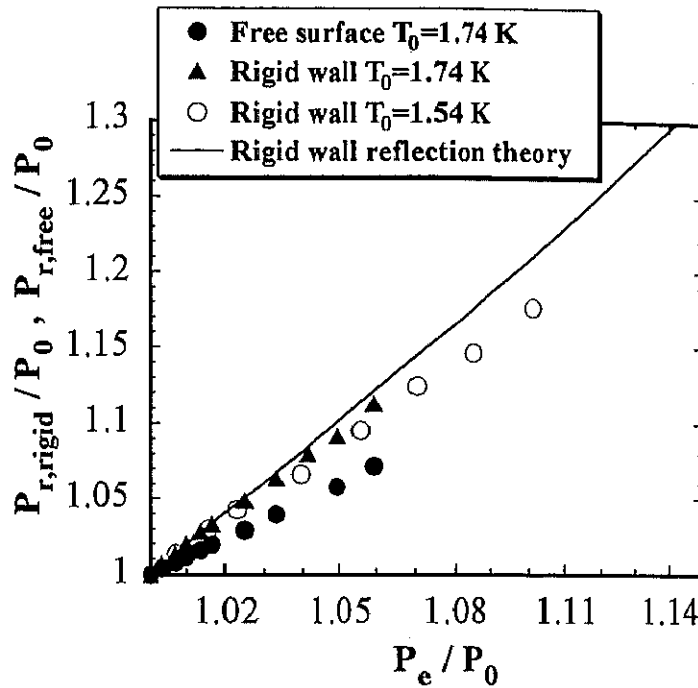


Fig. 7.3: The comparison of the pressure behind the reflected evaporation wave from a rigid wall with that from a free surface as a function of the shock strength P_e/P_0 . $P_{r,rigid}$: the pressure behind the reflected evaporation wave from a rigid wall. $P_{r,free}$: the pressure behind the reflected evaporation wave from a free surface. The solid line indicates the normal incident reflection theory applied with the Rankine-Hugoniot relation.

seen that the difference is caused by the effect of super thermal conduction. The super thermal conduction dose not arise in superfluid thin film due to clamping of the normal component on a solid wall. It is seen that the experimental results for both $T_0 = 1.74$ K and $T_0 = 1.54$ K well agree with the normal incident reflection theory applied with the Rankine-Hugoniot relation indicated by solid line for small $P_{r,rigid}/P_0$. This satisfactory agreement indicates that the reflection coefficient of the evaporation wave on the superfluid thin film is almost unity as evident from the fact that the pressure variation $\Delta P_{r,rigid} (= P_{r,rigid} - P_0)$ of reflected wave is twice as high as the pressure amplitude of the evaporation wave $\Delta P_e (= P_e - P_0)$. This consequence seems quite reasonable because super thermal conduction dose not

arise in superfluid thin film. And a solid surface covered with superfluid thin film acts merely as a pure solid surface upon reflection of evaporation wave. It is, therefore, concluded that the reflection coefficient of 0.7 assumed in the reference 24 is not correct. Furthermore, it is also seen that the discrepancy between the experimental results of $P_{r,rigid}/P_0$ and the solid line increase according to the value of the shock strength P_e/P_0 at particularly $T_0 = 1.54 K$. This discrepancy is caused by the conventional condensation on the rigid wall covered with superfluid thin film.

7.3 Reflection Property of Evaporation Wave on He II Free Surface

It is expected that the pressure amplitude reflection coefficient R_{GG} ($= \Delta P_{C2}/\Delta P_{C1}$), where ΔP_{C1} and ΔP_{C2} are the pressure rises in the impinging evaporation wave onto and in the reflected evaporation wave from

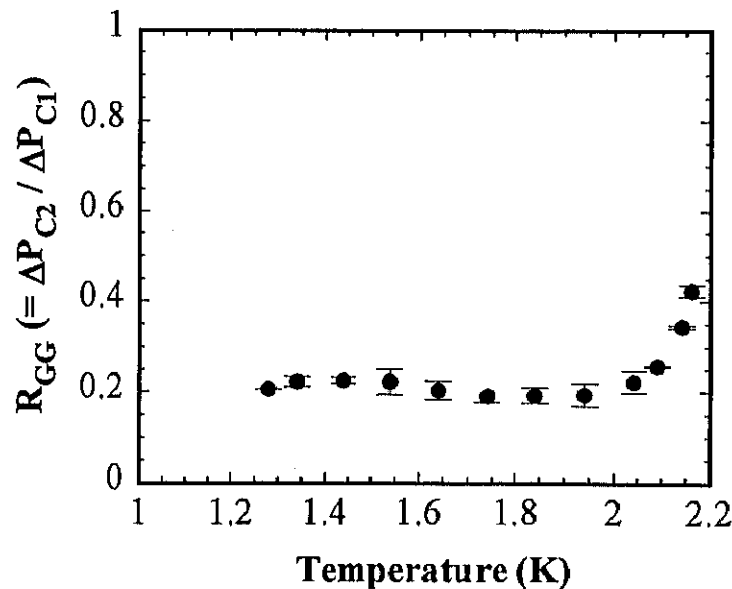


Fig. 7.4: The temperature dependence of the pressure amplitude reflection coefficient R_{GG} on a free surface defined by $R_{GG} = \Delta P_{C2}/\Delta P_{C1}$. ΔP_{C1} and ΔP_{C2} : the pressure rises with respect to P_0 in the impinging evaporation wave onto a He II free surface and in the reflected evaporation wave from a He II free surface.

a He II free surface, has similar temperature dependence to the condensation coefficient of He II as described above. The experimental value of R_{GG} is plotted as a function of temperature in Fig. 7.4. It is seen that R_{GG} is considerably smaller than unity, about 0.2. And it is seen that the reflection coefficient R_{GG} considerably increases as the temperature approaches to λ point. This increasing property is caused by the suppression of the super thermal conduction as the temperature approaches to λ point ($T_\lambda = 2.17 K$). It is reported in reference [25] that the reflection coefficient R_{GG} becomes unity at the temperatures higher than the λ point. It can be concluded that the decrease in the condensation coefficient of He II at the temperature close to the λ point is caused by diminishing the effect of the super thermal conduction judging from both the comparison of $P_{r,free}/P_0$ with $P_{r,rigid}/P_0$ and the temperature dependence of R_{GG} .

7.4 Concluding Remarks

The effect of super thermal conduction on He II condensation induced by an evaporation wave impingement onto a He II free surface is experimentally investigated, and following conclusions are drawn.

1. The effect of super thermal conduction on the He II condensation is experimentally confirmed by the comparison of the experimental result of the pressure behind a reflection wave from a rigid wall covered with superfluid thin film with that from a He II free surface.
2. It is found that the reflection coefficient R_{GG} considerably increases as the temperature approaches to λ point because of the suppression of super thermal conduction decrease. It is also seen that the pressure amplitude reflection coefficient R_{GG} has similar temperature dependence of the condensation coefficient of He II.
3. It can be concluded that the decrease in the condensation coefficient of He II at the temperature approaches to the λ point is caused by

diminishing the effect of the super thermal conduction judging from the conclusions of 1 and 2.

4. The pressure behind the reflected evaporation wave from a top plate of the experimental cell is compared with the normal incident reflection theory applied with the Rankine-Hugoniot relation. It is found that the conventional condensation is occurred on the top plate covered with superfluid thin film behind the reflected evaporation wave.