QCM Study on 2D Vortex in Superfluid ^{4}He and ^{3}He-^{4}He Mixture Films

M. Hieda, T. Oda, T. Matsushita, and N. Wada

Department of Physics, Nagoya University, Nagoya, Japan

Two-dimensional (2D) ^{4}He fluid films on various substrates show the Kosterlitz-Thouless (KT) superfluid transition where pairing and unpairing of the thermally excited 2D vortices play a major role. Important vortex parameters (the diffusion constant D, the core diameter a_0) have been extensively studied on flat and porous substrates by various techniques. Most of the researches have been done for the thicker films above the coverage with $T_{\mathrm{KT}} = 1$ K. On the other hand, in the thinner coverage region, there is only a few systematic studies on the vortex properties, and the important vortex parameters D, a_0, and even the combination of the two parameters $D/{a_0}^2$ are not well determined. In most of the experiments $D/{a_0}^2$ is estimated, since D and a_0 are the difficult quantities to be estimated independently. Here, we report the accurate determination of the parameter D/a_0^2 in the superfluid submonolayer of pure ^{4}He and ^{3}He-^{4}He mixture films by the frequency dependence of the superfluid onset from 20 to 180 MHz by a quartz crystal microbalance (QCM). By the comparison of the results of pure ^{4}He film on planar gold and H_2 substrates, the vortex diffusion in our study has the largest value $D \sim \hbar/m$ in the quantum limit. The core diameter a_0 is estimated to be the same magnitude as the de Broglie wavelength at T_{KT} between 0.1 and 0.9 K. In terms of ^{3}He-^{4}He mixture films, we observe no effect of ^{3}He on the vortex parameters up to the ^{3}He coverage of 15.1 μmol/m^2.