ABSTRACT

An experimental study is conducted to investigate the micro-scale heat transfer at an evaporating stationary and moving 3-phase contact line. The 3-phase contact line is defined as the interaction between a thin film of liquid, its vapor, and a solid surface. A liquid-vapor meniscus is formed between a two plates due to capillary forces. Fluorinated carbon fluid HFE-7100 ($C_4F_9OCH_3$, boiling temperature of 61°C at atmospheric pressure) is used as a working fluid.

The present work is divided into two parts. The first part of the study the working fluid HFE7100 is evaporated inside the channel under steady state conditions. Two-dimensional microscale temperature fields at the back side of the heating foil are observed with an infrared camera with suitable spatial resolution. The measured local wall temperature difference between the contact line area and the bulk liquid is up to 12 K. The liquid front undergoes a slow oscillatory motion which can be attributed to the instability of evaporating 3-phase contact line. The local heat fluxes from the heater to the evaporating meniscus are calculated from the measured wall temperatures using energy balance for each pixel element. The local heat fluxes at the contact line area are found to be about 5.4-6.5 times higher than the mean input heat fluxes at the foil.

In the second part, the moving evaporating meniscus is formed by pushing or sucking a liquid column of HFE7100 in the vertical channel of 600 µm width using a syringe pump. The gas atmosphere is pure HFE7100 vapor. Two-dimensional micro-scale temperature field at the back side of the heating foil is observed. A high speed camera is used to capture the shape of the moving meniscus, the images are post-processed to track the free surface of the meniscus. In the vicinity of the 3-phase contact line the heat flux distribution shows a local maximum heat transfer rates due to high evaporation rates at this small region. The local maximum heat flux at the 3-phase contact line area is found to be dependent on the input heat flux, the velocity and the direction of the meniscus movement. The results give detailed insight into the specific dynamic micro-scale heat and fluid transport process. For the advancing meniscus the maximum heat flux at the 3-phase contact line area is found to increase linearly with the increase of the contact line velocity for all the input heat fluxes in the range of the present measurements, while it is found to be constant for receding meniscus for all the measured velocities.