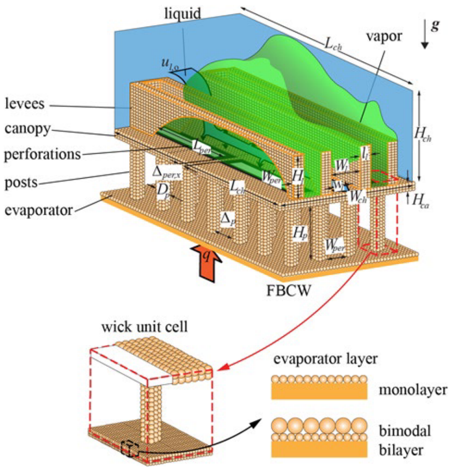
Control and Enhancement of Saturated Flow-Boiling Thermal Conductance and Crisis with Porous Metasurfaces



The capillary, porous metasurfaces are employed in phase-change systems to provide continuous liquid supply to the heated surface, preventing dryout, while simultaneously removing the competition between liquid and vapor flows, known to trigger the hydrodynamic limit in the boiling crisis.

Due to capillary action a curved liquid meniscus is formed in the porous wick, leading to meniscus evaporation in place of ebullition. This meniscus evaporation requires smaller superheat due to the high-conductivity solid particles, reducing the phase-change thermal resistance.

The *Flow-Boiling Canopy Wick* (FBCW) is a 3-D, multicomponent porous metasurface: Perforated canopy: liquid suction and vapor escape, Posts: liquid transport artery and vapor space formation; Evaporator: liquid spreading and meniscus evaporation. It controls and enhances the flow boiling critical heat flux and thermal conductance. Figure below shows the enhancements over the plain surface obtained with the addition of the FBCW. Plane surface, evaporator layer and posts (liquid spreading layer and liquid transport arteries, no canopy), FBCW, and FBCW with levees are schematically shown. The no canopy configuration indicates a hydrodynamic limit ($q_{CHF} < q_{CHF,c-v}$) CHF limit with FBCW is $q_{CHF,c-v} = 4.6$ MW/m². Good agreement with network model prediction for the same wick ($q_{CHF,c-v} = 5.0$ MW/m²). The final modification is the inclusion of the levees. The liquid entrainment among posts without the canopy affects the thermal conductance (heat transfer coefficient) G/A. Adding the posts and the bimodal bilayer evaporator wick increases the thermal conductance to $G/A = 0.36$ MW/m²-K. The right of the figure shows the CFD snapshots of the top view of the surface liquid track in the central region of the channel. The dryout surface fraction is marked for different heat flux.