

Heterogeneous Boiling on biphilic surfaces

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Abstract

In its latest report, the IPCC (Intergovernmental Panel on Climate Change) issued its direst warning yet about the potential impact of unmitigated climate change and urged drastic measures to curtail emissions of greenhouse gases such as CO₂ from fossil fuel consumption. Representing a majority of total energy use in the world, electricity production overwhelming relies on thermal conversion processes via phase change phenomena (as in steam turbines, evaporators, condensers, etc.), which often incurs significant exergetic losses due to poor heat exchanger performance. Thus, improvement of phase-change heat transfer proves to be critical for creating a carbon neutral society. The present research, as part of Project HMT-1 (phase change heat transfer) of Thermal Science and Engineering Research Division, focuses on enhancement of pool boiling heat transfer through surface wettability manipulation.

The performance of boiling heat transfer depends on two critical parameters: (i) the heat transfer coefficient (HTC), defined as the ratio between the applied heat flux and the resulting wall superheat (i.e., the difference between the wall temperature and liquid saturation temperature); and (ii) the critical heat flux (CHF), which marks the transition from the nucleate boiling regime to the less desirable regime of film boiling. Beyond the CHF, a dangerous dry-out conditions could emerge, causing suffer severe surface damages owing to drastic wall temperature spikes. The previous research has shown that surface wettability, as measured by the static contact angle (CA), plays a dominating role. On the one hand, hydrophilicity (CA<90°) can effectively suppress bubble formation and merging, leading to delayed onset of film boiling. On the other hand, hydrophobicity (CA>90°) promotes bubble nucleation and consequently contributes to higher HTC values. A smart combination of these characteristics (so-called *biphilic*) results in much improved boiling efficiency. By patterned coating of water-repellent PTFE (polytetrafluoroethylene) on a copper substrate, a 7-fold increase of HTC as compared with a plain mirror-polished surface was achieved under saturation conditions (Fig. 1). Furthermore, subcooled boiling on such a biphilic surface showed that bubbles could appear at extremely low—even nominally negative—wall superheats. The lowering of the incipience for bubble nucleation was attributed to the existence of incondensable gas in the water, whose effect on subcooled boiling was made evident through successful removal of dissolved air from the system (Fig. 2).

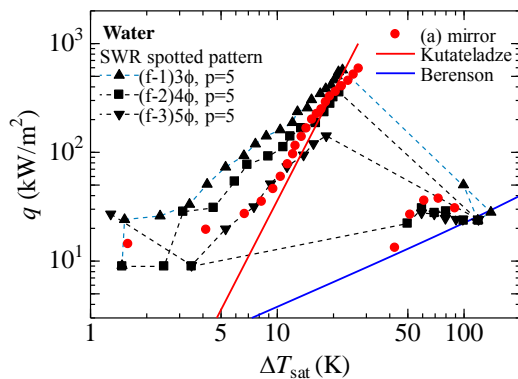


Fig. 1. Enhancement of boiling heat transfer on biphilic surfaces.

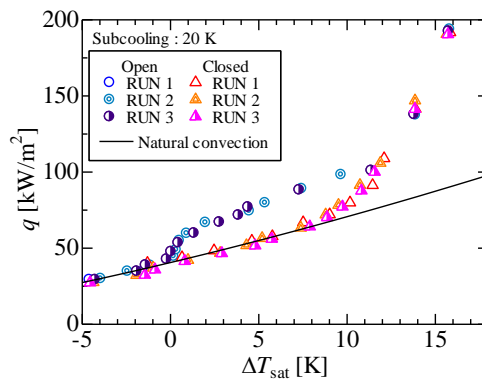


Fig. 2. Different boiling characteristics with/without dissolved air