Nucleation dynamics during atmospheric water vapour condensation on hydrophobic surfaces

Hyeongyun Cha

Ph.D. Candidate
Department of Mechanical Science and Engineering
University of Illinois at Urbana-Champaign

Thermal Science and Engineering Division
International Institute for Carbon-Neutral Energy Research (WPI-I2CNER)
Kyushu University

Hydrophobic surfaces have the potential to advance technologies used in the energy, transportation, electronics cooling, and HVAC&R sectors. However, the long term durability of hydrophobic surfaces has not been demonstrated, resulting in a lack of industrial utilization. Here, we study the fundamental mechanisms governing heterogeneous nucleation on hydrophobic surfaces during atmospheric water vapor condensation in the presence of non-condensable gases (NCGs). Water vapor condensation and evaporation on the hydrophobic surfaces in ambient laboratory conditions revealed deposition and growth of small agglomerates having cycle-dependent size and acting as preferential sites for heterogeneous nucleation. Energy dispersive x-ray spectroscopy (EDS) on the agglomerate particles revealed significantly higher concentrations of carbon (C), oxygen (O), and sulfur (S) when compared to clean hydrophobic areas adjacent to the agglomerates. The results indicate that atmospheric sulfur-based hydrocarbon contamination on the liquid-vapor interface governs the agglomerate deposition phenomena. The potential source of the hydrocarbons stems from sulfuric acid (H_2SO_4), formed from oxidation of sulfur dioxide (SO_2) emitted during sulfur-containing fossil fuel combustion, a major precursor of new airborne particles. In addition, human breath contains organosulfur compounds (OSCs), and livestock and farming practices are a significant source of methanethiol (CH_3SH), dimethyl disulfide (CH_3SSCH_3), and dimethyl trisulfide (CH_3SSSCH_3) airborne hydrocarbons. The outcomes of this work not only show the atmospheric deposition of hydrocarbon agglomerates, they paint a more complex picture of heterogeneous nucleation during water vapor condensation in the presence of NCGs, which are inexorably linked to the degradation and longevity of hydrophobic surfaces.