Title: Realize Sustainable and scalable Dropwise Condensation on Nickel-Graphene surface

Abstract
Steam condensation ubiquitously occurs in nature and also is one of the most efficient heat transfer mechanisms with broad applications ranging from water harvesting, cleaning, and to electric power generation. To date, the-state-of-the-practice (SOP) condensers are made from metals such as copper, aluminum, titanium, and stainless steel. Usually, with inevitable oxides, high surface energy metal surfaces lead to filmwise condensation (FWC). It has been observed that dropwise condensation (DWC) with discrete liquid droplets can result in an order of magnitude higher heat transfer rate compared to FWC. However, practically implementing DWC in aggressive industrial environments is extremely challenging due to the crucial requirements in sustainability and scalability. These hydrophobic functional coatings that have been developed to realize DWC in last several decades fail to meet these two critical requirements.

In this work, we have explored an innovative nickel-graphene (Ni-G) interface to successfully realize sustainable steam condensation. The superior robustness compared to state-of-the-art hydrophobic coatings have been comprehensively evaluated from both surface anticorrosion property and coating adhesion to substrates. We experimentally demonstrated that graphene grown on polycrystalline metal substrates with strong interfacial interactions can sufficiently protect the metal surface from oxidation and maintain highly desirable surface hydrophobicity under harsh condensation working conditions, i.e., with high temperature and percentage of non-condensable gas such as air. The unique three-dimensional (3D) structures and intrinsic high thermal and chemical properties of the few-layer graphene grown on the Nickle substrate form an intrinsic hybrid surface and facilitate sustainable and scalable DWC steam condensation. We have demonstrated a 2.5 times improvement in steam condensation at fresh state and a 2 times improvement in up to nearly two years continuous operations with high air concentrate ratios up to 6.3% compared to FWC, respectively. Furthermore, by alternating the graphene grain boundary density and size, graphene surface wettability can be further engineered for optimized condensation performance. This study makes it feasible to implement DWC in industrial applications.