2014 Research CAN Abstracts

Contents

SC 14-EPSCoR-0014

HEOMD, STMD, SMD
JPL, GSFC

Heat transfer
Nanotechnology
Modelling
Fluid Flow (in space)
Two-phase thermal control

Explore a Unified, Ultra-efficient and Gravity-insensitive Flow Boiling Pattern for Space Missions

College of Charleston

Dr. Cassandra Jane Runyon, PI, College of Charleston
Ochterbeck, Jay M; Co-I/Institutional PI; Clemson University
Khan, Jamil A; Co-I/Science PI; University of South Carolina
Li, Chen; Co-I/Science PI; University of South Carolina, Columbia

The science and technology of two-phase transport is critical and intrinsic to numerous space systems (e.g. power systems, thermal control systems, and life support systems). This collaborative project between the University of South Carolina (USC) and Clemson University (Clemson) aims to address NASA's needs in two-phase technologies by creating a new, unified and ultra-efficient flow boiling pattern that is especially favorable for applications in microgravity. Two-phase heat transfer coefficient can be ten times larger than that for single-phase systems. However, because of weak buoyancy effects, microgravity is not favorable to enhance flow boiling due to the difficulty in detaching bubbles and the disappearance of the convection. To date, the understanding of two-phase transport behaviors in microgravity is still lacking. In this project, we seek to create a gravity-insensitive flow pattern to drastically enhance nucleate boiling and evaporation as well as to passively introduce advection by inducing high frequency liquid renewal on walls. Equally important, in this unique flow boiling pattern, vapor and liquid flows can be effectively separated and the resulting two-phase flow pressure drop can be well managed.

Innovative nanostructures with two-tier of pore sizes will be designed and fabricated as the boiling surfaces to reduce bubble size to be less than 5 Âµm through sophisticated controls of bubble dynamics as well as to transform the direction of the governing capillary force from cross-sectional planes to in-wall planes during flow boiling in microgravity. Since buoyancy force is insignificant with bubble size less than 5 Âµm, the bubble departure would be governed by surface tension and inertia forces and thus it will be gravity-insensitive. Equally significant, the transformation of surface tension force direction will eliminate large dry areas on the wall during slug flow and induce strong capillary flows on the walls and hence radically overcome the low heat transfer rate resulting from vapor slugs. The methodology to achieve sophisticated controls of bubble dynamics and internal governing forces (e.g. surface tension force, drag force, etc.) at micro/nanoscale will be formulated and experimentally validated.

The understanding of two-phase transport at micro/nanoscale in microgravity developed in this project can advance space power systems, thermal management technologies, liquid handlings in space cryogenic and life support systems to support NASA future space exploration missions. For example, compared to existing single-phase loops, more efficient flow boiling loops will result in significantly decreased size and weight of the power generation and thermal control systems, and hence, lead to both an increase in mission capability and a reduction in mission cost. Experimental and theoretical studies of two-phase transport as outlined in this proposal are hence directly relevant to NASA's high priority. This NASA relevance is further evident from NASA thermal/fluid experts' support letters (enclosed in the full proposal). Micro/nanoscale two-phase transport also plays a critical role in advancing terrestrial technologies. The successful completion of this project would lead to developments of a more sustainable and efficient phase separation mechanism to boost life science research, a novel flooding management strategy to enable high power density and efficient proton exchange membrane fuel cells, and advanced two-phase cooling solutions to meet the growing needs of increasing heat dissipation from expanded avionic functionality, advanced electrical system architectures, and etc. The developed technology will also provide an intelligent thermal protection for Lithium-Ion battery to realize safer, more efficient, and reliable aircrafts. Thus, the initiative of this project is well aligned with the research thrusts (e.g., life sciences, energy, and transportation) identified by the State of South Carolina (SC).