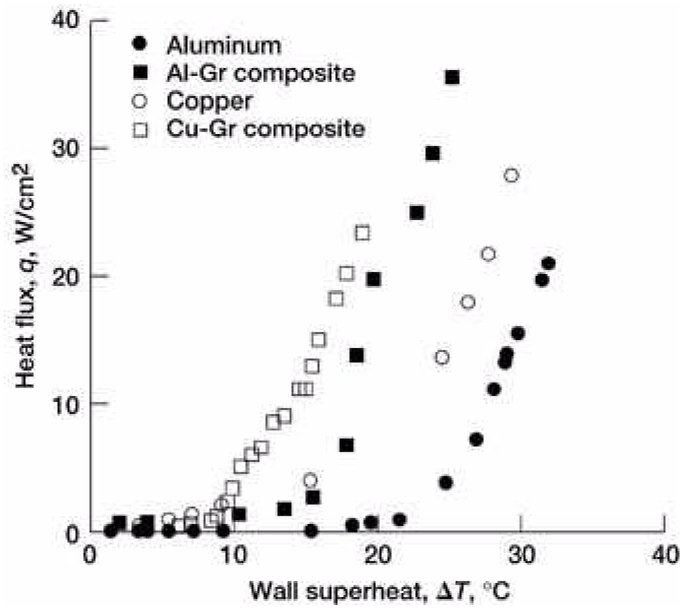
Boiling on Microconfigured Composite Surfaces Enhanced

Boiling heat transfer is one of the key technologies for the two-phase active thermal-control system used on space platforms, as well as for the dynamic power systems aboard the International Space Station. Because it is an effective heat transfer mode, boiling is integral to many space applications, such as heat exchangers and other cooling devices. Nucleate boiling near the critical heat flux (CHF) can transport very large thermal loads with a much smaller device and much lower pumping power than for single-phase heat exchangers. However, boiling performance sharply deteriorates in a reduced-gravity environment, and operation in the CHF regime is somewhat perilous because of the risk of burnout to the device surface.

New materials called microconfigured metal-graphite composites can enhance boiling. The photomicrograph shows the microconfiguration (×3000) of the copper-graphite (Cu-Gr) surface as viewed by scanning electronic microscope. The graphite fiber tips appear as plateaus with rugged surfaces embedded in the copper matrix. It has been experimentally demonstrated that this type of material manifests excellent boiling heat transfer performance characteristics and an increased CHF. Nonisothermal surfaces were less sensitive to variations of wall superheat in the CHF regime (ref. 1). Because of the great difference in conductivity between the copper base and the graphite fiber, the composite surfaces have a nonisothermal surface characteristic and, therefore, will have a much larger "safe" operating region in the CHF regime. In addition, the thermocapillary forces induced by the temperature differences between the fiber tips and the metal matrix play an important role in bubble detachment, and may not be adversely affected in a reduced-gravity environment. All these factors indicate that microconfigured composites may improve the reliability and economy (dominant factors in all space applications) of various thermal components found on spacecraft during future missions.

Cu-Gr composite surface.

The current experiment was conceived by Dr. Nengli Zhang of the Ohio Aerospace Institute. Experimental studies were conducted of the nucleate boiling heat transfer of pentane on metal-graphite composite surfaces with a fiber volume concentration of 50 vol %, including copper-graphite (Cu-Gr) and aluminum-graphite (Al-Gr) composite surfaces. The nucleate boiling heat transfer performance of metal-graphite surfaces is obviously much better than that of pure metal surfaces, as shown in the graph. In this figure, superheat ΔT is equal to the difference between the wall temperature and the saturation temperature of the working fluid (here, pentane), and q is heat flux transferred from the wall to the working fluid. On the basis of the experimental results and according to the two-tier configuration and mathematical model proposed by Zhang et al. (ref. 2), a correlation for the heat transfer performance in the nucleate boiling regime was derived.



Performance of nucleate boiling heat transfer.

More experimental study of the boiling heat transfer performance of metal-graphite composite surfaces is being conducted, including the CHF of pentane and the entire nucleate boiling regime of water on Cu-Gr and Al-Gr composite surfaces. The new experimental data will be used to recheck and improve the mathematical model.

References

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Glenn contact: Dr. David F. Chao, (216) 433–8320, David.F.Chao@grc.nasa.gov

Author: Dr. David F. Chao

Headquarters program office: OLMSA

Programs/Projects: Microgravity Science