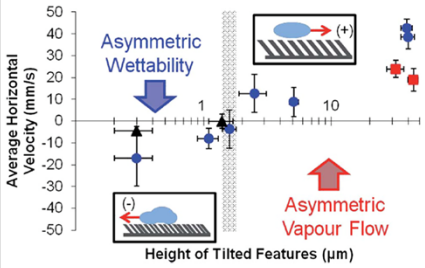
Controlling Leidenfrost Droplets Directionality by Tuning the Height of the Surface Features



Average horizontal velocity as a function of height of the tilted features. Negative velocity values indicate motion of the droplet in the same direction as the feature tilt on the nanoscale pillars, while positive velocity values indicate motion opposite to the feature tilt on the microscale pillars.

Scientific Achievement

We identify the interplay between wetting and vapor flow in the dynamic Leidenfrost regime, and demonstrate that directionality of the Leidenfrost droplet can be controlled by varying the height and the length scale of the surface features.

Significance and Impact

Asymmetric wetting, control of the Leidenfrost phenomena and multiphase flows are critical in establishing new fundamental approaches to enhanced heat transfer and mass transport.

Research Details

- The preferential movement of Leidenfrost droplets switches from moving with the tilt of the nanoscale pillars to against the the tilt of microscale pillars.
- Asymmetric wettability of dynamic Leidenfrost droplets upon impact is dominant on tilted nanoscale pillars array; while the forces induced by asymmetric vapor flow are stronger on much taller microscale tilted pillars.

Work was performed at the Center for Nanophase Materials Sciences, ORNL.

R.L. Agapov, J.B. Boreyko, D.P. Briggs, B.R. Srijanto, S.T. Retterer, C.P. Collier, N.V. Lavrik, *Nanoscale* (2014), 6, 9293.

U.S. DEPARTMENT OF ENERGY | Office of Science

OAK RIDGE National Laboratory

Narrative Highlight Text:
Arrays of tilted pillars with heights ranging from hundreds of nanometers to tens of micrometers were fabricated and used as Leidenfrost ratchets to control droplet directionality. Dynamic Leidenfrost droplets on the ratchets with nanoscale features were found to move in the direction of the pillar tilt while the opposite directionality was observed on the microscale ratchets. This remarkable switch in the droplet directionality can be explained by varying contributions from the two distinct mechanisms controlling droplet motion on Leidenfrost ratchets with nanoscale and microscale features: asymmetric wettability of dynamic Leidenfrost droplets upon initial impact appears to be the dominant mechanism determining their directionality on tilted nanoscale pillar arrays, while the forces induced by asymmetric vapor flow are the stronger mechanism on arrays of much taller tilted microscale pillars. The point of crossover between the two mechanisms coincides with the pillar heights comparable to the values of the thinnest vapor layers still capable of cushioning Leidenfrost droplets upon their initial impact. The proposed model of the length scale dependent interplay between the two mechanisms points to the previously unexplored ability to bias movement of dynamic Leidenfrost droplets and even switch their directionality.

Reference

"Length Scale of Leidenfrost Ratchet Switches Droplet Ddirectionality"

R. L. Agapov,[a] J. B. Boreyko,[ab] D. P. Briggs,[a] B. R. Srijanto,[ac] S. T. Retterer,[a] C. P. Collier,[a] N. V. Lavrik[a]
[a]Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge
[b]Bredesen Center for Interdisciplinary Research, University of Tennessee, Knoxville
[c]Department of Materials Science and Engineering, University of Tennessee, Knoxville

*Nanoscale (*2014), 6, 9293.

Acknowledgment of Support
This research was conducted at the Center for Nanophase Materials Sciences, which is sponsored at Oak Ridge National Laboratory by the Division of Scientific User Facilities, U.S. Department of Energy.