RAchets provide directionality in the motion of matter. We report motion of liq-
uid droplets in the Leidenfrost regime whose directionality is rectified by topological
ratchets. Topologically ratcheted gratings with the period ranging from millimeter
down to sub-micrometer were fabricated using micromachining techniques. Water
droplets dispensed on the ratcheted gratings start to move in a direction perpendic u-
lar to the gratings when the surface temperature reaches the Leidenfrost temperature.
At relatively low temperature ranges above the Leidenfrost temperature, the average
velocity of water droplet motion increases exponentially as the period of the ratchets
decreases. At the high temperature ranges, the velocity does not depend on the
ratchet size any more, maintaining a constant value of a few cm/s.

KEYWORDS: Leidenfrost (film-boiling) effect, ratchets, rectified motion

EXPERIMENTAL
Various sizes of ratchets down to sub-micrometer periods were fabricated using
micro- and nanoscale machining tools. Figure 1 shows an optical micrograph for mi-
croscale ratchets with 75 µm period and a scanning electron micrograph (SEM) for
sub-micrometer ratchets with 800 nm period. The aspect ratios of all the ratchets
were kept similar to each other. The ratchets were heated on a hot plate. After the temperature was stabilized and the ratchet surface temperature was measured with a thermocouple, water droplets were dispensed using a micropipette and the motion was captured using a video camera.

RESULTS AND DISCUSSION

Figure 2 presents a video sequence of motion of a water droplet on brass ratchet-grained gratings. The average droplet velocity was calculated based on the time interval from the motion start to the point when the droplet reaches the end of ratchets. Figure 3(a) shows the average droplet velocity as a function of temperature for different ratchet period. Surprisingly, a dramatic increase in the maximum velocity was observed as the period of the ratchets decreases, even reaching ~40 cm/s for the ratchet period of 800 nm. As shown in Figure 3(b), this increase in the velocity follows a logarithmic relationship with the ratchet sizes. This result clearly indicates that a nanoscale asymmetric potential enhances the propulsion of liquid motion dramati-

Figure 1. Micrographs of micro- and nanoscale ratchets (a) optical micrograph of brass micro-ratchet (period: 75 µm, depth: 15 µm). (b) SEM image of Ni nano-ratchet (period: 800 nm, depth: 200 nm).

Figure 2. Video sequence (time interval= 60-70 ms) of a 5 µL droplet of DI on a horizontally levelled, brass saw tooth gratings at 254°C (period = 1.5 mm, depth = 0.3 mm)
cally and thus this self-propulsion mechanism with a nanoscale asymmetric potential can be a powerful candidate to drive micro- and nanofluidic devices. At higher temperature ranges, ratchet size influences droplet velocity less, maintaining a constant value (a few cm/s).

CONCLUSIONS

We studied motion of water droplets on micro- and nanoscale ratchet surfaces at temperatures in the Leidenfrost regime. The velocity of liquid motion increases exponentially as the period of ratchets decreases around Leidenfrost points of liquids.

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