INTEGRATING EWOD WITH SURFACE RATCHETS FOR ACTIVE DROPLET TRANSPORT AND SORTING

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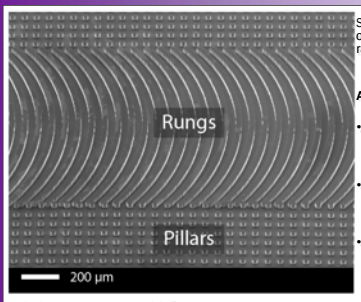
Abstract

Combining surface ratchets and electrowetting on dielectric (EWOD) produces novel microfluidic systems that achieve passive droplet transport along microscopically-rough surfaces and active droplet sorting by electric signals. The super-hydrophobic surface ratchet and EWOD plate sandwich a droplet; when vibrated, the device performs passive droplet transportation via the surface ratchet. The EWOD technology is utilized at particular junctions to implement several droplet-specific control functions, including the combination of a new ratchet design with an EWOD plate in a switch that sorts 10 µl droplets.

Surface Ratchets



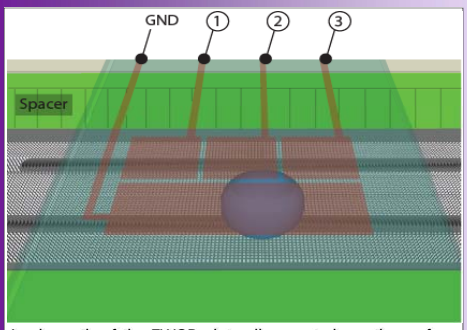
SEM micrograph of a surface ratchet

Attributes

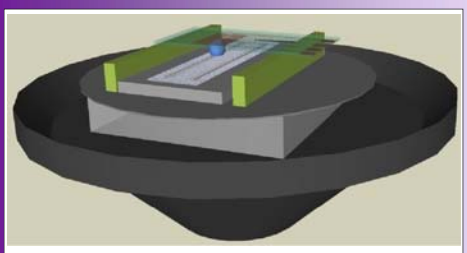
- Track: periodic semi-circular rungs
- Low-density pillars delimit the track
- Hydrophobic coating

- The curvature of the rungs creates asymmetric surface contact for a droplet when placed on a ratchet.
- When agitated by vibration the asymmetric bias causes passive droplet transport in direction of the curvature of the rungs (in the case shown here, to the right).

Integrating Ratchets with EWOD



A schematic of the EWOD plate alignment above the surface ratchet, with a droplet sandwiched in between.



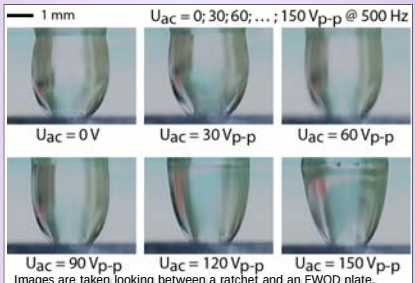
The system is attached to a stage mounted horizontally on an electromagnetic speaker, which delivers controlled vibrations to the system.

Novel Droplet Transport

A prior limitation of passive transportation is the difficulty to address and guide specific droplets. For surface ratchets, or any other passive droplet transportation method, to be useful in a wide range of microfluidic applications, a method of active, droplet-specific transport is essential.

We have implemented a device that integrates both passive and active transport, taking advantage of the simplicity of surface ratchets and the droplet-specific control of EWOD. Using the integrated system, we have demonstrated three added functions that could greatly expand the applications of surface ratchets. A device that functions primarily by passive droplet transportation with surface ratchets, moving multiple droplets over long periods of time, can be controlled at specific junctions, stopping droplet flow with a valve, moving droplets backwards with a flow reversal device, and sorting droplets at a switch.

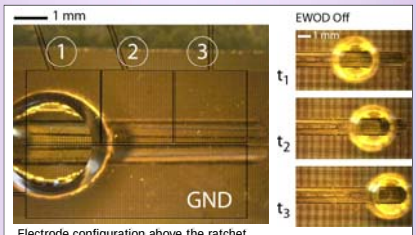
EWOD's Effect



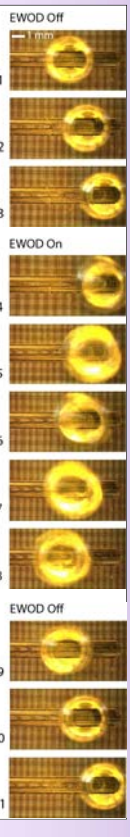
Images are taken looking between a ratchet and an EWOD plate.

As voltage is increased the contact angles with the EWOD plate are reduced, lifting the droplet's center of gravity further from the ratchet.

Valve and Flow Reversal in Droplet Transport



Electrode configuration above the ratchet.



Ratchet transport – passive
At t_1, the stage is vibrated inducing droplet transport along the ratchet's asymmetric bias.

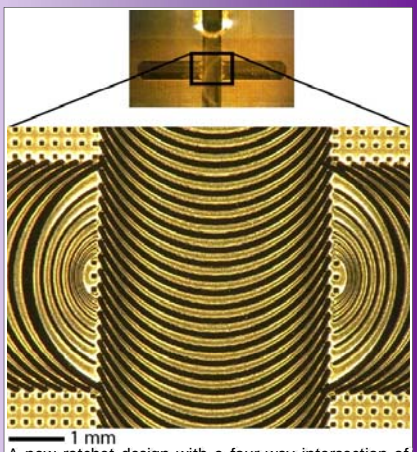
Valve - active
At t_4 electrode 3 is activated, which stops the droplets flow.

Flow reversal - active

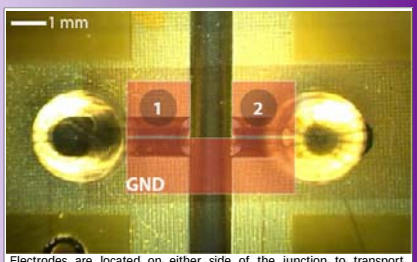
- At t_5 electrode 2 is activated, stretching the droplet to the left.
- At t_6 electrode 3 is deactivated and the droplet is pulled to the left, centering itself on electrode 2.
- The process in t_4-t_6 is repeated in t_6-t_8 with electrodes 1 and 2.
- At t_8 the droplet has moved backwards returning to the original position in t_1.

Ratchet transport - passive
When EWOD is disengaged at t_9, the droplet returns to its initial contact and resumes motion via the surface ratchet.

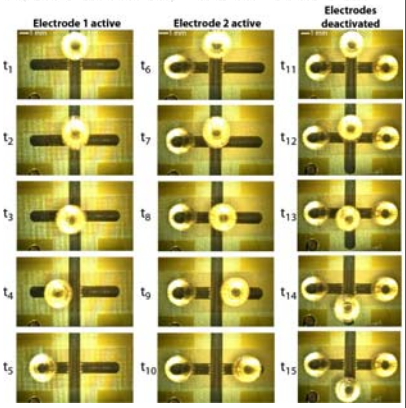
Sorting Droplets



A new ratchet design with a four-way intersection of tracks was used for sorting; one track's asymmetric bias is towards the junction while the other three point away from it.



Electrodes are located on either side of the junction to transport droplets against the track's asymmetrical bias in a chosen direction.



- In the left/middle columns, EWOD pulls a droplet to the left/right of the junction whereas the ratchet's asymmetric bias is in the straight downward direction. When the electrode is deactivated, the droplet resumes motion in the new direction.
- In the right column, when neither electrode is engaged, the droplet's motion is unaffected by the junction and continues straight along the track.

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