VIBRATON INDUCED DROPLET GENERATION ON TEXTURED SURFACES

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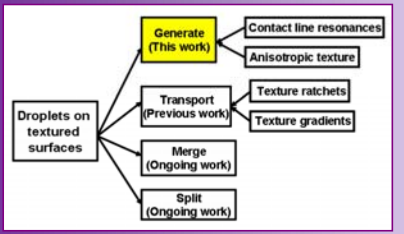
Abstract

We report a new method to create droplets from a large drop by using surface texture and vibration. Drops are vibrated on a PDMS substrate textured with ring shaped mesa structures. We created droplets of 0.1-0.3µL from a 0.5mL drop by vibrating the drop at its third mode shape. Droplets are generated at the frequency of contact line oscillation of the drop.

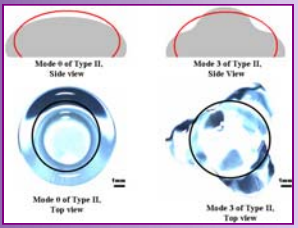
Introduction

- We propose a simple platform for droplet manipulation where droplets can be generated, transported, merged and split by using surface texture and vibration actuation.
- Our group previously presented methods for droplet transportation by using texture ratchets and gradients. Here we present a new method to generate droplets from a large drop on the same platform.

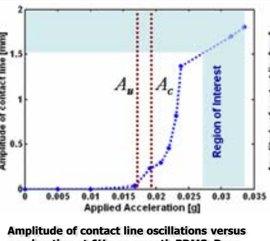


Vibration of Drops

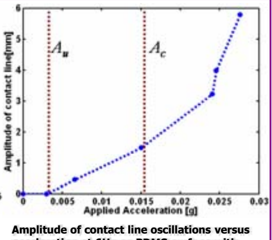
- The substrate on which the drop stays is vibrated at various frequencies and sinusoidal accelerations.
- There are two types of modes of vibration of a drop:
  - ***Type I Modes:*** Stationary contact line
  - ***Type II Modes:*** Oscillating contact line
- Figure shows the top view of water drops in *Type-II* modes 0 and 3 on a smooth PDMS surface and a schematic of their side view.



- There are two threshold values for the magnitude of amplitude of acceleration (*A*): A_u and A_c. Below A_u *Type-I* modes are observed.
- Above this threshold ($A_u<A<A_c$), the contact line overcomes hysteresis and starts to oscillate (mode 0).
- Above A_c the contour starts to oscillate at half of the agitation frequency with large amplitudes and axisymmetric mode shapes.



Amplitude of contact line oscillations versus acceleration at 6Hz on smooth PDMS. Drop vibrated is 0.5mL.



Amplitude of contact line oscillations versus acceleration at 6Hz on PDMS surface with roughness 1.16.

Modeling of the Contact Line

- The vibration of the contour around its equilibrium is described by Mathieu's equation where the eigen frequency is a function of time:

$$\ddot{u}+\omega_m^2(1+h\cos\omega_E t)u=0$$

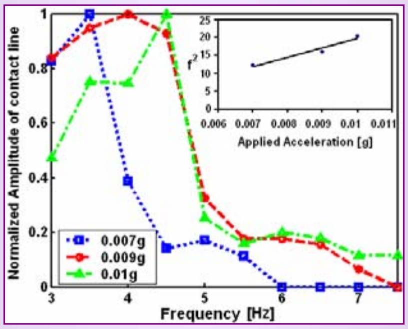
u : deformation of contact line, $R(\varphi,t)=R_e+u(\varphi,t)$

ω_m : resonant frequency of mode *m*, ω_E : excitation frequency, R_e :drop radius at equilibrium and $h=3\Delta R/R$.

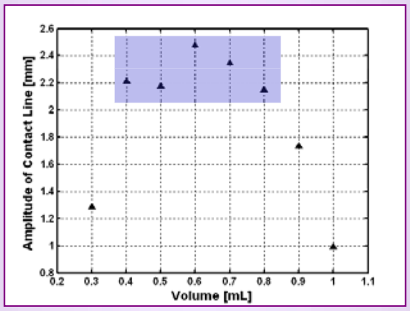
- The dispersion relation is given as follows: $\omega_m^2=\Im m(m^2-1)/\rho e_c R_e^3$

$\Im$: line tension $\Im\approx\theta_e^2\gamma\kappa^{-1}/2$, e_c : thickness of drop $e_c\approx\kappa^{-1}\theta_e$

θ_e : equilibrium contact angle, ρ : density.



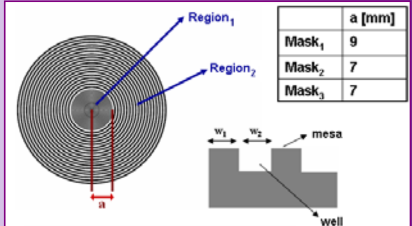
- Figure above shows the amplitude of contact line versus frequency at three different accelerations on smooth PDMS surface.
- The linear dependence of the squared excitation frequency on the applied acceleration results in parametric oscillations. The drop is 0.5mL.
- Figure below shows the amplitude of oscillation of different volumes (0.6mL<*V*<1mL) of drops at 6 Hz and *A* =0.03g on a smooth PDMS surface.
- The region of interest values for different volumes are different:



Droplet Creation

Design:

- Designs are composed of ring shaped mesa structures having ring shaped 'wells' (lower areas) in between.
- There are two regions in every design with different roughness: *Region I:* Center of drop is located, *Region II:* Has lower roughness and is the area where droplets are generated.



	a [mm]
$Mask_1$	9
$Mask_2$	7
$Mask_3$	7

$Region_2$	$Mask_1$	$Mask_2$	$Mask_3$
w_1 (um)	500	500	500
w_2 (um)	500	500	1000

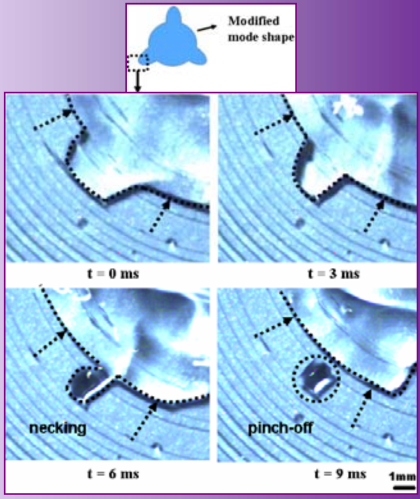
$Region_1$: w_1 = 50um, w_2 = 50um for all masks

Theory:

- There are three forces that affect the separation:
  - Force caused by pinning: $F_p=L\gamma(1-\cos\theta_e)$
  - Restoring force: $F_s=m\omega_m^2(1+h\cos\omega_E t)u$
  - Laplace pressure difference: $F_L=Area\cdot\gamma\left(\frac{1}{R_{mesa}(t)}-\frac{1}{R_{well}(t)}\right)$

Experimental Results

- Snapshots of droplet generation at the contact line in mode 3 is shown below.
- Tables show the average droplet volumes and number of droplets created for each mask design for two different volumes.



Conclusion

- We developed a novel method for droplet generation by using surface texture and vibration actuation. Droplets as small as 0.1µL were generated from a 0.5mL drop.

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