Directional Water Droplet Transport on Asymmetric Ratchet Conveyors with Wide Frequency Bandwidth

Di Sun, Karl F. Böhringer

Department of Electrical Engineering, University of Washington

National Nanotechnology Coordinated Infrastructure

UNIVERSITY *of* WASHINGTON

Introduction

Water droplets can be transported with asymmetric lateral vibrations[1] or with orthogonal vibrations using surface wettability asymmetry[2][3]. Our anisotropic ratchet conveyor (ARC) system transports droplets with micro-sized hydrophilic surface patterns on a hydrophobic background with a wide orthogonal vibration frequency bandwidth (20 ~ 500 Hz). An active self-cleaning surface is developed using an ARC system to remove surface contaminants with a single water droplet.

ARC Surface Design

- ❖ Periodic TMS (trimethylsilanol, water contact angle 53°) semicircular rungs are patterned on FOTS surfaces (perfluoro-octyltrichlorosilane, water contact angle 108°)
- ❖ Water droplet movement is driven by wetting anisotropic force at the hydrophilic-hydrophobic boundary of the leading and trailing edges

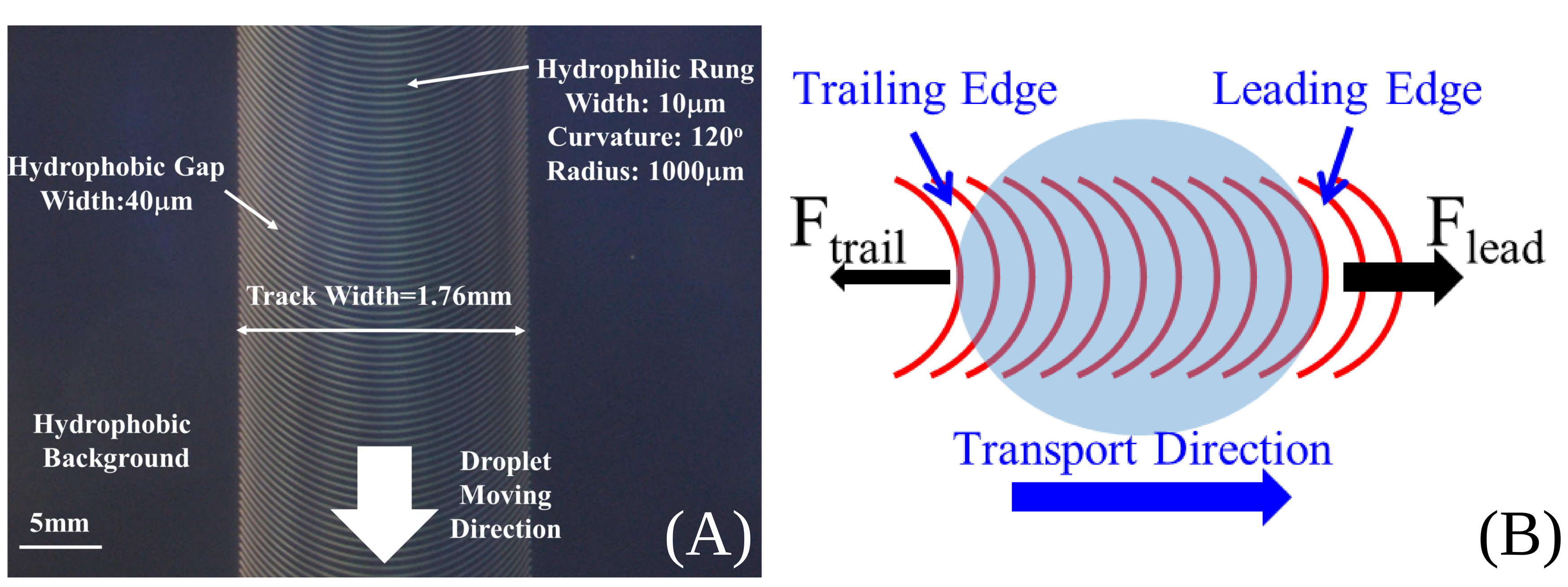

Figure 1: ARC Design and Function. (A) Ratchet rung structure after lithographic patterning. (B) Schematic drawing of water droplet sitting on the TMS-FOTS surface.

Water Droplet Transport

- ❖ Water droplet moves along the ARC track during each orthogonal vibration cycle and can climb up to 15° inclined surfaces
- ❖ Water droplet motion is captured by the high speed camera

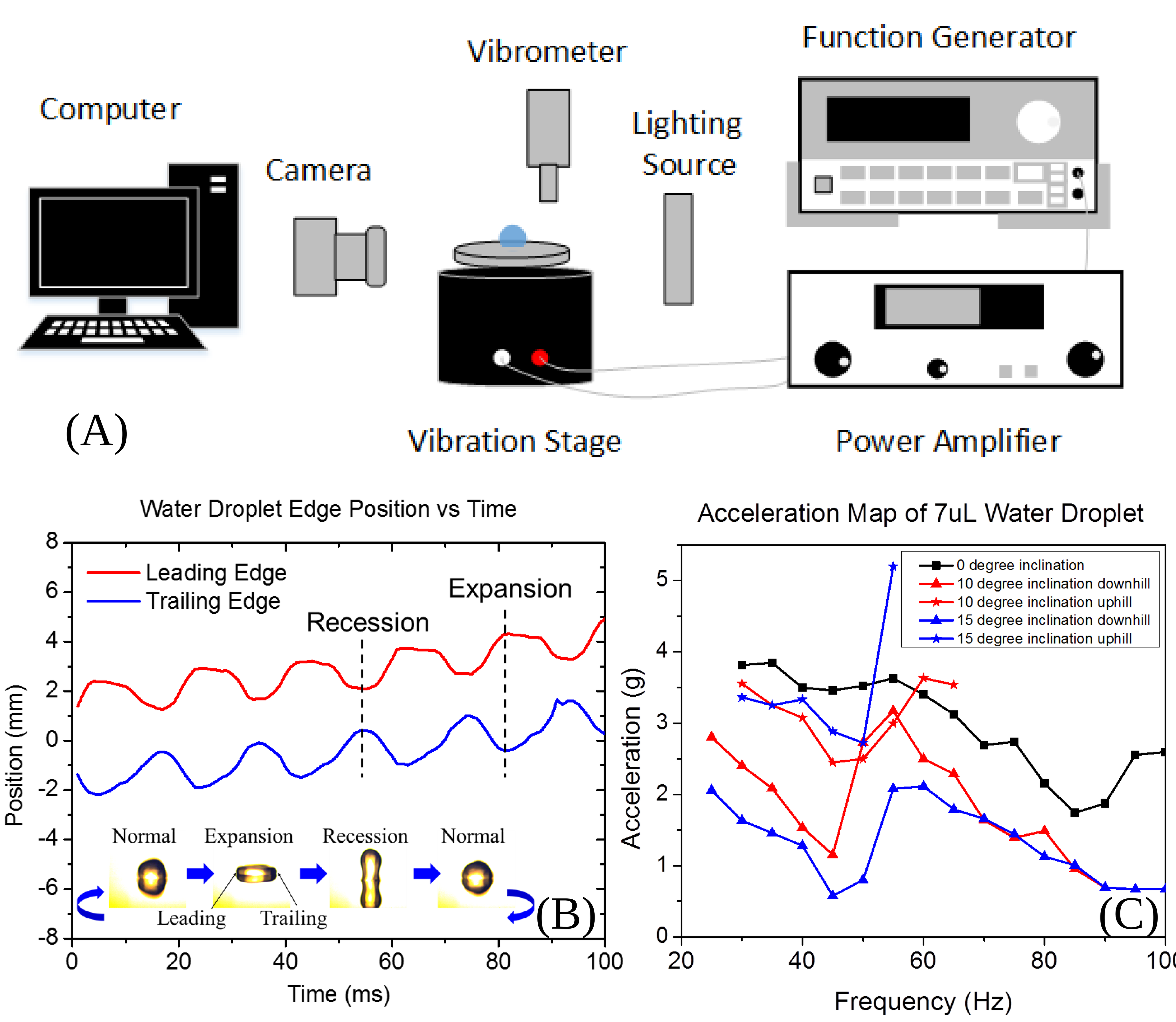

Figure 2: Directional Water Droplet Transport. (A) Test bench setup. (B) Relative position changes of the water droplet's leading and trailing edge. (C) Minimum vibration acceleration required to move the droplet on flat and inclined surfaces.

Water Droplet Vibration Resonance Modes

- ❖ Water droplet resonance frequencies depend on contact angle[4]:

$$f_j = \frac{\pi}{2}\sqrt{\frac{j^3\gamma}{24m}\frac{(\cos\theta^3 - 3\cos\theta + 2)}{\theta^3}}$$

where: θ – water droplet contact angle
m – water droplet mass
γ – surface tension
j – mode number

- ❖ Tested frequency bandwidth: 20 ~ 500 Hz

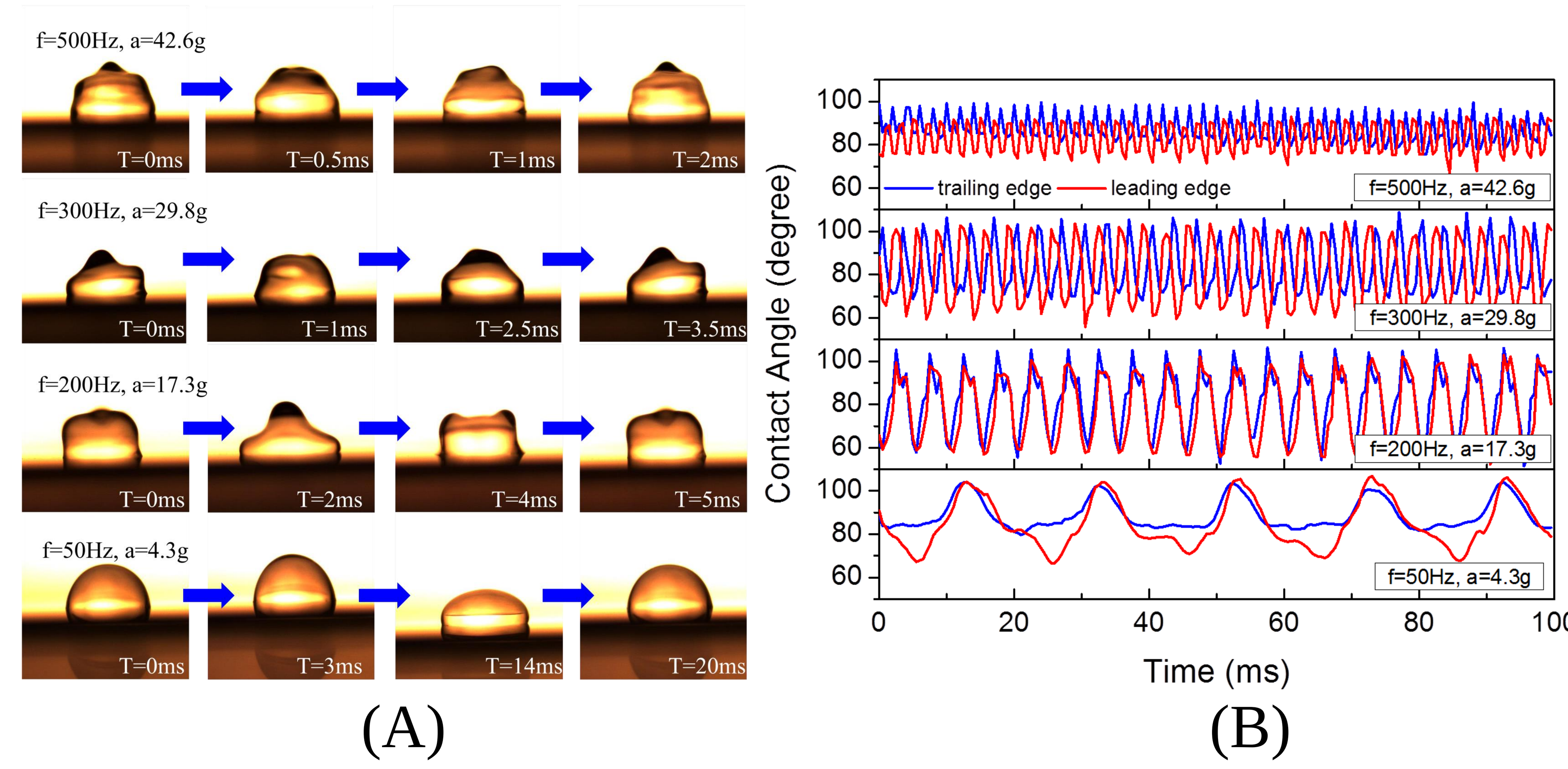

Figure 3: Water Droplet Directional Transport under Different Frequencies. (A) 7µL water droplet transport under different resonance modes. (B) The contact angle hysteresis of the leading and trailing edge.

Application: Self-cleaning Surface

- ❖ Self-cleaning surface is being developed based on ARC surface
- ❖ Water droplet is driven in a zig-zag pattern to dislodge the surface contaminants

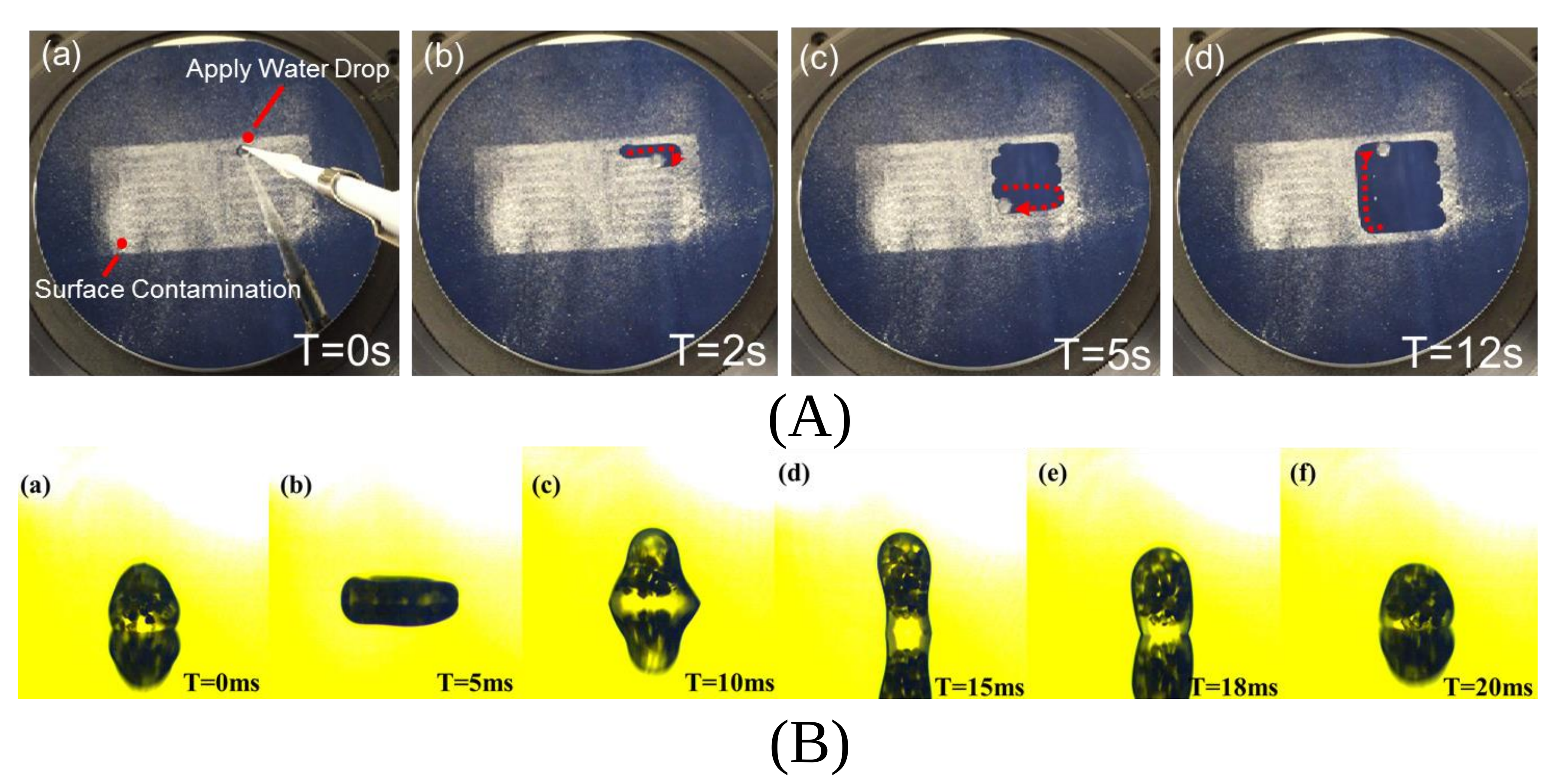

Figure 4: Self-cleaning Surface Design and Test. (A) Surface cleaning performance for sweetener (dextrose, maltodextrin, and sucralose) contamination on ARC surface. (B) 2 mg sand particles transported in 10 µL water droplet.

Table I: Materials tested on the self-cleaning surface

Material	Sand	Salt	Sweetener	Pepper	Dry soil
Can be cleaned or not	Y	Y	Y	N	N

Acknowledgement

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References

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