Introduction

- Superhydrophobic (SH) surfaces are of great interest because of low water adhesion and self-cleaning properties.
- SH surfaces occur in nature (e.g., lotus leaves) and have been created artificially mainly on inorganic substrates.

Why consider paper for SH substrates?
- Biodegradable
- Inexpensive
- Renewable
- Available worldwide

Definition of Superhydrophobicity

**Static** solid-liquid interactions
- Contact angle (CA):
  - $θ < 90°$ → Hydrophilic
  - $θ > 90°$ → Hydrophobic
  - $θ > 150°$ → Superhydrophobic

**Dynamic** solid-liquid interactions
- Contact angle hysteresis: difference between advancing and receding CAs

Hysteresis controlled by:
- Physical properties (surface roughness)
- Chemical properties (surface energy)

Control of Bulk Wetting: SH Paper

- SH surfaces require:
  1. Surface roughness
  2. Low surface energy
- Paper inherently has micrometer-scale roughness due to fiber dimensions
- Nanometer-scale roughness can be obtained via selective oxygen plasma etching of amorphous cellulose regions
  → Varying roughness
- Low surface energy through plasma-enhanced deposition of crosslinked fluorocarbon film from perfluoroethane (PFE) precursor

Control of Local Wetting: Patterning

- Printed patterns on SH paper control the local water droplet adhesion:
  - Thermal transfer printing of wax
  - Wax pattern less hydrophobic than surrounding paper
  - Same contact area → Variable drop volume with same dot size

Droplet Sampling: Procedure

1) Droplet resting on SH sheet, printed pattern above
2) Compress the droplet and then pull sheets apart
3) Droplet sample remains on the top sheet

Droplet Sampling: Volume Control

- Sampled volume controlled by hysteresis
- Adhesive force on printed dot is a function of the surface area
- Low hysteresis dots allow droplet to recede
- High hysteresis dots cause droplet pinning
- Manipulate hysteresis for control of sampled volume

Physical Control

- Wax dots pressed against different grades of sandpaper
  → Varying roughness

Chemical Control

- Different types of wax used
  → Varying surface energy

Application: Biomedical Testing

Volume control enables creation of well-defined microliter samples for quantitative biochemical assays
- Biomedical Testing: colorimetric reagents dried or bound to wax dots
- Proof-of-Concept: Glucose immunoassay

Summary

- Paper is a robust, inexpensive, biodegradable substrate to produce surfaces with controlled liquid wetting and adhesion properties
- Patterning SH paper with wax islands enables local control of adhesion, which can be used for advanced droplet manipulation
- Adjustable volume sampling from bulk drops can be achieved through hysteresis control
- Technique provides capability to perform quantitative immunoaassays

Future Work

- Further integration of reagents with printed wax patterns to optimize quantitative colorimetric assays
- Expansion of multi-island patterns for more complex sampling

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