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RESEARCH PAPER

Optically induced electrohydrodynamic instability-based micro-patterning of fluidic thin films

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Abstract Projected light patterns are used to induce electrohydrodynamic instabilities in a polymer thin film sandwiched between two electrodes. Using this optically induced electrohydrodynamic instability (OEHI) phenomenon, we have successfully demonstrated rapid, microscale patterning of polydimethylsiloxane (PDMS) pillar arrays on a thin-film hydrogenated amorphous silicon layer on top of an indium titanium oxide glass substrate. This glass substrate is the bottom electrode in a two-electrode, parallel-plate capacitor configuration with a micron-scale gap. Within this gap are a thin film of spin-coated PDMS and a thin layer of air. Primary pillar growth is first observed within 5–90 s in the dark regions of the projected patterns and pillar growth eventually spreads to the illuminated regions when the initial PDMS thickness is <2 μm. Experimental data characterizing the change in pillar diameters (between 15 and 30 μm in diameter) show that they can be decoupled from the inter-pillar spacing (maintaining a constant ~84 μm pitch between pillar centers) by controlling the applied DC voltage (between 110 and 210 V). Experimental results also show the importance of the optically induced lateral electric field on controlling pillar formation. This OEHI method of rapid pillar generation, with voltage control of the pillar diameter and control of pillar position via projected light patterns, presents new opportunities for low cost, efficient, and simple fabrication of micro, and perhaps nanoscale, polymer structures that could be used in many bioMEMS applications.

Keywords Electrohydrodynamic instability · Optically induced electrokinetics · Thin-film patterning · Micro-pillars

List of symbols

h	Local film thickness of the bottom fluid (m)
h_0	Initial uniform film thickness of the bottom fluid (m)
H	Distance between two electrodes (m)
$\mathbf{n}$	Surface normal vector
t	Time (s)
$\mathbf{t}$	Surface tangential vector
V	Externally applied voltage (V)
γ	Interfacial tension (N m^{-1})
ε_0	Permittivity of a vacuum ($\varepsilon_0 \approx 8.854 \times 10^{-12}$ F m^{-1})
ε_a	Dielectric constant of the a-Si:H
ε_a^I	Dielectric constant of the illuminated a-Si:H
ε_a^{NI}	Dielectric constant of the non-illuminated a-Si:H
ε_i	Dielectric constant, $i = 1$ for Fluid1 (air) and 2 for Fluid2 (PDMS)
λ	Pitch between pillar centers (m)
μ_i	Dynamic viscosity, $i = 1$ for Fluid1 and 2 for Fluid2 (Pa s)
ψ_b	Electrostatic potential at $z = 0$ (V)

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