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RESEARCH PAPER

Performances of a broad range of dielectric stacks for liquid dielectrophoresis transduction

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Abstract Among digital microfluidic techniques, liquid dielectrophoresis (LDEP) is well adapted to displace insulating liquids. One of the current challenges for LDEP concerns the robustness of both the dielectric and hydrophobic coatings (deposited atop the driving electrodes). Indeed, such layers may be exposed to high electric field, during operation. There is a need to optimize this stack of insulating layers to first prevent from their dielectric breakdown, secondly reduce the actuation voltage, and lastly ensure a reproducible and well-controlled droplet-generation process. For the first time, an extensive study is presented in that paper, comparing the performances of more than twenty different dielectric stacks (including SiN, High-K materials, hydrophobic coatings) from micro–nanoelectronics know-how and implemented onto a given LDEP design. This generic design features lateral bumps regularly spaced across coplanar electrodes to generate an array of 30 pL DI water droplets in a single open-plate architecture. The experiments have been carefully analyzed to identify which are the best stacks in terms of efficiency and quality for the LDEP transduction. As a result to that study, we propose a guideline to adjust the dielectric coating properties (thickness, material) depending on the liquids to displace and targeted applications.

Keywords Liquid dielectrophoresis · Dielectric materials · Actuation voltage · Droplet generation

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List of symbols

C_{air}*	Capacitance of the air (F m^{-1})
C_i*	Capacitance of the dielectric layer (F m^{-1})
C_{liq}*	Capacitance of the liquid (F m^{-1})
d_i	Dielectric layer i thickness (m)
E_{bd}	Breakdown electric field (V m^{-1})
f	Applied frequency (Hz)
f_{th}	Threshold frequency (Hz)
F_γ	Surface tension force (N)
g	Inter-electrode gap (m)
i	Nomination of a dielectric i
L	Electrodes length (m)
m_{eff}	Efficiency LDEP factor
m_{qual}	Quality LDEP factor
Na_1	Actuations number (see Table 2)
$Na_{1/2}$	Actuations number (see Table 2)
R	Bump radius (m)
$R_{d/b}$	Droplet-generation parameter (see Table 2)
$R_{w/d}$	Droplet-generation parameter (see Table 2)
V	Applied voltage (V)
V_{bd}	Breakdown voltage (V)
V_{RMS}	Root mean square voltage (V)
V_{th}	Threshold actuation voltage (V)
V_{tot}	Total actuation voltage (V)
w	Electrode width (m)
α	Equivalent dielectric thickness (m)
γ_{liq}	Liquid surface tension (N m^{-1})
Δt	Signal pulse duration (s)