INTRODUCTION OF A HIGH QUALITY NANOFILM OF ALUMINUM OXIDE ENHANCES THE PERFORMANCE OF EWOD MICROFLUIDIC PLATFORMS

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Introduction

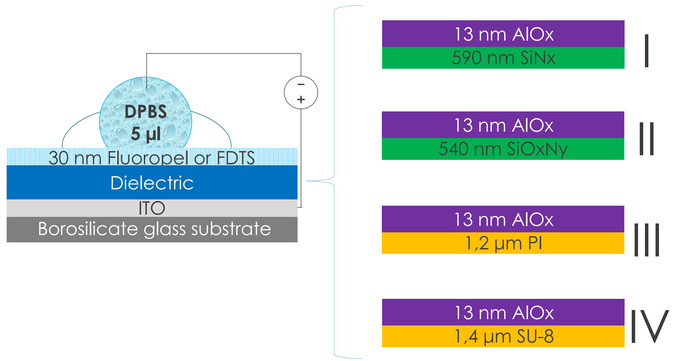
Electrowetting on dielectric (EWOD) is a technology utilizing the phenomenon of surface wetting by a liquid droplet in response to an applied electric field. In order to lower the voltage, a thinner dielectric material can be used. Another approach, proposed in [1], suggests the design of a "dielectric stack" consisting of different materials to 1) reduce the effects caused by the defects in an insulating layer, 2) provide better adhesion between the different layers in the stack and 3) reduce the current leakage.

Aim of the study

Evaluation of the effects of the introduction of a nanofilm of aluminum oxide (AlOx) deposited by Atomic Layer Deposition (ALD) on top of four dielectrics common in MEMS fabrication: "thin" ceramics deposited by Plasma Enhanced Chemical Vapor Deposition (PECVD), silicon oxynitiride (SiOxNy) and silicon nitride (SiNx), and "thick" spin-coated polymers, polyimide PI 2610 and SU-8 TF6002 in an attempt to fabricate a transparent EWOD biochip suitable for the in vitro cell culture.

Methods

1. Change of the static contact angles upon applied DC potentials (SCA (0) vs. SCA(V)) ranging from 20 V (ceramics) or 40 V (polymers) up to 200 V was measured in 3 replicates.
2. An Indium Tin Oxide (ITO) coated borosilicate glass was used as a substrate. Two methods of hydrophobization were applied: spin-coating of Fluoropel PFC1601V-FS (water contact angle: 115°-120°) or vapor-phase deposition of perfluorotridecyltrichlorosilane (FDTS, water contact angle: 100°-110°).
3. A 5 µl droplet of Dulbecco's Phosphate Buffered Saline (DPBS) was used as a conductive fluid.
4. Current leakage was monitored using a source measure unit. It was considered when the values exceeded 1 nA.

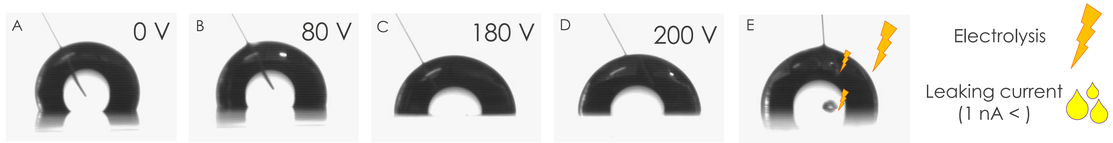


AlOx
ε ~ 9
Low breakdown field

SiNx, SiOxNy
ε ∈ (6-8) and ε ∈ (4-7), respectively
High dielectric strength

Polyimide, SU-8 [2-4]
ε ~ 3
"Weak" dielectrics

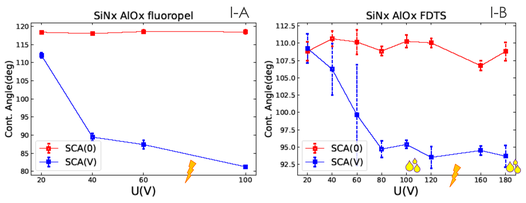
Results and discussion

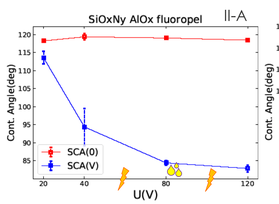


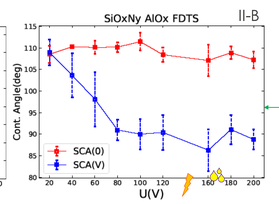
EWOD on SU-8-AlOx-FDTS stack upon 0, 80, 180 and 200 V application (A- D). Contact angle saturation is shown (C, D). Formation of air bubbles due to electrolysis on a SiNx-AlOx-FDTS dielectric stack at 140 V (E). On the right side, a legend with symbols representing electrolysis and leaking current is provided.

Polyimide:
better adhesion between the dielectric and hydrophobic layers with the AlOx interlayer. (Hence, big error bars in III-A vs. IIIB.)

SU-8:
negligible current leakage below 1 nA (IV-A vs. IV-B and IV-C).

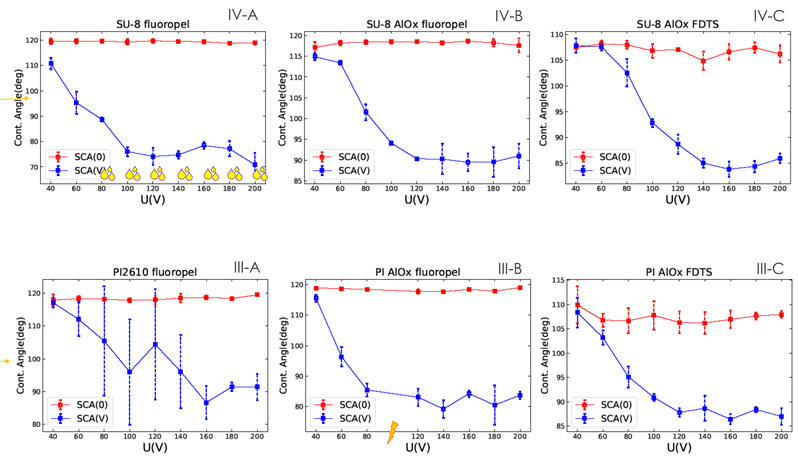






SiNx and SiOxNy:
enhanced range of operational voltages (fig. I, II), prevention from current leaking at lower voltages.

No characteristics could be drawn for SiOxNy and SiNx cases without the additional AlOx → electrolysis



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CONCLUSIONS & FUTURE PERSPECTIVES

The proposed multilayer dielectric stacks proved to be beneficial for:

- Extended range of operational voltages for submicrometer stacks which include SiOxNy and SiNx as first dielectric,
- Minimization of the processing time and features of chip components,
- Promoted adhesion between the layers in the stack,
- Prevention from the current leakage, enhancing the platform's reliability, especially in the case of weaker dielectric such as polymers,

Based on our experience, we are developing a fully transparent chip consisting of SiNx – AlOx – Fluoropel stack for the manipulation of mammalian embryos in vitro powered by EWOD.

References

[1] Schultz, A., Chevalliot, S., Kuiper, S. & Heikenfeld, J. Detailed analysis of defect reduction in electrowetting dielectrics through a two-layer 'barrier' approach. *Thin Solid Films* **534**, 348–355 (2013). [2] Ng, C. H., Chew, K. W. & Chu, S. F. Characterization and comparison of PECVD silicon nitride and silicon oxynitiride dielectric for MIM capacitors. *IEEE Electron Device Lett.* **24**, 506–508 (2003). [3] Chisca, S., Sava, I., Musteata, V. E. & Bruma, M. Dielectric and conduction properties of polyimide films. *Proc. Int. Semicond. Conf. CAS* **2**, 253–256 (2011). [4] Sahin, S., Nahar, N. K. & Sertel, K. Permittivity and Loss Characterization of SUEX Epoxy Films for mmW and THz Applications. *IEEE Trans. Terahertz Sci. Technol.* **8**, 397–402 (2018).