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Fault Modeling and Defect Analysis on Digital Microfluidics Based Biochips

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***Abstract*—** An emerging technology Digital Microfluidics Biochips, an integrating concept of electronics and biology is anticipated to play an important role in the area of medical diagnostics, drug discovery, DNA sequencing, toxicity supervising and other bio-chemical applications. This bio-microelectromechanical system is supposed to have defects if it fails to accomplish the specified assignment dedicated to it. This paper focuses on different possible cases responsible for the misbehavior of the bio-MEMS.

Keywords- *digital microfluidics; biochip; lab-on-a-chip; catastrophic faults;*

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I. INTRODUCTION

Digital Microfluidics based biochips employ the principle of electrowetting on dielectric(EWOD) to move micro or nanolitre volumes of droplet holding biological samples such as blood, serum etc. on a two-dimensional electrode array [1] [2] [3] [4] [5] [6] [7] [8]. This bio-MEMS is expected to become a substitute of a laboratory containing cumbersome instruments. A unit cell of this lab-on-a-chip has two parallel glass plates. The bottom plate carries an array of electrodes and the top plate is grounded. Electrodes are coated with a dielectric insulator to enhance the hydrophobicity. Any biochemical sample is placed on the aquaphobic surface of the bottom plate in the form of a droplet as mentioned in the figure 1.

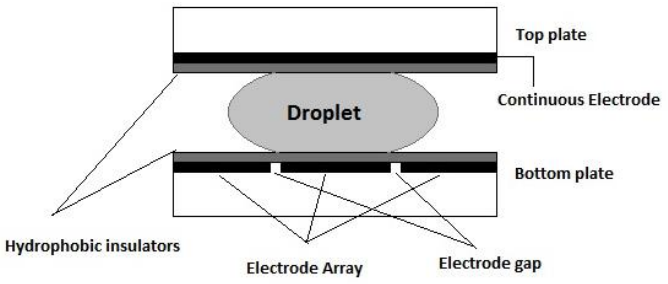

Figure 1. A unit cell of a bio-MEMS.

The droplet containing biochemical samples can be moved to any cell as per requirement. In order to move the droplet to its adjacent electrode, electrode under the droplet is deactivated where as the destination electrode is activated. This mechanism results an interfacial tension in between the gap of the two adjacent electrodes causing the droplet to move [8] [9] [10] [11] [12] [13] [14].

II. FAULT MODELING AND DEFECT ANALYSIS

Faults in Digital Microfluidic Biochips can be either Catastrophic or Parametric. Catastrophic faults causes complete malfunctioning of the system where as Parametric faults degrade the system performance. Catastrophic faults may occur mainly due to physical defects [8] [10] .Few instances of physical defects which may misdirect the system from behaving in a normal mode are stated in [8][10][11][12][13][14].

A. Overweening actuation voltage, applied to an electrode may create a short between the droplet and the electrode. As a result, the droplet undergoes electrolysis which prevents its further transportation.

B. Electrode actuation for longer duration may cause charge concentration permanently which results unintentional droplet movement or the droplet gets stuck on the electrode surface.

C. Excessive mechanical force applied to a chip may lead to the misalignment of the parallel glass plates. As a result droplet transportation occurs without the activation voltage. Figure 2. Shows a probable instance of this phenomenon.

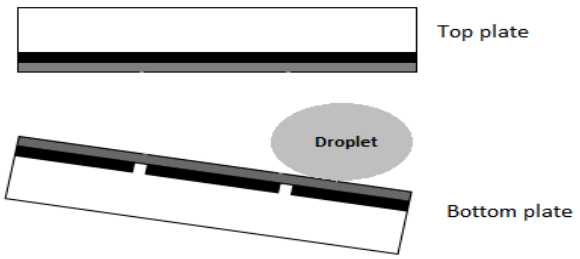

Figure 2. Misalignment of glass plates.

D. If the coating of dielectric insulator is not properly done and somehow it gets fragmented then the droplet splits. Smooth transportation is hampered.

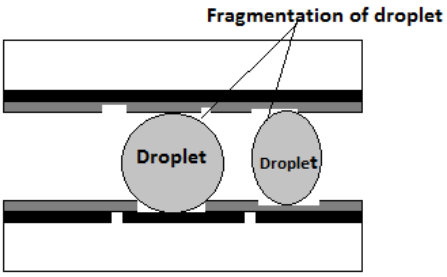

Figure 3. Coating Failure.

E. Due to abnormally deposited metal layer or contaminated particles and variation during the etching process of fabrication a metal connection is established between the two adjacent electrodes causing an electrode short. As an effect the droplet resides on the middle of the two adjacent electrodes and its further movement is impeded as depicted in figure 4.In some situation grounding failure or collapsed wire connection to control source may be experienced as shown in figure 5 and figure 6.

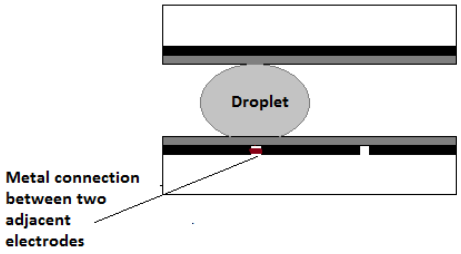

Figure 4. Deposited metal layer or contaminated particle.

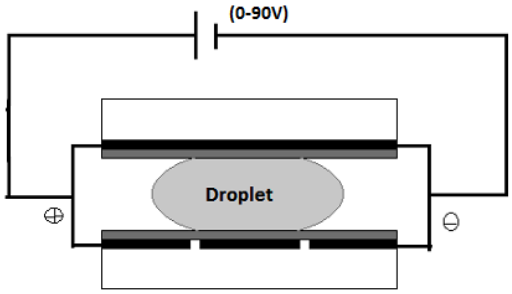

Figure 5.Wire Connection is not grounded.

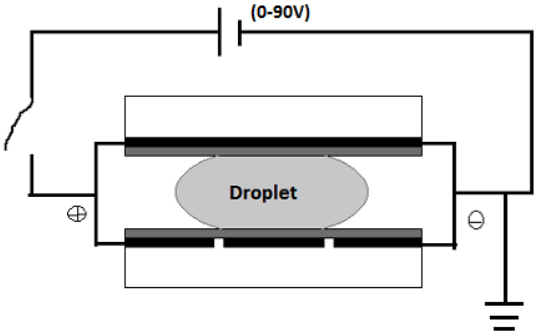

Figure 6. Wire connection is broken.

F. Circumstances may arise that after removal of the biochemical sample fluid a certain amount of residue remains on the electrode surface. This residue converges with the biochemical sample taken for another assay operation which results an outcome beyond the set of possible anticipated outcomes.

Common parametric error may originate due to deflection in electrode length, height between parallel plates, variation in dielectric insulator thickness, changes in environmental temperature, unpredicted biochemical reaction etc [8].

III. CONCLUSIONS:

In this paper, we have observed possible defect types relating to fault models which may occur in a Lab-on-a-chip. Bypassing these faulty situations during assay operation is an important area of concern as it is essential for ultra sensitive detection in emerging healthcare market.

REFERENCES:

[1] V. Srinvasan, V. K. Pamula, M. G. Pollack, and R. B. Fair, “Clinical diagnostics on human whole blood, plasma, serum, urine, saliva, sweat, and tears on a digital microfluidic platform,” in *Proc. MicroTAS*, 2003, pp. 1287–1290.

[2] A. Guiseppi-Elie, S. Brahim, G. Slaughter, and K. R. Ward, “Design of a subcutaneous implantable biochip for monitoring of glucose and lactate,” *IEEE Sensors J.*, vol. 5, pp. 345–355, 2005.

[3] R. B. Fair, A. Khlystov, T. D. Tailor, V. Ivanov, R. D. Evans, P. B. Griffin, V. Srinivasan, V. K. Pamula, M. G. Pollack, and J. Zhou, “Chemical and biological applications of digital-microfluidic devices,” *IEEE Design & Test of Comput.*, vol. 24, pp. 10–24, 2007.

[4] M. G. Pollack, R. B. Fair, and A. D. Shenderov, “Electrowetting-based actuation of liquid droplets for microfluidic applications,” *Appl. Phys. Lett.*, vol. 77, pp. 1725–1726, 2000.

[5] J. Berthier, *Microdrops and Digital Microfluidics: Processing, Development,and Applications (Micro & Nano Technologies)*. : William Andrew, 2007.

[6] H. Ren, R. B. Fair, and M. G. Pollack, “Automated on-chip droplet dispensing with volume control by electro-wetting actuation and capacitance metering,” *Sensors and Actuators B-Chemical*, vol. 98, pp. 319–327, 2004.

[7] V. Srinivasan, V. K. Pamula, and R. B. Fair, “Droplet-based microfluidic lab-on-a-chip for glucose detection,” *Anal. Chim. Acta*, vol. 507, pp. 145–150, 2004.

[8] K. Chakrabarty, “Design Automation and Test Solutions for Digital Microfluidic Biochips”, IEEE Transaction on Circuits and Systems, Vol. 57, 2010.

[9] F. Su , K. Chakrabarty and Richard B. Fair, "Microfluidics-Based Biochips: Technology Issues, Implementation Platforms and Design-Automation Challenges, ”IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, Vol. 25, 2006.

[10] F. Su, S. Ozev, and K. Chakrabarty, “Testing of droplet-based microelectrofluidic systems,” in *Proc. IEEE Int. Test Conf.*, 2003, pp. 1192–1200.

[11] K. Chakrabarty, "Towards fault-tolerant digital microfluidic lab-on-chip: defects, fault modeling, testing, and reconfiguration", *Proc. IEEE International Conference on Biomedical Circuits and Systems* (invited paper), pp. 329-332, 2008.

[12] T. Xu and K. Chakrabarty, "Parallel scan-like testing and fault diagnosis techniques for digital microfluidic biochips", *Proc. IEEE European Test Symposium*, pp. 63-68, 2007.

[13] T. Xu and K. Chakrabarty, "Fault modeling and functional test methods for digital microfluidic biochips", *IEEE Transactions for Biomedical Circuits and Systems*, vol. 3, pp. 241-253, August 2009.

[14] T. Xu and K. Chakrabarty, "Functional testing of digital microfluidic biochips", *Proc. IEEE International Test Conference*, 2007.