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The Future of Laboratory Work Lab-On-Chip Device: An Overview

***Bayan Alarishi*[1] *and Christian Bach*[2]**

[1]Department of Biomedical Engineering,
University of Bridgeport
Bridgeport, CT, USA

[2]Department of Technology Management,
University of Bridgeport
Bridgeport, CT, USA

ABSTRACT: The technology of carrying out laboratory operations using scaled down Lab-On-a-Chip (LOC) device is really appealing. The whole laboratory being reduced into a small chip. The time taken to analyze a reaction can be reduced through volume reduction of the reagents used; the distinctive behavior of liquids at the nano scale allows increased control of molecular interactions and concentrations. The cost of reagents and the chemical waste amounts can also be very much reduced through the use of this technology. The LOCs also provide for the analysis of samples at the point of need instead of a centralized laboratory. The main aim of this research is to review about a newly device known as the Lab-on-chip device. This research was carried out to study and well understand all the aspects of this device, including its history, advantages, disadvantages, where it is applied and the challenges. It is evident that with the development of Lab on Chip devices, everything becomes better and easier. Even though the technology is at its initial stages of development, it proves to be very efficient. This clearly shows how much more will be achieved with continual development in this field.

KEYWORDS: Lab On Chip; LOC; Microfluidics; Laboratory; Technology.

PURPOSE

The main aim of this research is to review about a newly device known as the Lab-on-chip device. This research was carried out to study and well understand all the aspects of this device, including its history, advantages, disadvantages, where it is applied and the challenges.

METHODOLOGY

This research was carried out on books as well as articles so as to gather the information that will help in the discussion of relevant matters and also to obtain the required information in the study research.

FINDINGS

The major findings were the information on the history of Lab on chip devices and how they were improved with time. Also, the advantages of the devices e.g. efficiency and cost effectiveness and why it is of real importance. The disadvantages were also found and some of the areas where this technology has been applied.

Corresponding Author: Bayan Alarishi (Balarish@my.bridgeport.edu)

RESEARCH LIMITATIONS

It was not possible to observe and learn how to operate and work with the devices themselves. Most of the evidence given is based on the available literature and articles on the device.

PRACTICAL IMPLICATIONS

The practical implication in this study is how the devices can be improved in a way that they become cost effective in manufacture and increasing its availability to medical centers and research institutions.

ORIGINALITY

The originality is brought about by the need of the medical services to be improved e.g. increasing the ability to detect protein signatures of a disease or infection on blood samples and body fluids before the symptoms arise, for early intervention.

1 INTRODUCTION

A lab on chip (LOC) device is a device which can be able to integrate miniaturized laboratory functions on a single microprocessor chip using minute fluid volumes in quantities of up to less than picolitres and nanolitres[1]. The LOCs are categorized as a subclass of micro-electro mechanical systems[2] and are able to combine miniaturized sensing system, a suit of fabrication techniques used by the semiconductor industries like material deposition, surface patterning, electrical property modification and material removal, and control concepts of fluid flow from microfluidics[3-5].

1.1 HISTORY

The Lab on Chip technology was first brought forth by Michael Widner at Ciba-Geigy (now Novartis) in the 1980s and it was described theoretically in 1990 [6]. An extensive work was published in 1992 on the same[7]. Additional development was carried out as a new field of discovery—microfluidics—was established in the 1990s[8]. Microfluidics is an interdisciplinary field that deals with of extremely small, minute volumes of fluids, their behavior and control, and the designing of the systems which use these minute volumes [9]. Besides being commonly found in ink-jet printers, major microfluidics applications have been encountered in biotechnology research[10]. As a matter of fact, some experts regard this field as a biotechnology branch[11]. In some ways, Microfluidics counterparts nanotechnology where the fluid behavior at the micro scale can vary substantially from the fluid behavior at the macro scale[12]. Phenomena like surface tension, fluid resistance and heat conduction start becoming important, and matters like evaporation, threat posed by air bubble presence and absence of turbulent flow, are very critical to system design [13].

Initially, much of the stimulus for continued development of LOCs originated from the Human Genome Project, a project coordinated by DOE and National Institutes of Health (NIH) for 13 years, which began in 1990 and ended in 2003[14]. As at now, much of the push for the continued development of LOCs originates from the craving for point-of-care medical diagnostics, be it on a space craft, in the doctor’s office, or other remote location. Moreover, development research is compelled by the growing need for miniaturization, to reduce the expenses and the environmental research impacts (green analytical chemistry)[15, 16]. The LOC technology, already significant, is still viewed to be in its initial stages. Research in the LOC technology still continues in many fields[17].

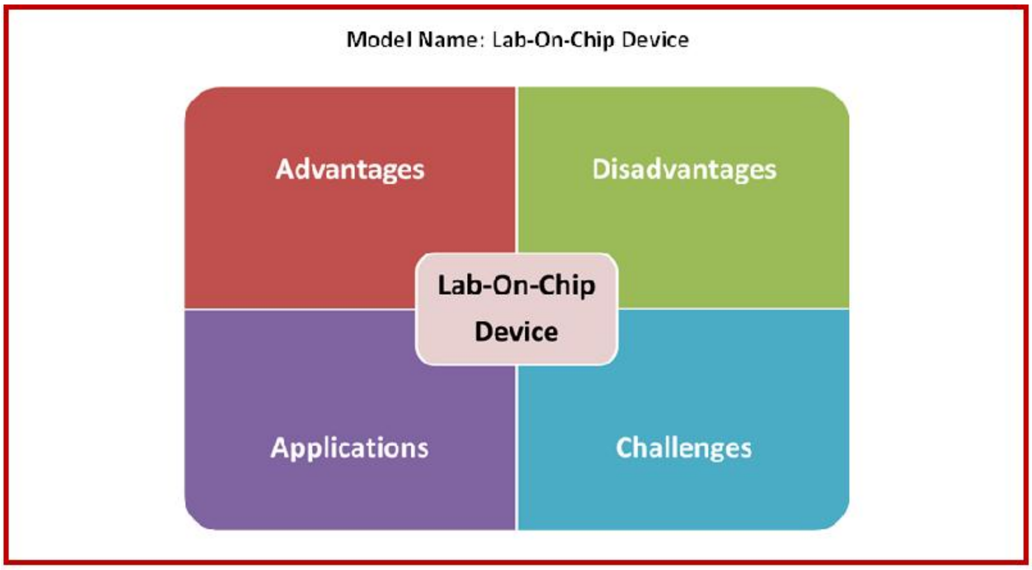

Fig. 1. The Lab-On-Chip Device and its four aspects

1.2 ADVANTAGES

They enable fast analysis of fluid samples. This is simply because, the diffusion distances are short, there is very fast heating because of the small volumes, the small volumes also increase the surface area to volume ratio. All these factors fasten the analysis process of the fluid samples[18]. The lab on chips also lead to cost effectiveness in the purchase of reagents. This is because the LOCs have miniaturized laboratory functions to usage of small amounts of fluids in the order of picolitres and nanolitres[19]. This reduces the amounts of reagents required for the laboratory operations. It is also easy to collect required samples since they are not required in large quantities. Multiplexing can also be done with this device. Very many analyses can be analyzed simultaneously and still obtain very accurate results. Because of this, a series of tests can be done on the same device at the same time[20].The device is also highly sensitive and can detect toxins and impurities.[21].The device is portable and very easy to use since it is automated and with a simple touch screen interface.

1.3 DISADVANTAGES

LOC devices are very effective in areas that are developed technologically and industrially. The developing and the under developed areas may not benefit much from this technology. The other disadvantage is that this technology is not fully developed. It is still in its initial development stages and may not be effective in every aspect or diverse in various fields.

1.4 APPLICATIONS

The LOC devices are used in the health care for diagnostics. They detect protein signatures of infections and diseases in body fluids. Through this, early interventions can be done and prevent diseases before the symptoms start showing up[22]. EPA is funding an environmental LOC project with the objectives of creating a novel, nanomaterial-based submersible microfluidic device, for exploiting distinctive properties of carbon nanotubes and metal nanoparticles for continuously, rapidly, and economically monitoring various categories of priority pollutants [23]. This project is also seeking to understand the relationship between the chemical and physical properties of the nanomaterials and the behavior observed[24, 25]. The addressed challenge is helping to transform the LOC model to a good and effective environmental monitoring system. It involves examination of nanotube and nanoparticle materials for the detection processes and separation respectively[26].

NIH is supporting the development of point detection disposable LOC which has built-in mercury precursor electrodes for detecting heavy metals[27, 28]. In the fabrication materials field, investigation of LOCs that are constructed using soft lithography techniques, and not silicon microchip fabrication processes, is done [29]. Soft lithography is a substitute to silicon-based micromachining which uses replica molding of nontraditional elastomeric materials in fabrication of stamps and microfluidic channels. As an addition to the soft lithography approach, multilayer soft lithography, which are used to fabricate multiple layers from soft materials, is used to come up with active microfluidic systems containing switching valves, on/off valves, and pumps entirely out of elastomer[30]. The tenderness of these materials makes the device areas be reduced by over two orders of magnitude in comparison with silicon-based devices.[31]

The LOC technology is also applied in the field of medicine, in the rapid, automated, point of care system (RapiDx) which was developed by Sandia National Laboratories. The Sandia National Laboratories was trying to find possibilities of developing point-of-care analyses of health and disease status that is rapid. The LOC devices were used to detect protein signatures of diseases, exposure to toxic substances or infections in body fluids like blood and saliva. This would help in early intervention before the symptoms start appearing. The RapiDx was a miniaturized device which used nanoliters of samples to measure protein signatures. Using this technology, it was easy to take only a drop of blood or saliva at the point of care for analysis and drawing tubes of blood were no longer needed [9][14].

1.5 Challenges

The different climates of different parts of the world are a challenge to this technology and therefore, the chips should be designed in a way that the reagents are kept safe so as to remain effective for a long period of time. Other parts of the world are not advanced in terms of the health care and this may bring in a reason to improve the ease of use so that it may be beneficial also to people living in such areas. Materials of use and the techniques of coming up with them and maintenance should be considered so that they don't lead to high prices in obtaining and maintaining the chips so as to make them accessible.

2 Conclusion

It is evident that with the development of Lab on Chip devices, everything becomes better and easier. Even though the technology is at its initial stages of development, it proves to be very efficient. This clearly shows how much more will be achieved with continual development in this field. Through LOCs, it is easier to carry out medical tests easier and faster and prevent some diseases before they become serious. Laboratory functions involving solutions are made easier, efficient and fast to carry out at minimal reagent costs and still obtain very accurate results within a very short period of time[32]. With much development in the LOC technology, the field of science and technology will experience a great revolution brought about by the LOC devices. A lot of researches will be easy and efficient, and experiments carried out on small chips instead of labs. It will cost less to venture into research in the field of science and technology. With experiments being able to be carried out on small chips rather than big labs, and in quantities of less than a picoliter, it's easy and less costly. With their accuracy too, the LOCs will improve the research in science to obtaining accurate results and increase precision.

From this research, it was realized that the LOC devices are still in the development process and not much has been exploited in the technology. This therefore implies that with much development and improvements, the world will be made a better place by this technology.

Authors' Profiles

Bayan Alarishi

Second semester graduate student at the University of Bridgeport, Biomedical engineering Major, Engineering school. Took a B.S. degree in Biotechnology from the University of New Haven, class of 2013.

Christian Bach

Professor Christian Bach serves as an assistant professor of Technology Management and Biomedical Engineering. He holds academic honor as: PHD in information science and executive MBA at Albany/SUNY, as well as an MBA from University at Albany/SUNY, and a MS in Biochemistry from University of Freiburg.

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