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Microfluidic Silicon-Based Analytical Devices for Glucose Analysis

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Abstract **-** This review's objective is to give a thorough overview of the Silicon Micro fluid devices. silicon was chosen as the experimental material. Silicon is stable at high temperatures, has a large surface area, and is chemically resistant. The fabrication and detection techniques used for these applications are described, and the performance of the Silicon micro fluid devices is evaluated critically with regard to their precision and accuracy. A critical examination of these devices' potential for use in everyday life is also conducted. In addition, the outcomes of the spectroscopy analysis were also contrasted with those obtained from ImageJ processing and Matlab Image processing.

Keywords**:** Micro fluid Silicon based Analytical devices; Glucose Assay, Ultra Short Laser Pulsar, Matlab image processing

1. Introduction

The development of novel quick test kits has been the subject of numerous studies, including those on various paper-based microfluidic devices. Paper-based analytical devices (μPADs) with microfluidic technology are acknowledged as a potentially formidable analytical platform. However, there are various drawbacks to using paper as a substrate for analytical applications. Paper-based devices cannot be used with corrosive substances or left in difficult environments to be later picked up to see the results. For instance, they cannot be submerged in liquids for an extended period of time and then picked up. The use of silicon as an analytical substrate has a number of benefits, including being widely available and affordable, easily pattern able into discrete zones using laser cutting technologies, lightweight and portable, disposable, and biodegradable. It is possible to submerge silicon-based microfluidic devices in liquids, pick them up later, and analyses the findings. This article outlines a system that quantifies assays conducted in silicon-based micro fluidic devices and suggests an information-focused component of the system that sends the assay findings to experts off-site for review. These tools are capable of quantifying the colorimetric outcomes of the microfluidic system and transmitting the digitized readout off-site. Earlier studies have worked on Inkjet printed microfluidic paper-based analytical device (μPAD) for glucose colorimetric detection in artificial urine. In order to create microfluidic paper-based analytical devices (PADs) with increased analytical performance for colorimetric measurements, a unique inkjet printing technique is presented in this work **[1]**. Camera Phones and Paper-Based Microfluidic Devices for Real-Time, Off-Site Diagnosis have been researched on **[2]**. The system makes use of paper-based microfluidic devices to run multiple assays at once, camera phones or portable scanners to digitize the intensity of color associated with each colorimetric assay, and established communications infrastructure to transfer the digital information from the assay site to an off-site laboratory for analysis by a trained medical professional. Developments of microfluidic paper-based analytical devices (μ PADs) for water analysis have been studied **[3]**. A thorough rundown of the(μPADs) that have been created for figuring out critical water quality factors like nutrients, metals, and organic pollutants in a variety of waterways are given. Microfluidic Paper-based Analytical Devices (μPADs) For Analysis of Lead has been investigated **[4]**. In this study, two designs of microfluidic paper-based analytical devices (PADs) are compared. These devices use wax printing to create hydrophobic zones on chromatographic paper, and they are used to detect lead in waste samples. It was discovered that changing the power and frequency of the laser processing changed the bandgap as well as the structural properties of the silicon semiconductor **[5], [6]**. Raising the frequency and power resulted in the production of silicon nanostructures and variations in the characteristics of the produced nanostructures. The effect of various control parameters on porous silicon surface topology, including theoretical limitations for minimum diameter of nanofibers for sensing applications, is discussed, as is a modern and inexpensive approach to laser ablation for fabrication of porous and

fibrous thin-film, primarily for silicon **[7]**. Nano fibrous thin film with tuned optical properties induced by picosecond plasma ionization Examine the optical characteristics of nano fibrous structures generated by plasma ionization at a variety of pulse counts controlled by laser frequency and scanning speed **[8].**To build hydrophobic channels, five lane μ PADs were created and printed on chromatography paper with wax ink **[9]**. Two distinct microfluidic paper-based analytical devices (PADs) were designed to quantify nitrite and nitrate in human saliva samples to aid in the identification of certain diseases and health issues linked with these ions **[10]**. Using the newly established manufacturing technology, two types of miniaturized μPADs are produced: (a) compact PAD for multiplexed testing and (b) lateral flow assay (LFA)-type PAD for semi-quantitative test reading **[11].** the color development on the strips with a smartphone reader, yielding binary qualitative results were monitored **[12]**. The performance parameters of the PAD approach were thoroughly assessed in terms of accuracy, detection capability, and ruggedness. Lastly, the PAD properties were compared to well-established procedures, specifically an in-house BChE microplate assay and spectrometric with tandem mass spectrometry. A new nanocomposite catalyst with enzyme mimetic activity was developed **[13]**, similar to peroxidase, for the colorimetric glucose detection using glucose oxidase. The developed method has been successfully applied to the determination of glucose in sports and energy beverages.BLGF-capped gold nanoclusters (Au NCs) with red, green, and blue emission levels were created using a pH-dependent plan **[14]**.

2. Methods

Ultra-Short Laser Pulsar for In-situ Nanostructure Generation (ULPING):

By controlling the laser parameters and pattern, researchers can create highly customized samples with specific shapes and sizes. In this research, it's important to vary these parameters systematically to determine which combination yields the best sample for your specific experiment. By changing laser parameters such as frequency, power, scan speed, pitch, and number of loops, you can tailor the properties of the resulting nanostructures to meet specific experimental requirements.

Silicon:

The experiment was carried out on silicon n-type (Si-100) wafers with a thickness of 20 micro meters. The nanostructures were made by irradiating silicon with a pulsed fiber laser (IPG Model: YLPP-1-150V-30)

Fabrication of Silicon Samples:

To select the ideal sample, I experimented with numerous samples using various laser parameters, including frequency, power, pitch, the number of loops, and scan speed. In order to get the best laser, cut sample later on in the experimental portion, one or more of the factors listed were altered for each sample and reported. The amount of fiber produced on silicon during this manufacturing stage was shown to be inversely proportional to the scan speed, meaning that the slower the scan speed, the more fiber is produced on the sample. The output power of the laser employed in the experiment ranged from 0 to 30 W. To explore the results and effects of power on the samples, numerous samples were created using various laser powers. If the power was too high and very close to the device's maximum power, it would penetrate the silicon sample and create a hole inside of it. On the other hand, it was discovered that more fibers are created as the power is increased. 20 W was determined to be the ideal power by using a trial-and-error methodology and creating samples with various power outputs. The number of loops the laser would cut in a particular location is the other element influencing how much fiber is produced on silicon. The number of times the laser device repeats cutting a particular designated area depends on how many loops it passes through. For instance, two loops decide that the laser will pass across the cut region once more once the initial cut is complete.

Preparation of Glucose Assay:

The Glucose Oxidase/Peroxidase Reagent was dissolved in 39.2 mL of deionized water. The o-Dianisidine Reagent was reconstituted with 1.0 mL of deionized water and was mixed in order to solve completely. For the

Assay reagent. 0.8 mL of the o-Dianisidine Reagent was added to the amber bottle containing the 39.2 mL of Glucose Oxidase/Peroxidase Reagent. Then the bottle was inverted several time allowing them to get mixed. During these stages the light exposure to the solution was kept minimal. this solution was keep in the fridge with the temperatures between 2–8 degrees Celsius and finally 6 M solution of sulfuric acid was prepared. All the glucose assays used in this experiment were purchased from Sigma Aldrich.

Results and Discussion:

the experiment was started on the silicon samples obtained from the laser-cut device. The results of the test indicated that the samples with the greatest amount of fiber were the best silicon samples. As a result, each sample was laser-cut into two loops with the following settings: 20 Watts of power, 1200 KHz of frequency, 0.025 mm pitch, and 10 mm/s of scan speed. The samples generated in this way displayed the most pronounced color change in the silicon samples.

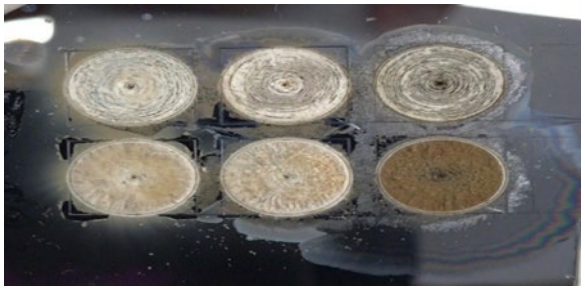

Figure 1. Amount of fiber produced by 20 Watts of power, 1200 KHz of frequency, 0.025 mm pitch, and 10 mm/s of scan speed and 2 loops.

Detection Methods:

Image processing: the images were processed by imageJ, spectroscopy and Matlab. For this purpose, the sample below was made and all the samples were activated except the top left and bottom left that were used as the control sample. Then the glucose is added to each sample based on the concentration values mentioned in table 1. After letting the samples to dry for 30 minutes in the temperature of 37 degrees Celsius, an Image was taken using mobile phone camera and then analyzed using ImageJ software. As discussed earlier the suitable sample for this experiment was recognized as the 2 loop laser cut with the following characteristics: P=20w, f=1200KHZ, S=10 mm/s and Pitch=0.025 mm

Figure 2. Laser cut Silicon samples prepared. Top row samples were 2 loops laser cut and bottom row were 1 loop laser cut. Both were used for the experiment but the 2 loops (top row) yield better results.

The results gathered from spectroscopy for 1-looploop sample and 2-loop sample are provided in figure 3.

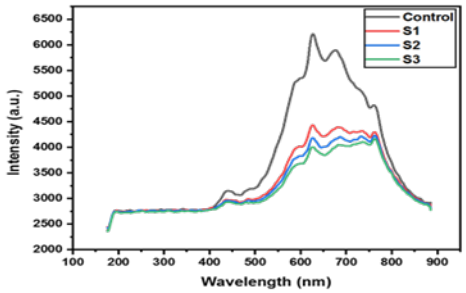

Figure 3a.

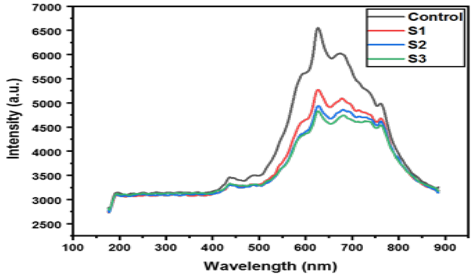

Figure 3b.

Figure 3. figure 3a illustrates the results obtained by spectroscopy of sample containing 1 loop. figure 3b illustrates the results obtained by spectroscopy of sample containing 2 loops

3. Results:

A regression line is a line that depicts the relationship between two variables, where one variable is independent and the other is dependent. The closer the value of R (correlation coefficient) gets to 1, the better the relationship between the two variables is the Regression values and equation of lines obtained from Image J and spectroscopy for both 1 loop and 2 loops samples are summarized in table 1:

Table 1. R^2 and equation of Line analysis of different approaches

Applying Method	Normalized Data 0-1		Normalized Data 0-100	
	R^2	Equation of Line	R^2	Equation of Line
ImageJ 1L	0.938	Y=2.14x-1.52	0.93	Y=1.51x-0.57
ImageJ 2L	0.966	Y=2.11x-1.32	0.96	Y=1.49x-0.43
Spectroscopy 1L	0.92	Y=-2.1x+1.28	0.92	Y=-1.49x+1.42
Spectroscopy 1L	0.95	Y=-2.1x+1.31	0.95	Y=-1.49x+1.42
Matlab 1L	0.95	Y=-2.1x+1.3	0.95	Y=-1.49x+1.4
Matlab 2L	0.96	Y=-2.11x+1.3	0.96	Y=-1.5x+1.4

The equations in the table demonstrate how well they consistently confirm the high caliber of the silicon samples and the appropriate method used in this study. Since the R square value is so close to one, the relationship is perfectly linear.

4. Conclusion

An integrated method for identifying and diagnosing diseases is made possible by the integration of silicon-based micro fluid devices with a portable detector. Based on the critical assessment of the silicon microfluidic devices developed so far for glucose analysis, it can be concluded that significant progress has been made in adapting existing batch and flow analysis methods to silicon microfluidic devices. These devices have shown promise for the detection of glucose in various applications, including medical diagnostics and food analysis. Furthermore, the use of silicon microfluidic devices for glucose analysis has highlighted the potential for the development of similar devices for the detection of other inorganic and organic analytes of environmental and health concern.

Acknowledgments

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