ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 8, Issue 1 , January 2021

The behaviour of IV characteristics of porous silicon upon different sugars of various concentrations

Ayah A. Hafez*, Gamal M. Youssef,Seiya Tsujimura ,Magdy M.Mohammed ,I.H. Ibrahim

MSc student, Department of physics, Ain Shams university,Cairo, Egypt
Professor, department of physics, Ain shams university,Cairo, Egypt
Assoc. Professor, Bioelectrochemistry , Tsukuba university, Ibaraki ken, Japan
Professor, Department of Biochemistry, Ain Shams university, Egypt
Professor, Department of physics, Ain Shams university, Egypt

ABSTRACT: Porous silicon sensor was fabricated (Ag/Ps/Si/Ag) from p-type silicon; Electrochemical etching process was performed for 15 min at 50 mA current density, the morphological structure was obtained by scanning electron microscope SEM and gravimetric method for monitoring the porosity and porous layer thickness, Ag 200 A^o layer were deposited by sputtering on both sides, then different concentrations (0.1, 1, 10, 100 mg/mL) of each sugar (Fructose, glucose, maltose, galactose, sucrose, lactose) and amino acid were exposed to the surface, and IV characteristics was obtained.

I. INTRODUCTION

Silicon is promising candidate in sensors and medical application because of being abundant non-toxic and biocompatible material and also its carrier mobility [1]The surface area of silicon can be extremely enlarged by electrochemical etching and formation of porous layer , Porous silicon seems to be an promising choice due to its fast and easy fabrication by electrochemical etching ,large surface area ,various accessible pore sizes and morphologies and controllable surface modification [2][3]

According to this interesting characteristics;Many recent researches hadchosen porous silicon as transducer for bio-molecules sensing such as glucose, urea , DNA ,Penicillin and triglycerides [4]

II. MATERIAL & METHOD

A. Porous silicon preparation:

p-type single crystalline boron-doped 2 × 2 cm2,<100> crystal orientation, resistance 0.1 to 100 Ω cm, thickness 525µm [*As one company*], PS layers were prepared using galvanostatic electrochemical etching process on the polished surface by*anatech* programmable power supply, Current density 50 mA/cm2 and time of etching 15 min, the O-ring etching cell body is made of Teflon as an inert material, the electrochemical soln. is composed of HF 40%: ethanol 99.9% , 1:1 , where aluminum back represents anode and platinum electrode represents cathode as shown in Fig (1) .

The samples were cleaned with Ethanol, then subjected to the galvanostatic etching process, then rinsed with acetone to depart its residue followed by ethanol to scrub off acetone residue.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 8, Issue 1 , January 2021

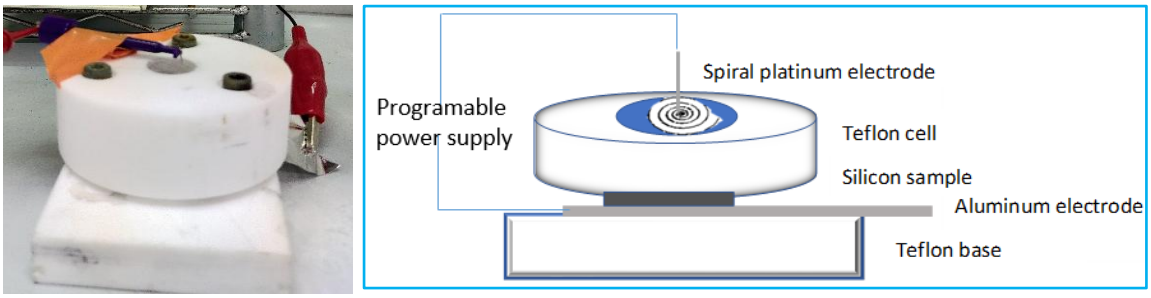

Fig.1 electrochemical etching setup

B. MORPHOLOGICAL STUDY

Porosity and porous layer thickness were calculated using the gravimetric method, the Sample was prepared the same way, The weight was calculated after and before etching by analytical balance [*ASP114 As one, accuracy 0.0001 g*], Alkaline solution was prepared to dissolve the porous layer, 10 ml 1 M of aqueous KOH: 2 ml of ethanol; ethanol is added to cut the surface tension and improve the dissolution efficiency, samples were immersed 10 min. in the aqueous KOH soln. then rinsed with ethanol then the final mass was obtained.

[*All chemicals were obtained from [Weko Pure Chemical Industries], KOH is solid dissolved in distilled water*]

C. ELECTROCHEMICAL ANALYZER

After the etching process, Ag thin layer 200 A was deposited using the Sputtering technique, the lower surface was totally covered, and a circular patch cover 15% of the upper porous layer area.
Different concentration (0.1, 1, 10 , 100 mg/mL) were prepared from different sugars with distilled water ; Xylose , monosaccharides (Glucose , Galactose Fructose) and oligosaccharides (Sucrose , Lactose ,Maltose) .
I-V characteristics was carried out for all concentrations by electrochemical analyzer ALS/CH industry model 611A linear sweep mode

III. RESULTS

A. POROSITY

Porosity is the ratio of the volume of the pores to the total apparent volume of the film, it can be represented b the following equation

$$P = \frac{V_{pores}}{V_{total}} \text{Eq. (1)}$$

The volume can be substituted by V= mass X density, so the porosity can be written in the mean of masses as following

$$P = \frac{m_1 - m_2}{m_1 - m_3} \text{Eq. (2)}$$

Where; $\mathbf{m_1}$ mass before etching, $\mathbf{m_2}$ mass after etching , $\mathbf{m_3}$ mass after chemical dissolution of the porous layer , fig 2 demonstrates the dissolution process.
The porosity of the sample was calculated = 86%

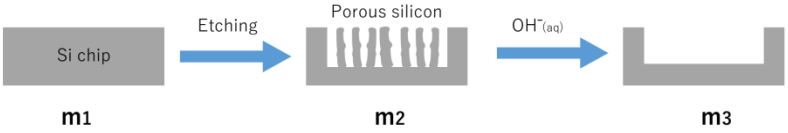

Fig 2. Schematic diagram showing the silicon structure in every step-in porosity calculation

Also, the porous layer thickness can be calculated using the following equation

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 8, Issue 1 , January 2021

$$W = \frac{m_1 - m_3}{A\,\delta_{Si}}$$ Eq. (3)

Where, W Thickness of the porous layer, **A** The wafer area exposed to HF during the electrochemical etch. = 1.77 cm^2 ,δ_{Si}The density of elemental silicon 2.33 $g ml^{-1}$.
The thickness is found to be 3.1 mm .
The formation of the porous layer can be observed from the SEM images, fig 3 represents the area exposed to the etching process, cracking of the surface is clear, further magnification shows the formation of pores in the grooves, the average diameter of pores is 1.5 mm

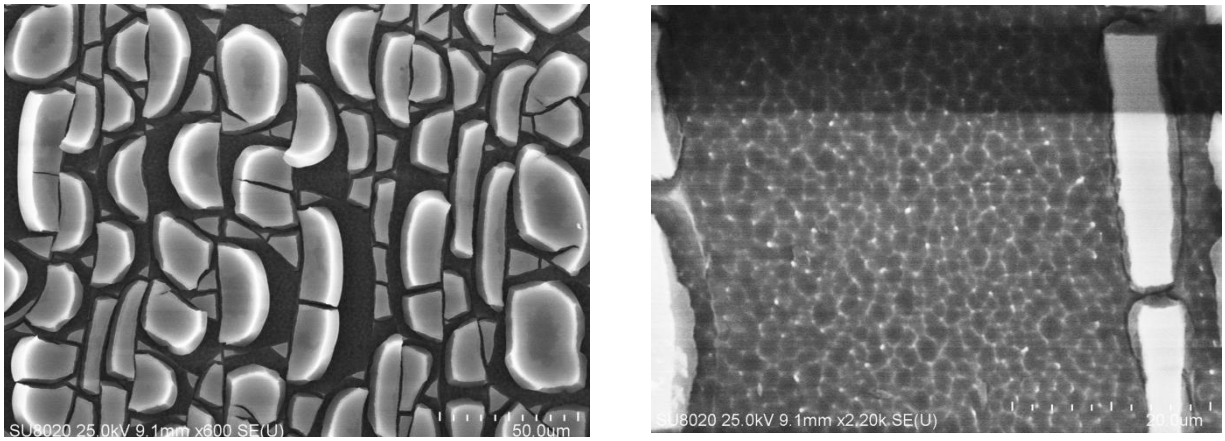

Fig.3 SEM images of silicon surface after etching represents the porous structure
a) 50 mm scale b) 20 mm

B. I-V characteristics

The I-V characteristics shows rectifying behaviour, the curve inclination is affected by the concentration as illustrated in Fig. 4 ,5 , the resistance of the samples is directly proportional to concentration mainly . the mean of the current data has been calculated in Fig.6

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 8, Issue 1 , January 2021

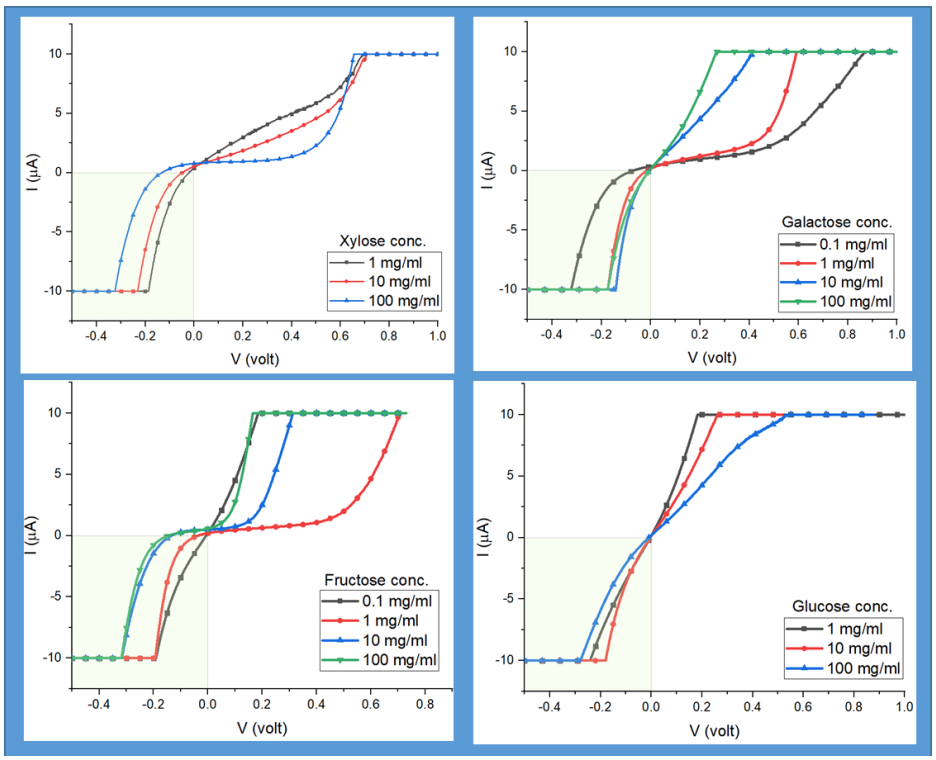

Fig. 4 I-V characteristics of monosaccharides Xylose, Fructose, Galactose , Glucose

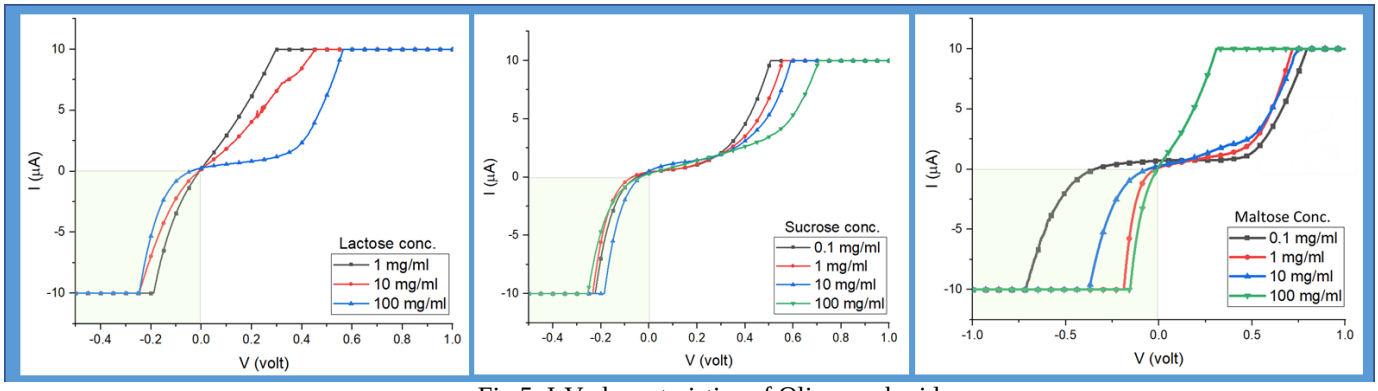

Fig.5 I-V characteristics of Oligosaccharides

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 8, Issue 1 , January 2021

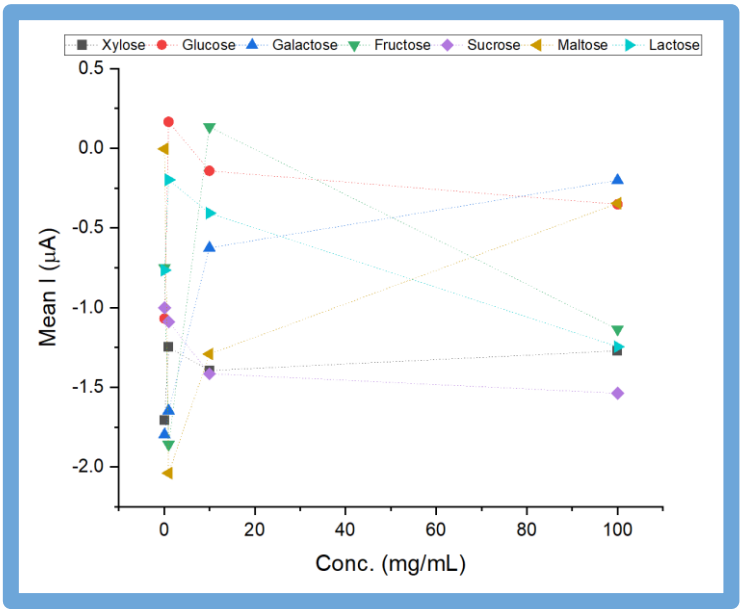

Fig. 6 mean values of current of I-V of sugars vs. the concentrations

IV. CONCLUSION

The SEM images show clear pores formation at etching parameters 15 min. 50 mA/cm^2 ,
the I-V characteristics show a link between different sugars concentration, the mean of each data curve shows similar behavior of each sugar type, the results show a promising possibility of using porous silicon as a primitive sensor of saccharides.

V. REFERNCES

1) Libertino, S., Aiello, V., Scandurra, A., Renis, M., & Sinatra, F..” Immobilization of the enzyme glucose oxidase on both bulk and porous SiO2 surfaces”.*Sensors*, 8, 5637-5648(2008)
2) Sailor, M. J. “Porous Silicon in Practice: Preparation, Characterization, and Applications.”, chapter 2 ,Wiley-VCH Verlag & Co. KGaA, Boschstr. 12, 69469 Weinheim, Germany (2012)
3) Gore, G..”On hydrofluoric acid.” J. *Chem.* Soc., 22(0), 368–406 , (1869)
4) Salis, A., Setzu, S., Monduzzi, M., Mula, G., Chimiche, S., Csgi, C., Fisica, D., & Cagliari, U. .” Biosensors”online book ,ISBN: 978-953-307-328-6”chapter 17 : Porous Silicon-based Electrochemical Biosensors”. (2010)
5) Gallach, D., Martín-Palma, R. J., Recio-Sánchez, G., Torres-Costa, V., López-García, J., &Manso, M. “Towards the Development of Electrical Biosensors Based on nanostructured Porous Silicon”. *Materials*, 3(2), 755–763. (2010)
6) Hovhannisyan, A. S., Aroutiounian, V. M., Martirosyan, K. S., & Galstyan, V. E..” Investigation of Glucose Sensitivity of Porous Silicon”,*Materials Science*, 38–42. (2008)
7) Kern, W. “Overview and Evolution of Semiconductor Wafer Contamination and Cleaning Technology. In Handbook of Semiconductor Wafer Cleaning Technology” ed. W. Kern, pp 3-57. Park Ridge, *New Jersey: Noyes Publishing* (1993)
8) Lai, C., Li, X., Liu, C., Guo, X., Xiang, Z., Xie, B., & Zou, L. “Improvement in gravimetric measurement for determining the porosity and thickness of porous silicon using an optimized solution”. *Materials Science in Semiconductor Processing*, 26, 501–505.(2014)
9) Lehmann, V. “Electrochemistry of Silicon: Instrumentation, Science, Materials and Applications” *Wiley-VCH Verlag* ,ISBNs: 3-527-29321-3” (Vol. 3). (2002)
10) Kordás, K., Remes, J., Beke, S., Hu, T., &Leppävuori, S.. “Manufacturing of porous silicon; porosity and thickness dependence on electrolyte composition”. *Applied Surface Science*, 178(1–4), 190–193. (2001)
11) Balaguer, M., Matveeva, E. “Quenching of porous silicon photoluminescence by molecular oxygen and dependence of this phenomenon on storing media and method of preparation of pSi photosensitizer”. *J Nanopart Res* 12, 2907–2917 .((201)