



## Effect of wafer resistivity and light intensity on the topography of porous silicon surfaces produced by photo chemical method

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### 1. Introduction

The porous silicon wafers may be used to produce diodes and detectors, when solar cells doped with materials that increase their efficiency or even increasing the surface area of the solar cell exposed to light, all of this would encourage the entry into such research's, it is worth mentioning that the size of the mitral approached the dimensions of atomic so it based to the laws of quantum mechanics instead of the laws of classical physics [1,2].

The adoption of the behavior of the material on its size enables us to control the engineering of its properties. There are two ways to manufacture a nanoscale size of the material, one from top to bottom and the other from the bottom up. [4, 3] For the growth and production of porous surfaces with nanoscale dimensions such as the electro-chemical method .

The method used in this work is the photochemical method, which is one of the important methods of forming a porous layer on the silicon wafer by using a Teflon Cup (acid-resistant material) and the silicon wafer and the backers are immersed in the HF hydrofluoric solution and at a certain concentration, A specific light source (halogen light) 1000(watt/cm<sup>2</sup>) was used as on the cell as in Fig. 2

### 2. Theoretical part

#### 2.1 The surface Topographic

### Abstract

This study includes the effect of wafer resistivity and intensity of light on topography of porous silicon surfaces which produced by photo chemical etching method, the results showed that changing of the resistivity led to change the porosity, where it found the porous silicon layer be less of high value resistivity.

Once all the wafers have same resistivity's value that's found the light intensity effect on porosity, the less value of porosity produced by the less value of intensity light focused.

The production of Nano crystalline silicon structures and control of their production conditions is the first step to control the properties of the devices (detectors, diodes, solar cells, sensors) and their appropriate applications. Ultimately, this is important in promoting research and development of renewable energy.

The surface topography of the material is important to explain the properties and behavior of the material. Nanomaterial's are different from other conventional materials by increasing the surface area and the presence of most of their atoms on these surfaces because all chemical and physical activities and changes always occur on the surface. the topography study shows how the atoms are distributed on the surface and the difference in homogeneity and properties related to each crystalline structure. [5] .The surface topography of the wafer prepared by Etching Photochemical has been demonstrated by the Atomic Force Microscope (AFM) test, which has a nanoscale structure and high homogeneity.

#### 2.2 Nano porous silicon

The discovery of porous silicon gave a new dimension to technologies which based on porous silicon, in 1990 and the discovery of photoluminescence at room temperature of porous silicon by Canham [6], did not use bulk silicon in the field of light sources (LED) , Because silicon is a semi-conductive material with an indirect band gap semiconductor, and therefore the light fluorescence occurs at room temperature very small [6,7].

Nanoparticle silicon is brought in a number of ways, including photochemical imaging of a crystalline silicon slides surface in a hydrolysis solution of HF

acid. Researches are currently focused extensively on the study of the properties of nano-porous silicon as a luminescent material. The importance of porous silicon is not limited to photovoltaic applications but depends on its properties as a crystal with a bright light [8], which changes the optical properties and absorption, optical reflectivity, making it sensitive to specific wavelengths and useful in optical applications. By controlling the etching conditions (time, slide specification, acid concentration) so that a suitable crystalline structure for porous silicon nanoparticles can be obtained with different porous layers. The large surface area of nanoparticle silicon and its unique surface structure provided ideal conditions for use as an optical sensor or a diode due to the difference between the number of surface and base carriers[3]. The importance of using porous silicon nanoparticles in the manufacture of photoconductor and diodes and their properties Especially in terms of industrial use compared to other materials used in this field of low cost of manufacture and the possibility of preparing the surface for high selectivity [9] as well as the provision of raw material and the lack of energy loss due to the small size of manufacturing

### 2.3 Nanostructure Porous Silicon

The bulk silicon is an inappropriate material for photovoltaic applications because of the occurrence of many non-radioactive phenomena that hinder the process of re-unification of the hole-electron pair. One possible way to increase the quantitative limitation is to limit the movement of the charge

carriers and the exciton in the crystalline space, which reduces the probability of non-radioactive phenomena, if we can limit or confinement the movement of exetons in a very small area in dimensions of the order of nanometer It is well known that the properties of matter in Such a region is changing radically, Since the De Broglie wavelength of an electron or hole is ( $\sim 1\text{nm}$ ), the particles (electrons and holes) in this region behave like particles in a box and can be solved by quantum mechanics. This is called an exciton inventory in a region with nonmetric dimensions in the sense of quantitative restriction. The physical crystal structure in which the excitons are quantified is called nano-structured material. According to the shape of the nano-crystalline structure, the quantitative enumeration process can occur in one dimension Only or in two dimensions or in three dimensions [10].

Each direction of inventory corresponds to a change in the promoter's causative properties and as a result a series of discrete levels appears. Bearing in mind that the charge carrier is free of movement in all directions in crystal size, the (2-D) structure can move freely only in two directions while the third direction determines the direction of quantitative restriction. In the single-dimensional structure (1-D), there is only one possible direction for free movement and two directions in which quantification can occur. In the zero structure (0-D) is obtained completely quantitatively in all directions and the given particle cannot move free movement at all [11].

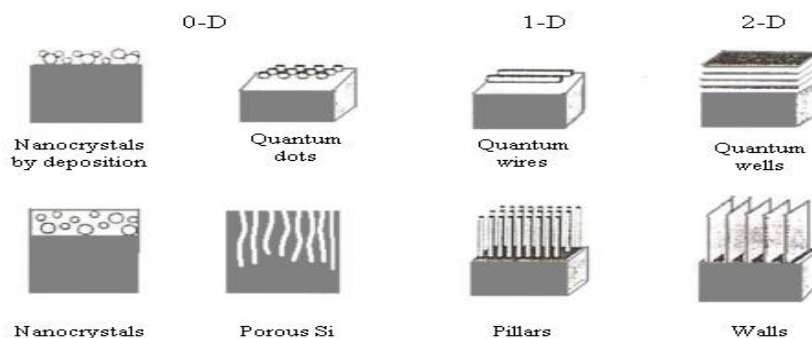


Fig. 1 is a schematic representation of the crystalline nanoparticle models [12].

### 2.4 Methods for preparing porous silicon nanoparticles

There are several methods for preparing porous silicon and the properties of this silicon vary from one method to another. Here are the most common methods of preparing porous silicon: (A) Photochemical etching. (B) Photoelectrochemical etching.(C) Stain etching.(D) Laser etching. (E) Electrochemical etching.

The method used in this research is the method of photochemical etching.

#### (A) Photochemical etching

This method of photochemical etching was chosen in this study to distinguish it from the other by controlling the properties of produced porous silicon

and producing large and homogeneous surface areas. The light on the models is uniformly distributed and vertically producing relatively similar nanostructures.

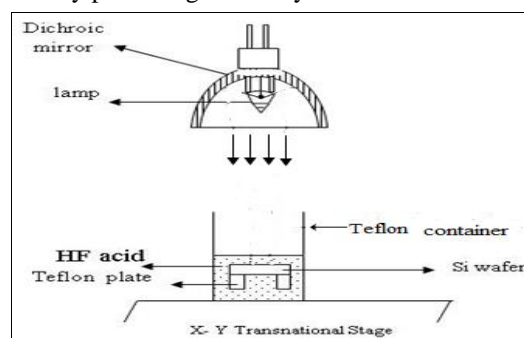
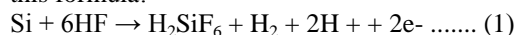
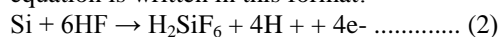


Figure (2) A schematic diagram of the photochemical cell.

During the process of forming freckles there are two atoms of hydrogen synchronized with the silicon atom and the ratio of hydrogen atoms decreases when they reach the electronic polishing system at the surface and disappear during this process, the semi-spherical interaction of the anode during the process of the formation of the hole is written equivalent to this formula:



During the process of electronic refinement, the equation is written in this format:



The final and constant output of the presence of silicon inside HF and their interaction together produce  $\text{H}_2\text{SiF}_6$  or the formation of some ions. This means that during the process of the hole formation, two of the four electrons on the silicon atom leave the atom and move with the removed part while the other two remain adhered to the silicon atom and undergo corrosion later. In contrast, during the electronic polishing process all four silicon electrons are chemically effective. [13] Lehmann and Gösele, proposed the most acceptable mechanical disintegration form (3).

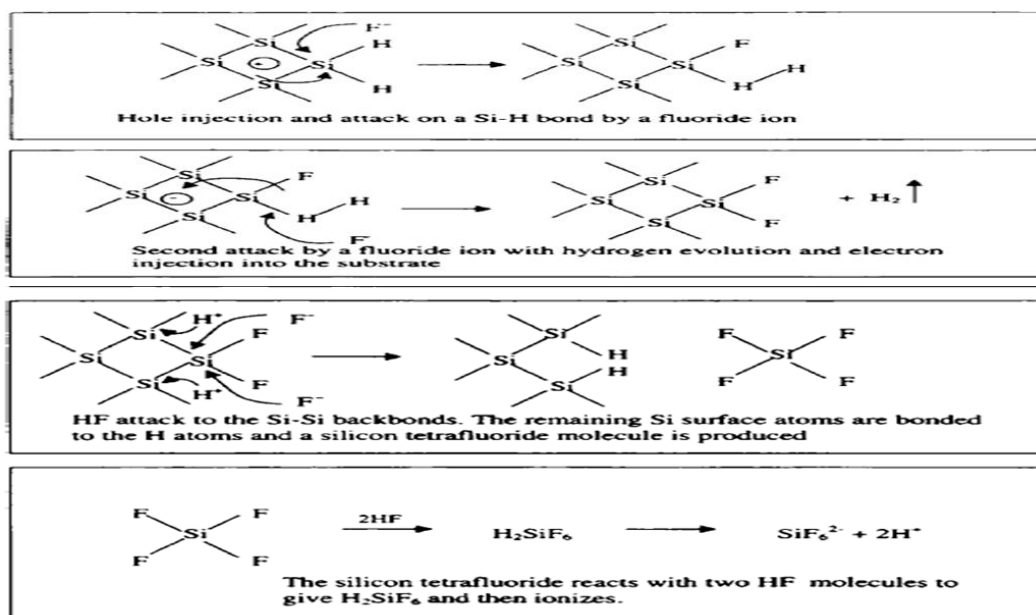


figure 3: The silicon breakdown scheme proposed by Lehmann and Gosele [13]

### 3. Experimental part

The n-type silicon wafer were selected with 100 and two resistors ( $\rho_h = 10 \Omega \cdot \text{cm}$  and  $\rho_l = 4.3 \times 10^{-4} \Omega \cdot \text{cm}$ ) respectively to study the effect of resistance (qualitative resistance) on chemical scaling processes ( $250 \pm 10 \mu\text{m}$ ) and cut in dimensions ( $1 \times 0.5 \text{ cm}^2$ ). cleaning the samples with acetone and ethanol to remove the suspended materials and then put them in HF and 10% concentration for 10 seconds to remove the oxide layer usually on the silicon surface.

After cleaning the silicon samples, they are immersed in HF 40% inside a teflon vessel based on the same Teflon material Fig.(2) with its glossy surface facing the light source. In this way the holes (positive charges) required for the mechanical Fig. (3) the light source used in this experiment is a Phillips halogen

lamp (1000W), which provides uniformly distributed illumination intensity on the sample surface to ensure the smoothness of the flattened layer. The illumination is highly controlled by moving the light source by approximating the sample to the intensity of the light ( $1.5 \times 10^5$ ) LUX can be obtained when It lied just (3)cm of the sample, This study focused on the following:

#### 3.1 Effect of light intensity on topography

The samples of n-type and directional silicon (100) and resistivity of (10)  $\text{cm} \cdot \Omega$  and different light intensity ( $0.7 \times 10^5$  and  $1 \times 10^5$  and  $1.5 \times 10^5$ ) LUX were selected and the min (70 min) was studied to study the effect of light intensity on the topography of silicon chip surfaces By the photochemical method.

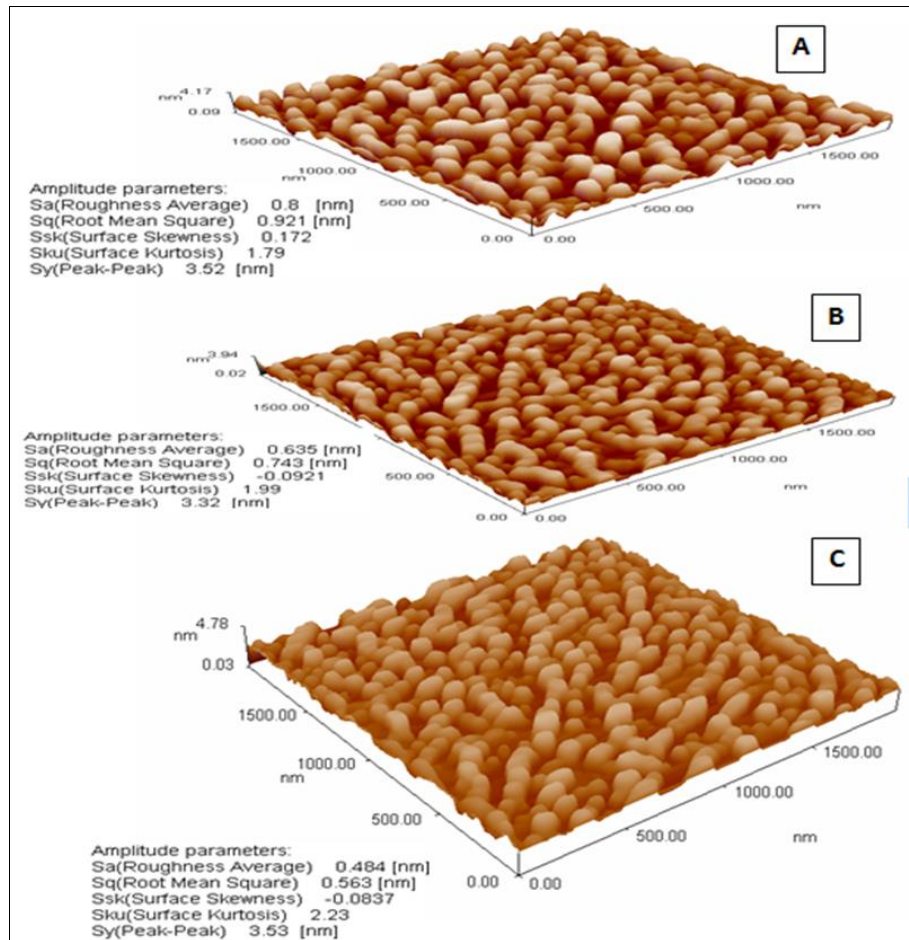
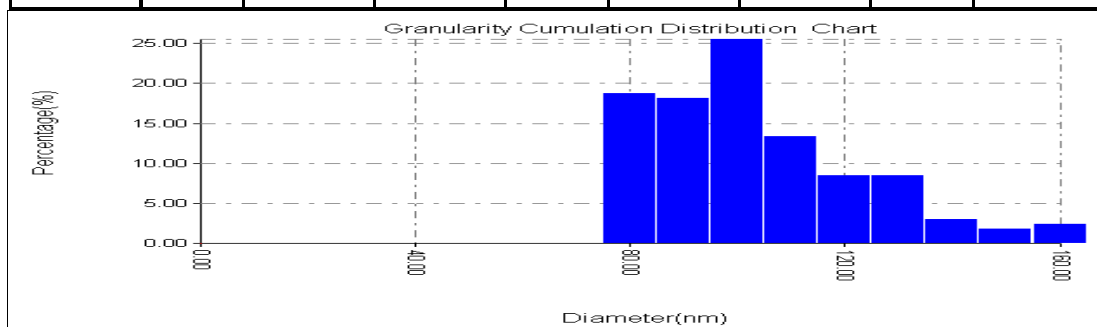


Fig. (1-A.B.C) Samples of silicon wafer n-type (100) and resistivity ( $\rho=10 \Omega \cdot \text{cm}$ ) Using the same conditions of the endoscopy are different in terms of light intensity ( (A) $0.7 \times 10^5$  and (B) $1 \times 10^5$  and (C) $1.5 \times 10^5$  ) LUX and HF 40% and time (70) min.

**A** Avg. Diameter:98.42 nm

Diameter(nm)<	Volume(%)	Cumulation(%)	Diameter(nm)<	Volume(%)	Cumulation(%)	Diameter(nm)<	Volume(%)	Cumulation(%)
80.00	18.79	18.79	110.00	13.33	75.76	140.00	3.03	95.76
90.00	18.18	36.97	120.00	8.48	84.24	150.00	1.82	97.58
100.00	25.45	62.42	130.00	8.48	92.73	160.00	2.42	100.00



**B** Avg. Diameter:84.93 nm

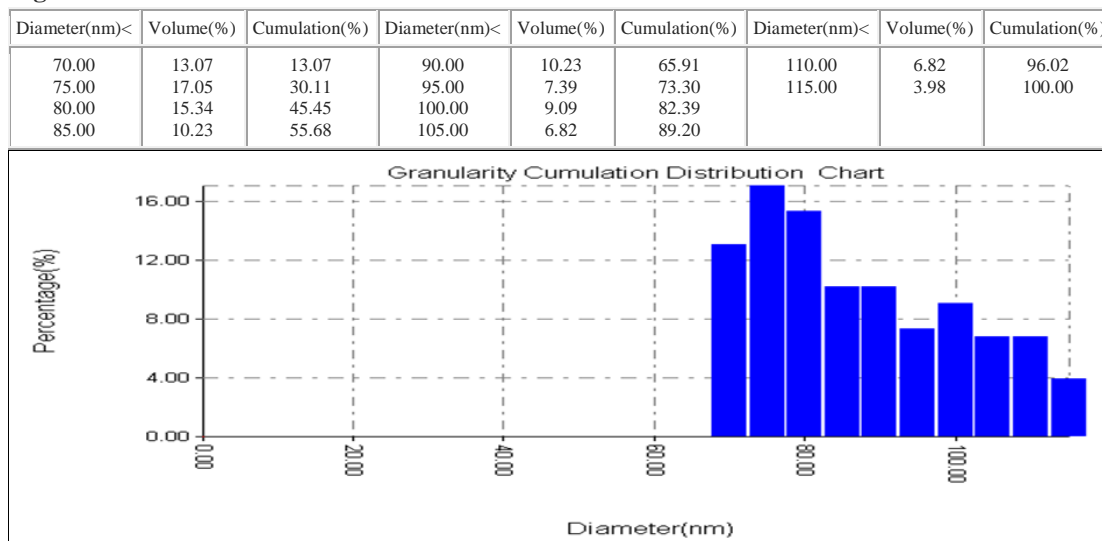


Figure 2 (B.A) The statistical distribution of the size of the nanoparticles formed on the surface of the samples (A, B) in Figure (4-1), respectively.

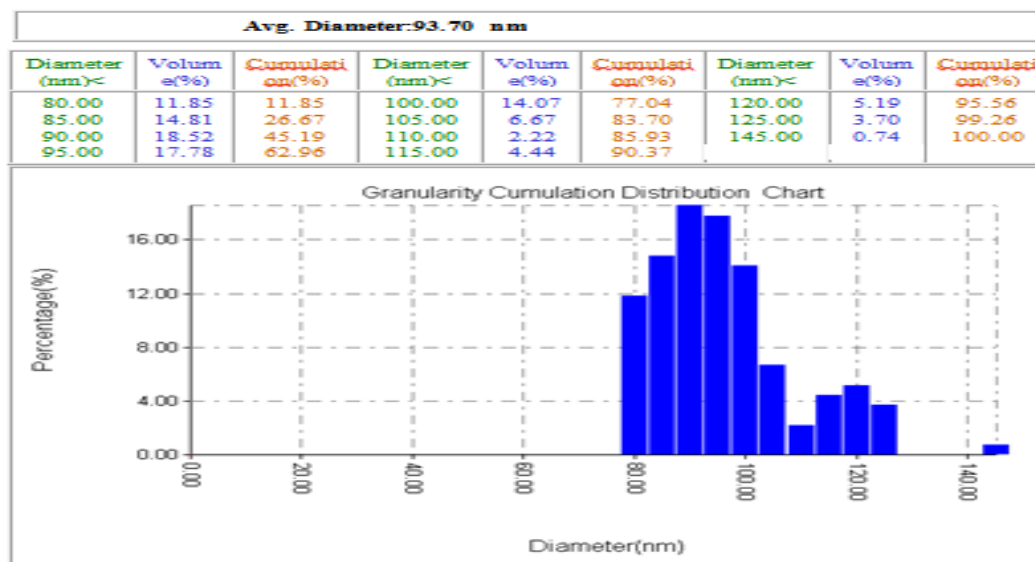


Figure (3): Statistical distribution of the sizes of nanoparticles formed on the surface of sample (c) in Fig.(1)

(A)- This section is concerned with studying and discussing the effect of light intensity on the topography of the produced pore layer when all the conditions of the binoculars are the same (1-3). In the Wafer which facing (  $0.7 \times 10^5$  ) LUX the results of AFM Fig.(a-1) showed porous layer of (4.17) nm thickness and a spherical structure at a diameter of (98.2) nm (Figure 2-A) The statistical distribution of the particles in question shows the range of these particles ranging from (80 to 160) nm and the highest percentage With diameters (100) nm of 25%. Other details can be seen in the attached table with Figure (A -2).

The mean surface roughness is (0.8) nm and the mean square root is equal to (0.921) nm The mean value of the square root represents (the sum of the surface heights and decreases divided by the total number of

squares under each square root). This value explains and explains the roughness of the surface The higher the mean square root, the higher the surface roughness of the membrane and vice versa. This can be used to obtain the surface topography of the sample according to the required applications, the surface spacing (1.17) and the distance from top to top (3.52) nm.

(B) - This section is concerned with the study and discussion of the effect of light intensity on the topography of the produced pore layer when all the conditions of the binoculars themselves are (1-3). In the Wafer which facing (  $1 \times 10^5$  ) LUX the results of AFM Fig (B-1) showed is a porous layer with a thickness of (3.94) nm and a spherical structure at a diameter of (84.93) nm. Figure(B- 2) and statistical distribution of the particulate matter shows a range of

the diameters of these particles ranging from (70 to 115) nm With diameters (75nm) where 17% can be observed and other details can be seen in the attached table with Figure (B -2) .

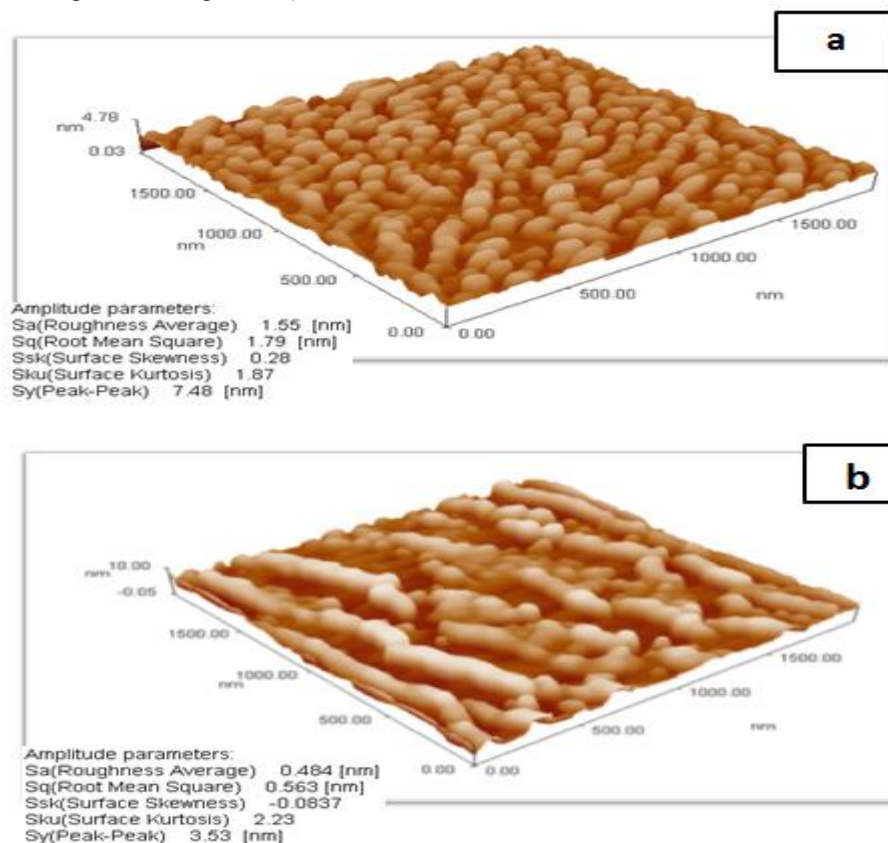
The roughness of the surface was (0.635 nm) and the mean square root value was equal to (0.743 nm), the surface torsion (-0.0921) and the distance from peak to top (3.32 nm) .

(C)- This section is concerned with the study and discussion of the effect of light intensity on the topography of the produced pore layer when all the conditions of the endoscopy itself are (1-3). In the Wafer which facing ( $1.5 \times 10^5$ ) LUX the results of AFM Fig. (C-1) showed a porous layer with a thickness of (4.78) nm and a semi-spherical structure at a diameter of (93.70 nm) (Figure 2-C) and the statistical distribution of the particles in question shows the extent of the train of these particles ranging from (80 to 145)nm The other particulars in the attached table are given in Figure( 3.)The surface

roughness was (0.484) nm and the mean square root value was equal to (0.563) nm, The mean value of the square root represents the sum of the surface heights and decreases divided by the sum of the total number under the square root. This value explains the roughness of the surface The higher the mean square root, the higher the roughness of the surface of the membrane and vice versa. This can be used to obtain surface morphology of the sample according to the required applications, surface spacing (-0.0837) and the distance from top to top (3.53) nm

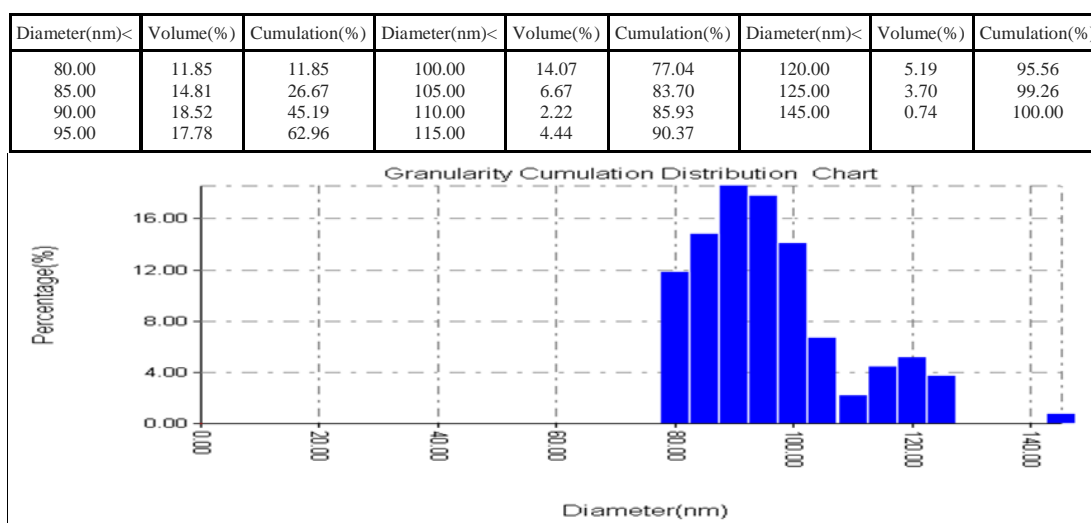
### 3.2 Studying effect of Wafer Resistance on Morphology of The Porous Si layer

The samples were selected n-type and directional (100) with resistivity ( $\rho_1= 10$ )  $\Omega$ . cm and ( $\rho_2= 4.3 \times 10^{-4}$ )  $\Omega$ . cm and the magnification time (70 min) was performed under light conditions (HF40%) and intensity of light ( $1.5 \times 10^5$ ) LUX to study the difference in resistivity on the produced porous layer.

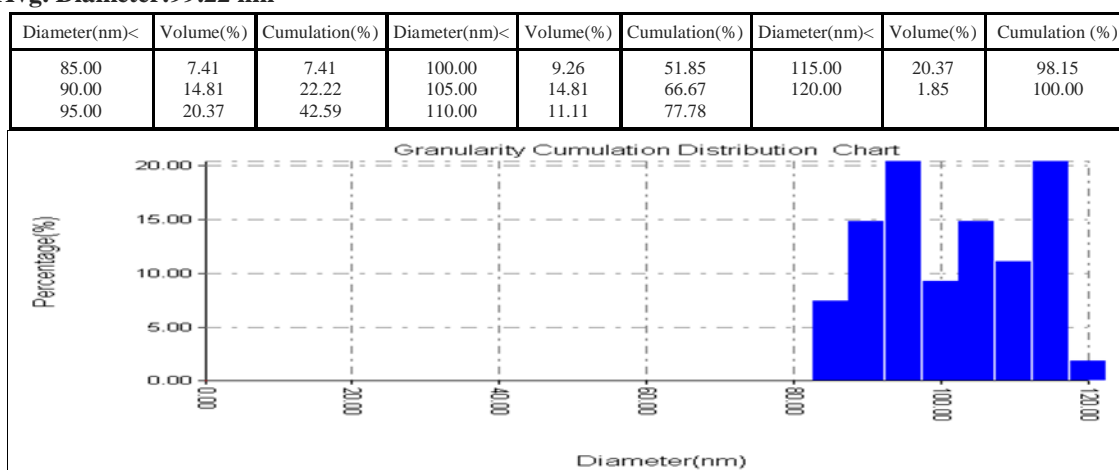


**Figure (a, b -4) The topography of two samples of n-type and directional silicon (100) was carried out by photochemical crystallization under light intensity ( $1.5 \times 10^5$ ) LUX and by using 40% HF and (70) min ( a-  $\rho_h= 10$ )  $\Omega$ . cm and (b-  $\rho_1= 4.3 \times 10^{-4}$ )  $\Omega$ . Cm**

**a** Avg. Diameter:93.70 nm



**b** Avg. Diameter:99.22 nm



**Figure (a, b- 5) The statistical distribution of the nanoparticles formed on the surface of samples (a, b) in Fig. (4).**

(a) This section is concerned with the study and discussion of the effect of silicon wafer resistance on the porosity of the produced pore layer when all the conditions of the bifurcation are the same (2-3) In the high resistivity class ( $\rho_h = 10$ )  $\Omega$ . Cm (a. -4) A porous layer of (4.78) nm and semi-spherical structures with a diameter of (93.7) nm and a statistical distribution of the particulate matter, showing a range of (80 to 145) nm The percentage of particles in diameters (90) nm is 18.5%. Other details can be seen in the attached table with Figure (A.5).

The mean surface roughness is (1.55) nm and the root mean square average is equal to (1.79) nm. The mean of the root mean square (the sum of the surface heights and decreases divided by the sum of the total number under the square root). This value explains the roughness of the surface The higher the root mean square, the higher the roughness of the surface of the membrane and vice versa. This can be used to obtain the surface morphology of the sample according to the required applications, the surface spacing (0.28) and the distance from top to top (7.48) nm.

The results of the atomic force microscope for the low-resistivity silicon sample ( $\rho_l = 4.3 \times 10^{-4}$ )  $\Omega$ . cm, which were tolerated under the same conditions, showed that the porous layer was different from its predecessor in terms of thickness of this layer (10nm) The particles, which were mural structures and longitudinal grooves with relatively large dimensions compared with the number of peaks formed, give us a sign of greater dissolution of the porous layer. By comparing the thickness of this layer (10 nm) with the higher resistivity sample (4.78 nm) The second is less resistant to the melting of its layers, and can be explained (3) where the small resistivity means that the holes (positively charged) are greater in the sample towards the surface and then the development process occurs and that the development is not limited to the surface, but even on the same wall structures as opposed to the high-resistivity sample In which positive charges (holes) meet internal resistance (through the silicon layer) as they move towards the surface, which explains the formation of

larger particles and heads in the higher resistivity sample.

The surface roughness rate (1.55 nm) of the ( $\rho_h$ ) sample compared to the surface roughness rate (0.484 nm) for the ( $\rho_l$ ) sample and the mean square root mean of these structures ( $\rho_h$ ) (1.79 nm) compared to (0.56 nm) ( $\rho_l$ ) and surface torsion (0.28) for the sample with  $\rho_h$  with (0.0837-) for the sample with  $\rho_l$ . The mean diameter of these particles was (99.22nm) and the statistical distribution and percentages are shown in Fig.(b. 5)

**4.Results and Discussion:**

In this part of the research, the Atomic Force Microscope (AFM) was studied and analyzed by studying the shapes and sizes of the formed nanoparticles, most of which ranged from (60 - 120nm), which are within the dimensions of nanotube particles, As well as the statistical distribution of the size of these particles and the development of scientific explanations to form, and the results of the microscope of atomic power is conclusive because of the richness in the information it provides such as average roughness and the value of the average root square object (Root Mean Square) and the value of surface torsion (Surface Skewness) and the distance between Peak-Peak and a lot of information on which the characteristics of manufactured devices can be explained. The control of producing porous layers with certain specifications is provided for use in their appropriate applications. As mentioned in item (3), the work is focused in two parts:

(A) Study of the effect of silicon wafer resistance on the topography of the porous layer produced when all the conditions of the endoscopy itself (1.3) conclude from paragraphs (a, b, c-1) that the surface roughness decreases as the intensity of light increases, The crystalline structures on the surface are reduced by the increase in the process of formation, where erosion and scraping is not confined to the depth, but there is also a marginalization on the walls and grooves produced by photochemical etching. We also note that the thickness of the porous layer of the etched simple under the influence of ( $1 \times 10^5$ ) LUX is less with increasing the intensity of the light, because

the continuation of drilling and colonization may uproot The same layer is etching and the etching begins as if the newly flattened layer becomes less dense by increasing the optical intensity of the light source.

(B)- Study of the effect of silicon wafer resistance on the topography of the porous layer produced when all the conditions of the endoscopy are the same (2-3) where one of the two wafers have a high resistivity ( $\rho_h = 10 \Omega.cm$ ) fig.(a-4) a porous layer with a thickness of (4.78) nm and a spherical structure with a diameter of (93.7) nm (a-5) and a statistical distribution of the particles in question. The range of these particles ranges between (80 to 120) nm and the highest percentage (90)nm with 18.5%. Other details can be seen in the attached table with Figure (a-5). The roughness of the surface was (0.48 nm) and twisting the surface (-0.083) and the rate of the distance from the top to the top (3.53) nm.

The results of the atomic force microscope for the low-resistivity silicon sample ( $\rho_l=4.3 \times 10^{-4} \Omega.cm$ ), which were tolerated under the same conditions, showed the porous layer different from its predecessor in terms of thickness of this layer (10 nm) The particles, which were mural structures and longitudinal grooves with relatively large dimensions compared with the number of peaks formed, give us a sign of greater dissolution of the porous layer. By comparing the thickness of this layer (10 nm) with the higher resistivity sample (4.78 nm) The second is less resistant to the processes of melting its layers, and can explained this by reference to the solubility mechanism in Figure (3) where the small resistivity means that the holes (positively charged) are greater in the sample towards the surface and thus the melting process occurs in contrast to the high resistivity sample where the positive charges (holes) During the silicon layer as it moves towards the surface, which explains the formation of more particles and heads in the higher resistivity sample so as this resistance impedes the mechanism of uprooting because the generate holes due to absorption of light inside the wafer be less.

**Table (1) Effect of light intensity on porous silicon surface topography.**

roughness nm	root mean square nm	The statistical distribution Nm	Pour diameter nm	porous layer thickness nm	Light intensity LUX
0.8	0.921	160-80	98.4	4.17	$0.7 \times 10^5$
0.63	0.74	115-70	84.9	3.94	$1 \times 10^5$
0.48	0.563	145-80	93.7	4.78	$1.5 \times 10^5$

**Table (2) Comparison The effect of wafer resistance on some porous silicon surface morphology parameters is shown at one light intensity ( $1.5 \times 10^5$ ) LUX**

roughness (nm)	root mean square (nm)	The statistical distribution (nm)	Pour diameter (nm)	porous layer thickness (nm)	resistance CmΩ .
0.48	0.563	145-80	93.7	4.78	10
1.55	1.79	120 -85	0.99	10	$\times 10^{-4} 4.3$

We conclude from Table (1) that by increasing the intensity of the light, the processes of etching are

increased, as shown by the increase in the thickness of the porous layer, but this process may be



counterproductive as the drilling processes disappear by increasing the optical intensity applied to the surface of the wafer to be reclaimed. May be exposed to the porous layer produced because the drilling may be created on the grooves and walls itself, which is the layer of porosity, thus uprooting the layer with increased intensity of lighted and shows the etching as if we start to resurgence again, as for Table (2), the processes of etching appear best when For resistivity for segments to be etching, for easy of transmission holes from the far side to the opposite side of the light falling thus increasing the possibility of the etching processes towards the rear, so the depth of the porous layer and the surface roughness larger ones to slice resistivity least of them to slice resistivity top shows.

### 5. Conclusions

1- The resistance has affected the porosity. The porosity layer increased in the silicon wafer surfaces by increasing the resistance, where the movement of

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the carriers impedes the high resistivity, which leads to a decrease in the extraction ratios of the surface material of the wafers.

2- The light intensity has effective in the proportions of porosity, where it acts as a urges for the acid responsible for the removed and uprooting atoms of the surface of the wafer required to be developed, increased porosity by increasing the intensity of light.

3- The resistance and intensity of light effect in the porosity where the resistance impedes the mechanism of uprooting and the intensity of light enter as urges for the produced the electron holes pairs begin to generate by absorption of light inside the wafer , there is a percentage of both types of electrons and holes from a not directly -energy gap silicon, by the current of these curriers the surface atoms of the wafer will be removed and the etching process occurs .

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## تأثير مقاومة الشريحة وشدة الاضاءة على طبوغرافية سطوح شرائح السليكون المسامي المنتجة بالطريقة الكيميائية الضوئية

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### الملخص

شملت هذه الدراسة تأثير مقاومة الشريحة وشدة الاضاءة على طبوغرافية سطوح السليكون المسامي المنتجة بطريقة التتميش الكيميائي الضوئي، وقد اظهرت النتائج ان تغيير المقاومة ادى الى تغيير في المسامية ، حيث وجد ان اقل سمك للطبقة المسامية كان عند اعلى قيمة للمقاومية. عندما تكون قيمة المقاومة نفسها لجميع الشرائح وجد ان شدة الاضاءة تؤثر على المسامية ، فاقل قيمة للمسامية تنتج عند اقل قيمة للشدة الضوئية المسلطة.

ان انتاج تراكيب السليكون النانوي والتحكم في ظروف انتاجها تعتبر الخطوة الاولى للتحكم في خواص النبايط (كواشف، مفارق (Diodes)، خلايا شمسية ، متحسسات) وتطبيقاتها المناسبة وفي النهاية كل هذا مهم في تعزيز عمليات البحث والتطوير للطاقة المتجددة.

**الكلمات المفتاحية:** التتميش (The aching) ، الخشونة (roughness) ، السليكون المسامي (porous silicon) ، الإكسيتون (exiton)، التتميش الكيميائي الضوئي (Photochemical etching) .