Surface Area of Porous Silicon

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Abstract

The surface area of porous silicon layers produced by different methods has been measured in this work. It is found that the surface area of the porous silicon is optimum when high laser power density is used to etch n–type silicon wafer via the laser induced etching process compared with that for porous silicon produced by lower laser power density or by electrochemical etching process. A scanning electron microscope (SEM) micrographs were used to estimate the surface area. The surface area of the porous layer is strongly dependent on the porous layer geometry and its depth.

Keywords: porous silicon , laser induced etching.

المساحة السطحية للسيلكون المسامي

الخلاصة

تم قياس المساحة السطحية للسيلكون المسامي المنتج بطريقتين مختلفتين, حيث وجد بأن المساحة السطحية لطبقة السيلكون المسامي المنتج بعملية القشط المحتث بالليزر وقدرة ليزرية عالية تكون اكبر مما هي عليه من استخدام كثافة قدرة ليزرية واطئة أو عند أنتاج السيلكون المسامي بعملية القشط الكهروكيمياوية . تم اعتماد صور لجهاز المسح الالكتروني(SEM) لطبقة السطح الطبقة المسامي وذلك لقياس المساحة السطحية . وقد وجد أن المساحة السطحية للسيلكون المسامي تعتمد على الشكل الهندسي وسمك هذه الطبقة .

1. Introduction

Silicon is at the heart of the electronic industries but it is application in optoelectronics is limited due to its indirect band gap and poor photo emissivity. Its dominance over other semiconductor is intimately tied to its superior materials and processing properties and to the tremendous base of revolution that has developed around it Therefore, semiconductors are not likely to displace silicon as material of choice in electronic application other [1].

Porous silicon was first discovered by Uhlir et al in the 1956 [2], which was first produced by electrochemical (EC) etching of crystalline silicon wafers a Tremendous amount of research have been carried out on the synthesis and surface modification of this material [3]

.The morphology and size of pores which produced by these techniques may be controlled by varying different conditions such as silicon doping, HF concentration, power density of

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the laser used and current densities, etc… [4].

Much of the interest in P-Si and its morphology derives from its photoluminescence (PL) properties which make it a useful platform for electronic and optoelectronic devices as well as chemical micro sensors [5].Porous silicon has already found applications in diverse fields such as the development of solar cells, micro optics [6] chemical sensors [7], bio analysis and utilizing a number of different signal schemes [8].Various mechanisms were employed to synthesize porous silicon layers. The most common one is the electrochemical etching where the electrical current is required to initiate the etching process. This is a familiar an iodization process while in the photochemical etching, the laser light is required instead of electrical current. Moreover, both electrical current and light are required in another technique which is called photo electrochemical etching. Ultimately ,stain etching of silicon in acid mixture could also be used to produced porous silicon. Being the effective surface of PS enormous (more than 500 m^2/cm^2 depending on the do pant level and the substrate), its chemistry is determinant to the electronic, optical and electrical properties. Chemical composition on the result, the effect of aging, the intentional oxidization and the intentional surface modifications are all discussed here [10]. The internal surface of a PS layer is very large and Values as a high as 1000 m^2/cm^2 can be measured Such a large surface contain an enormous quantity of impurities coming from the electrolyte used for electrochemical etching and from the ambient air.

The structural characteristics of P-Si have been studied by a range of techniques [11].

Structural of P-Si have been investigated by scanning electron microscopy (SEM) which the direct imaging of the material could be carried out, although the resolution achievable (down to < 2 nm) and the available contrast make it difficult to visualize the smallest structures,

X-ray scattering in these techniques small angle scattering measurements allow the determination of nanostructure dimensions and alignments, the surface area per unit volume and the sharpness of the Si interface with internal voids, X-ray absorption can give information on the band gap and local atomic order of the material [8]. Surface morphology investigations was also obtained by the optical microscope which provides a clear view of the porous nature and type of the structure besides, dimensions of the pores constructing the surface.

The surface-volume ratio in m^2/cm^3 could be measured by [12]:

$$\left[Surface\ Area(m^2/cm^3) = \frac{Area\ of\ one\ pore \times No.\ of\ pores}{Area\ of\ P-Si\ structure \times Depth} \right]$$

Where the pore geometry was considered as cylindrical in shape and thus, the area of one pore is:

The surface area of pore is ($2\pi\ r\ h$) Where h: is the height of pore measured in (m), r: radius of the pore measured in (m).

Because the designable materials properties,

Compatibility with conventional Si fabrication and thin film processes, and unique physical and chemical properties, P-Si is a versatile material with potential in a number of different application areas [13].

For sensors application and medical applications, P-Si is a twofold promising material for sensor applications. Furthermore, its electrical and optical properties strongly depend on the environment because of its large specific area [14]. The high specific surface area of porous layer enables applications in chemical/biological sensing and can be exploited in future heterogeneous chemical catalysis [8, 15].

A new capacitor technology based on P-Si uses the advantage of macro porous structure formed on n-type Si wafers (higher specific capacitance).

In silicon micromechanics, P-Si is utilized as a sacrificial layer (microlithography) active component (movable freestanding membrane, cantilever, etc.) on an insulator layer between conductive layers.

Aim of this paper is to utilize the surface morphology investigation by scanning electron microscope to estimate the surface area of the porous silicon layer and to study the affecting parameters in order to control the surface area and subsequently use it in the proper application.

Experimental

A scanning electron microscope has been employed to calculate the surface area of the porous layers. These micrographs have various structures depending on the preparation conditions.

Our sample stricture was made by a photo chemical etching [12] Different laser wavelengths were used (514,810 and 1064 nm). The laser beam was focused to a small area by a focusing lens of (10cm).The laser power density appropriate for this process should be in the range (5-20 w/cm^2).

Some Samples were prepared by electrochemical etching of silicon wafer in 30% HF concentration and Current density of 20 mA/cm^2 .A typical portion from each structure of each porous structure separately.

This sample represents an equal side's square geometry with dimensions given at the top of the SEM micrograph. The depth of each structure was measured separately. A depth of 120 µm, 90 µm and 90µm for the pore-like, column –like and trenches –like structures, respectively were measured.

The surface area represents the ratio of the area of the porous structure on the volume of a unit structure. Therefore, a unit of m^2/cm^3 was estimated for each structure.

Results and Discussion

The pore formation in silicon initiates as defects at the crystalline silicon surface. In the laser –induced etching process, pore formation occurs only at the regions of charge carriers accumulation since these charge carriers initiate the chemical reaction and this step followed by charge carriers redistribution due to variations in the surface environment.

The surface morphology investigations of the porous layer structure produced by different methods were carried out to estimate the surface area of the porous layer. A column- like structure porous layer can be easily recognized for the laser induced etching process as, while a pore – like porous structure has been another porous structure called trenches –like.

When a low laser power density of about 10 w/cm^2 was used to produce the porous silicon with irradiation time of 90 minutes, we found that a column-like structure includes columns of average night of 90 µ and average radius of 8.6 µm is produced as shown in fig(1). Therefore, the surface area of this structure is (180 m^2/cm^3).it is found that these columns distributed perpendicularly to the silicon surface and very fine structures were observed at the top of these columns.

While. When a high laser power density of 20 w/cm^2 is used to irradiate the silicon water immersed in HF acid, a pore-like structure of 120 µm depth and pore diameter of 7 µm was distinguished as shown in fig 2. The surface area for such a structure was (480 m^2/cm^3).

The high laser power density leads to generate high number of electron-hole pairs which make the chemical reaction much faster and from a pore – like structure .This pore –like structure has a different pore diameters which are distributed randomly . The pore – like porous structure has an extremely large surface area due to the large internal surface area of the pores as well as the high number of small pores.

Moreover, the porous structure produced by electrochemical etching shows a trench- like structure. The depth of this structure was 90µm.It is found that surface area of 330m^2/cm^3 was calculated. This value is smaller than that for the pore - like structure and that is related to the small thickness of the porous layer. Table 1 represents a comparison between the surface areas of the experimentally prepared porous layers.

Concluding Remarks

We can conclude from this study that the surface area can be increased drastically to a very large value, which enables porous

silicon to be used in various applications.
The surface area value depends on the formation mechanism of the porous silicon. Larger surface area could be achieved by laser – induced etching process when a high laser power density is used, while the smaller surface area was achieved when another porous structure is produced by using a low laser power density.

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Table (1) the surface area of different porous structures

	Laser - induced etching		Electrochemical etching
	Law ($10w/cm^2$)	High ($20w/cm^2$)	
The surface Area(m^2/cm^3)	180	480	330

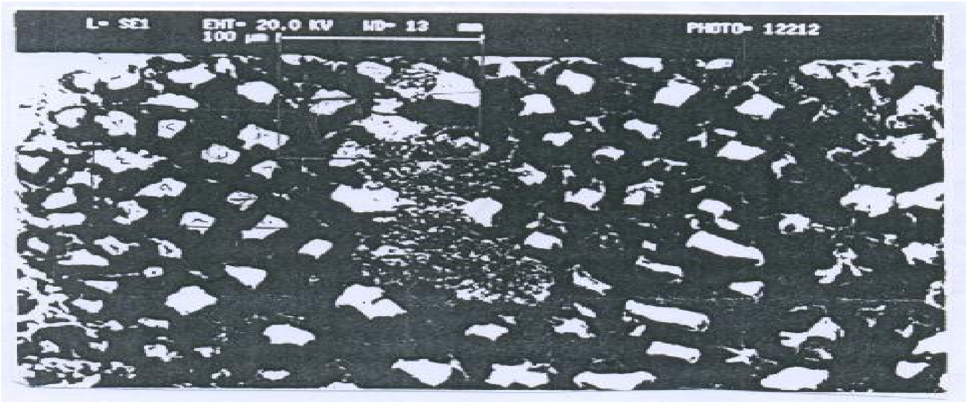

Figure (1) A columnar – like porous structure produced by low laser power density

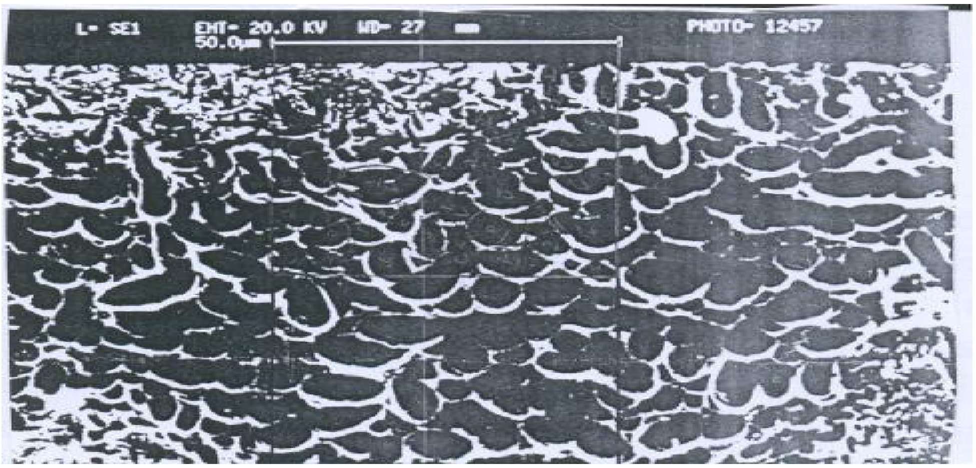

Figure (2) The pore-like porous layer produced by high laser power density.

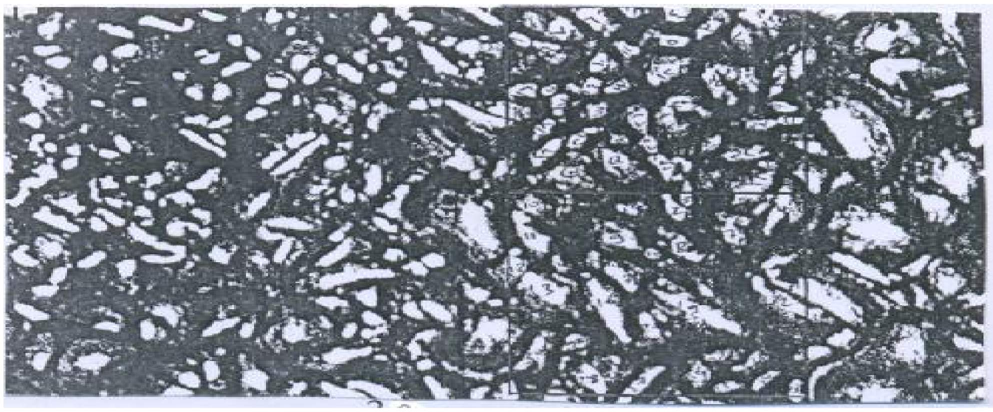

Figure (3) Trench-like porous layer structure produced by the electrochemical etching.