

Green and blue emission from stain-etched porous silicon

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ABSTRACT

Visible light emission is reported from boron doped p+ type porous silicon films. These films were prepared by stain etched method. In this method KOH pellets were used in de-ionized water at 75°C for etching silicon samples. Blue and green light area observed from these porous silicon samples. The visible photoluminescence originates from direct transitions between energy levels in the quantum wells.

Key words: Porous silicon(PS), photoluminescence (PL), Quantum Wells, quantum wires, stain-etching.

INTRODUCTION

The surface morphology of photoluminescent porous silicon has turned the much attention to its electronic and optical properties¹⁻². The discovery of photoluminescence in porous silicon³ at room temperature generated its use in optoelectronic industries. The increasing use of silicon in integrated circuits and their techniques have been developed. The restriction on silicon over GaAs in making optoelectronic devices is due to indirect band gap of silicon. So efficient light emitting devices have not been achieved in silicon technology. Therefore an extensive research on formation of porous silicon and observation of efficient visible light at room temperature have been going on since last decade. Rather photoluminescence, electroluminescence⁴ is achieved at room temperature from porous silicon based optoelectronic devices. The formation of porous silicon in hydrofluoric acid electrolyte under anodic bias was reported first by Turner⁵ and Uhlir⁶. The anodic oxidation is widely used technique for preparation of porous silicon⁷⁻⁹. However electrodeless (stain-etching) techniques¹¹⁻¹² can also be used to grow porous silicon layers. Both thickness and structure of pore size can be controlled with

anodic oxidation technique. This controls the electrical and optical behaviour¹⁰ of porous silicon layers. In this letter, we present a novel nano engineering technique of porous silicon preparation and optical properties of the formed porous silicon films. This new technique enable us to grow PS from vapors etchant instead of anodic oxidation. This technique can be used for etching the selective area of surface of semiconductor. It is an electrodeless technique for making less thicker layer compared to anodic oxidation. This technique presents a new nano structure for optical and electrical properties of interest of porous silicon. The capability of fabricating electroluminescence and photoluminescence devices, the pattern of nano-structured silicon is very important for application in flat panel display devices and monolithic integration. The electroluminescence is reported from stain-etched (HF:HNO₃:H₂O mixture) optical devices by Xu¹¹. In this paper we present green and blue emission under direct UV light illumination.

Fabrication

Porous silicon samples were prepared by gas etchant method. In this method silicon wafers with boron doped P⁺ type (100) of resistivity 10-15

Ω -cm were used in 80% KOH solution (100 ml demonized water + 80 gm KOH pallets). The whole system is kept in temperature controlling bath at 75°C. A teflon cell used in order to expose silicon wafer surface to vapors evaporating from KOH solution as shown in fig. 1.

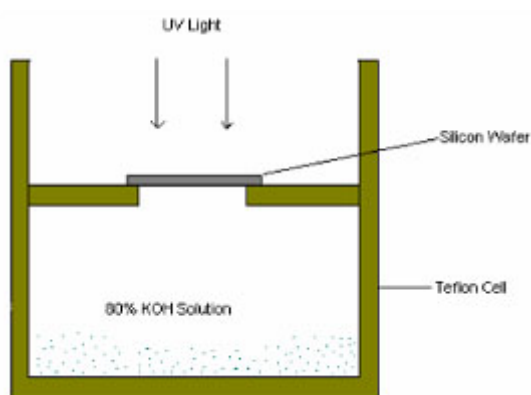


Fig. 1: Schematic diagram of a gas etchant cell. In this silicon surface is etched by fumes

So after being exposed to silicon surface, vapors are constantly exhausted from the surface. The growth rate is about 50nm per minute. A UV lamp (365 nm) is kept at 30cm distant. During of porous silicon, the UV light exposure makes PL intensity stable. On decreasing the percentage of KOH solution, a monhomogeneous porous film is obtained. So to require a homogeneous layer of porous silicon the percentage of KOH solution can be increased. In this method the etching rate is less but a smooth and homogeneous PS layer is achieved. The samples were then rinsed in de-ionized water and dry with nitrogen. All measurements were carried out at room temperature under-ambient atmosphere.

RESULTS AND DISCUSSION

A weak photoluminescence of green (546nm) and blue (450nm) from porous silicon wafers were observed under excitation of UV lamp at the end of porous silicon formation. The formation mechanism of both samples was identical. The peak maxima of both samples are found at 546nm and at 450nm, which presented in fig. 5 and fig. 6. It is

expected that the origin of these photoluminescence is from 'S' shaped quantum wires spread over the exposed surface. These 'S' shaped structure, called quantum wires, are observed to run perpendicular to surface and a morphology of interconnected pores and quantum wires is found. The transition energy (ΔE) for green colour is ~ 2.27 eV with 70% measured porosity while transition energy (ΔE) for the colour with 80% porosity is ~ 2.8 eV. It is also expected that the photoluminescence originates from transition in degenerate¹³ energy levels in the quantum wires. The direct transition dominated mechanism is believed. It is known that the different wavelengths are emitted from samples of different porosities and size of quantum wires in porous silicon. Table - 1 shows the combination of photoluminescence and quantum wells with porosity. The dimensions of the observed surfaces are summarized in the table 1. The dimension of sample-1 and sample-2 are compared, the quantum wells of small width are observed from sample-2 and it is noted that the quantum wells of 150 nm width are observed for sample-1, and quantum wells of 50 nm width are for sample-2. However the lateral extension of the surface remain almost constant.

Table 1: The summary of different wavelength for corresponding porosity and quantum well width is presented.

Porous silicon samples	Porosity (%)	Emitted wavelength	Quantum well width
Sample -1	70	546	450 nm
Sample -2	80	450	50nm

A blue of shift is observed as porosity is decreased. The photoluminescence spectrum taken from porous silicon films under UV (365) excitation has emission bands peaked at ~ 546 nm and at ~ 450 nm. The recombination mechanism of luminescence is proposed by almost everyone. On the basis of experimental studies of photoconductive¹⁴ properties of porous silicon as anodized PS excited with UV light emit efficient visible photoluminescence and emission of electroluminescence at room temperature is

observed by applying forward bias voltage, so there exist a correlation between the porosity¹⁵ of porous silicon and photoluminescence. The results indicates that some carries are influenced by UV illumination and also, it enhances the PL intensity of emitted light to some extent. This silicon nano structure is obtained by gas etchant, core radius ionic cell is ~ 5 nm and therefore possibility of defect generation is negligible. This indicates that both green and blue emission might come from quantum wires via transition in conduction band.

However photoluminescence intensity could be enhanced. Although radiative recombination centers can be generated during illumination but these have no effect on photoluminescence intensity. It remains almost constant during experiment as shown in fig.1. The intense blue emission from carbon-plasma implanted porous silicon reported silicon reported by Liu¹⁶ *et al.*, but a sustainable and stable intense photoluminescence is questionable. However the photoluminescence are confirmed by quantum wire

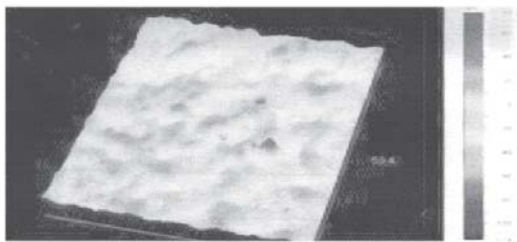


Fig. 2: Surface image of P⁺ porous silicon wafer (sample-1). The spots are micropores spread over surface

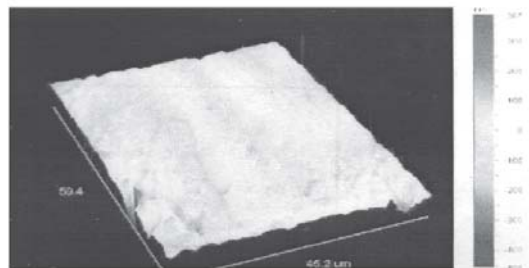


Fig. 3: Surface image of P⁺ porous silicon wafer (sample-2) and Micropores spread over surface

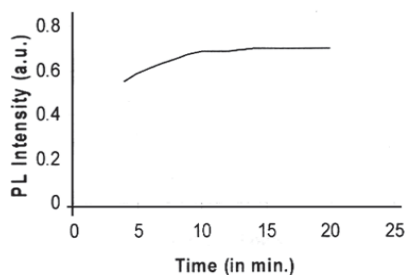


Fig. 4: Shows PK intensity with time of illumination

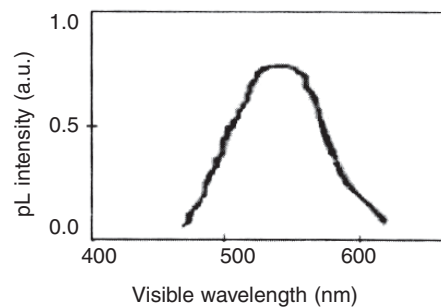


Fig. 5: The measured PL intensity of the green photo-luminescence emission for sample-1

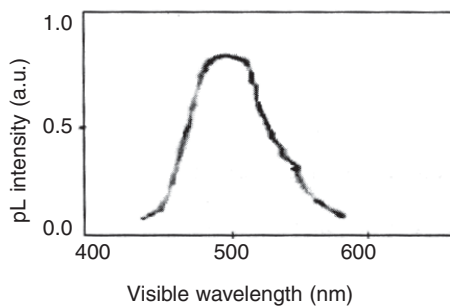


Fig. 6: The measured PL intensity of the blue emission for sample -2

model. To the best of our knowledge direct monochromatic visible light silicon sources are not present. A need of novel quantum wire engineering is to be developed to achieve low visible wavelength.

CONCLUSION

We reported porous silicon films fabricated with KOH fumes as etchant by exposing silicon wafer surfaces. The prepared films exhibit weak intense

green and blue emission. This emission of visible light is due to transition mechanism among the energy levels in quantum wires. The high porous surfaces shows the blue shift. If emission of stable and intense visible light would be achieved from porous silicon, the crystalline silicon become the heart of optoelectronic industries. For this a quantum

mechanical study is under way and would be presented in future.

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