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 pallets 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 properties\textsuperscript{1-2}. The discovery of photoluminescence in porous silicon\textsuperscript{3} 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, electroluminescence\textsuperscript{4} 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 Turner\textsuperscript{5} and Uhlir\textsuperscript{6}. The anodic oxidation is widely used technique for preparation of porous silicon\textsuperscript{7-9}. However electrodeless (stain-etching) techniques\textsuperscript{10-12} 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 behaviour\textsuperscript{10} 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:HNO\textsubscript{3}:H\textsubscript{2}O mixture) optical devices by Xu\textsuperscript{11}. In this paper we present green and blue emission under direct UV light illumination.

Fabrication

Porous silicon samples were prepared by gas enchant method. In this method silicon wafers with boron doped P+ type (100) of resistivity 10-15
Figure 1: Schematic diagram of a gas etchant cell. In this silicon surface is etched by fumes.

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 ($\Delta E$) for green colour is ~2.27 eV with 70% measured porosity while transition energy ($\Delta E$) for the colour with 80% porosity is ~2.8 eV. It is also expected that the photoluminescence originates from transition in degenerate 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 form 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                | 50 nm              |

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 ~450nm. The recombination mechanism of luminescence is proposed by almost everyone. On the basis of experimental studies of photoconductive 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 porosity of porous silicon and photoluminescence. The results indicate 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 by Liu et al., but a sustainable and stable intense photoluminescence is questionable. However the photoluminescence are confirmed by quantum wire 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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