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GREEN PHOTOLUMINESCENCE FROM STAIN-ETCHED POROUS SILICON FOR PHOTONIC DEVICES

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ABSTRACT

Green photoluminescence is reported from boron doped P^+ porous silicon layer. The porous silicon layer is prepared by stain-etching method. In this method, we used KOH pallets in de-ionized water at 75^0C for etching the silicon sample. Green photoluminescence originates from direct transitions between the energy levels, and PL intensity remains almost constant.

Keywords: Porous Silicon (PS), Photoluminescence, Bohr Excitation, Quantum Wires

I INTRODUCTION

The invention of porous silicon has attracted attention of scientists and engineers due to photo emission from porous silicon at room temperature[1]. It is assumed that the visible light is originating from nano-structure formed on the surface of the silicon substrate. Therefore, the crystalline silicon becomes a dominant material in the nano-photonics since 1990s. However, crystalline silicon is not used in fabrication of photonic devices because of its indirect band gap(~1.1eV)[2]. The porous silicon may be considered as a spongy phase of silicon having a network of nano-pillars spread over the surface[3]. Until early 1990s, a uniform network of nano-wires was not reported due to some change in electrochemical cell, electrodes and other formation parameters. The porous silicon does not need any expensive instrumentation for its preparation. It can be prepared in very short time and in a controlled manner. The emission of visible photoluminescence at room temperature is the most acceptable property of the porous silicon. The several efforts have been initiated to describe the properties and the mechanism of photoluminescence, but no one could put forward an appropriate mechanism of the photoluminescence. However, a well known quantum confinement effect[1] is the most acceptable theory and it defines the cause of band gap widening. This band gap widening between valence and conduction bands is more important for photoluminescence in porous silicon, because optical transitions and radiative recombination depend on it. Any significant change in band gap would change the physical and optical properties of the porous silicon[4-7].

II FABRICATION

Here, porous silicon is fabricated by the stain-etching technique. It is a noval nano engineering technique for the porous silicon formation. This technique enables us to grow nano-wires on the silicon substrate by a vapor etchant instead of using

anodization technique. A silicon wafer with boron doped P^+ (100) of resistivity 10–15 Ωcm is used in 75% KOH solution. The whole system is kept in temperature controlling bath 75^0C. the rate is about 50nm/min. A UV lamp (365nm) is kept at 35 cm distant. We proposed that UV light exposure makes PL intensity stable during the formation of PS layer. Again, on decreasing the percentage of KOH solution, a non-homogeneous porous film is obtained. So, to require a homogeneous layer of porous silicon, the percentage of KOH solution may be increased. In this way, etching rate is less but a smooth and homogeneous porous silicon film is formed. The sample is then rinsed in de-ionized water and dried. All the measurements were carried out at room temperature.

III RESULTS AND DISCUSSION

Fig.1. shows porous silicon film. An efficient green photoluminescence is observed under photo-excitation with UV lamp at the end of PS formation. The photoluminescence peak is observed at 546nm, which is presented in Fig.2. It is expected that the origin of photoluminescence is from 'S' shaped quantum wires spread over the exposed surface. This 'S' shaped array is observed to run perpendicular to the surface of the substrate. Green photoluminescence from PS sample corresponds to the energy gap about 2.30eV. However, the calculated porosity of the sample is 70%. We proposed that the green wavelength is emitted from quantum silicon wires by direct transitions in the degenerate quantum states. The quantum efficiency of the porous silicon LEDs depends on radiative transition rate in the degenerate quantum states. The photo-conductive properties of porous silicon excited with UV light were analyzed. Treating energy states as Bohr like quantum states, Bohr excitation is responsible for light emission in PS. The quantum pillars of the order of 50-150 nm in P^+ silicon is expected to have luminescence quantum states in the green region(500-550nm)[8]. Although, radiative recombination centres might be generated during illumination, but on the basis of experimental studies, these have no effect on PL intensity[9]. It remains almost constant as shown in Fig.3. The intense blue emission from carbon-plasma implanted porous silicon is observed also[7]. But actually, an efficient and more stable intense photoluminescence is questionable. To the best of our knowledge direct visible light silicon sources are not present. So, a need of noval quantum wire engineering is to be developed to achieve the most intense and stable photoluminescence.

IV Conclusion

It can be stated that the band gap widening or quantum shift in the energy states is to accommodate visible wavelength related quantized energy above the band gap energy. The quantum confinement model deserves to explain the shift in the energy states beyond the energy gap of the silicon. The main property of porous silicon is that it emits light mainly in visible region of the electromagnetic spectrum and this emission of visible light depends on porosity of the material. The highly porous sample emits low wavelengths while less porous film emits large wavelengths of the visible region it means highly porous films show blue shift. If the highly intense photoluminescence would be achieved from porous silicon, silicon becomes the heart of optoelectronic industries.

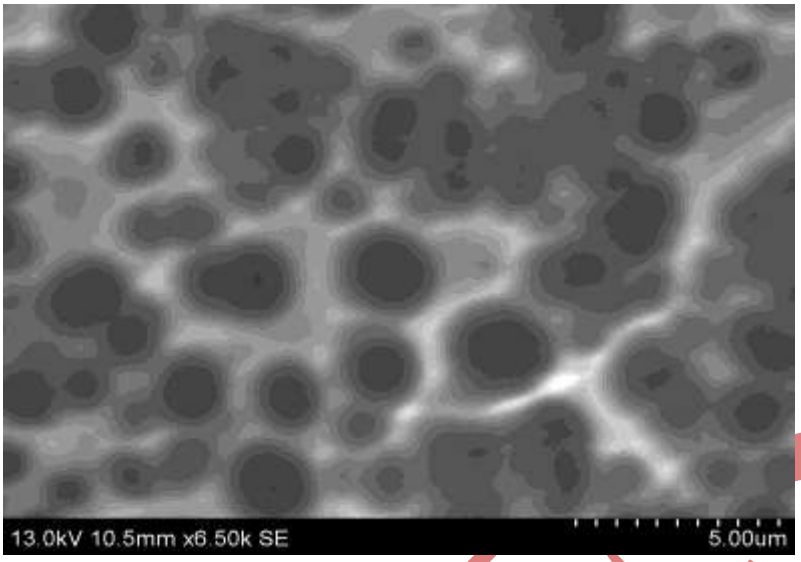

Fig.1. SEM image of P+ porous silicon

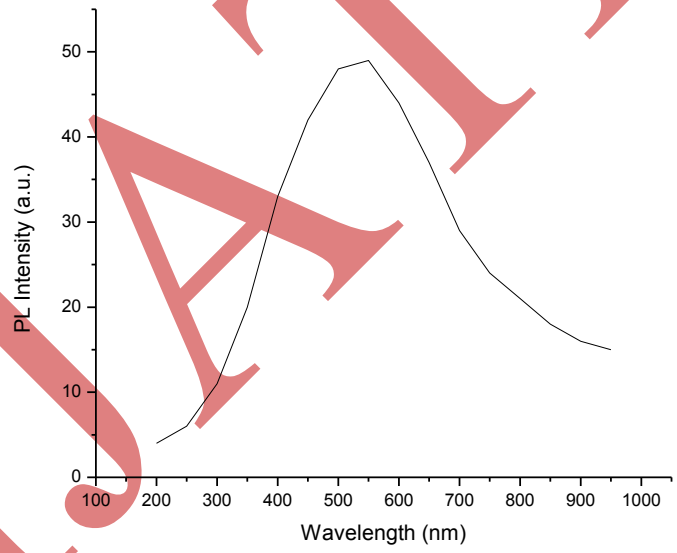

Fig.2. Pl Intensity of Green Photoluminescence

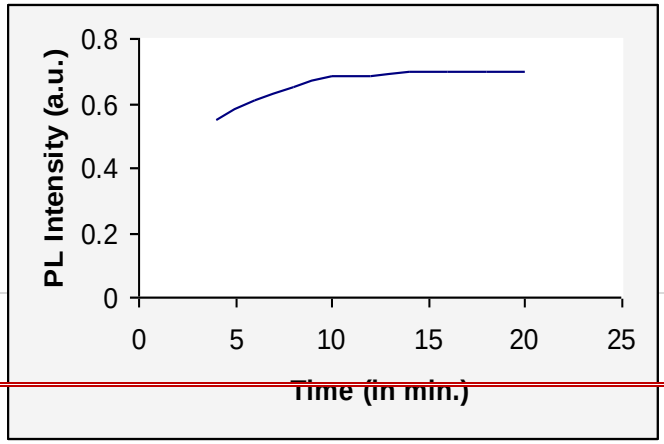

Fig.3. PL Intensity with Time of Illumination

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