International Journal of Materials Science and Applications
2015; 4(1): 31-34
Published online January 23, 2015 (http://www.sciencepublishinggroup.com/j/ijmsa)
doi: 10.11648/j.ijmsa.20150401.16
ISSN: 2327-2635 (Print); ISSN: 2327-2643 (Online)

Effect of light intensity on the I-V characteristics of LaF_3/Porous-Silicon structure prepared by chemical Bath deposition technique

Md. Hafijur Rahman[1, *], Abu Bakar Md. Ismail[2]

[1]Department of Physics, Pabna University of Science and Technology, Pabna-6600, Bangladesh
[2]Department of Applied Physics & Electronic Engineering, University of Rajshahi, Rajshahi-6205, Bangladesh

Email address:
hafiz.ru08@gmail.com (M. H. Rahman), ismail@ru.ac.bd (A. B. M. Ismail)

To cite this article:
Md. Hafijur Rahman, Abu Bakar Md. Ismail. Effect of Light Intensity on the I-V Characteristics of LaF_3/Porous-Silicon Structure Prepared by Chemical Bath Deposition Technique. *International Journal of Materials Science and Applications*. Vol. 4, No. 1, 2015, pp. 31-34.
doi: 10.11648/j.ijmsa.20150401.16

Abstract: Effect of Light intensity on the I-V characteristics of LaF_3/PS heterojunction has been investigated in this report. LaF_3 layers have been deposited by a novel chemical bath deposition (CBD) technique. With this simple technique LaF_3 produced as $LaCl_3$ are made to react with hydrofluoric (HF) acid on the porous silicon substrate. This enables direct deposition of LaF_3 on the pore walls of the porous silicon leading to a successful passivation of PS. The compositions of the deposited LaF_3 were confirmed by Energy Dispersive of X-ray (EDX) analysis. The current increases with light intensity. From the experimental results it can be concluded that lanthanum fluorides can be deposited on the PS surface by the CBD technique, which provides the required passivation for PS. This passivation can enable the PS to be considered as an important material for photonics.

Keywords: Porous Silicon, Passivation, Photonics, Chemical Bath Deposition (CBD), Light Intensity

1. Introduction

Recently, there has been increasing interest in semiconductor materials, which find applications in optoelectronic, photovoltaic industries and photo electrochemical solar cell devices. Among these materials, LaF_3 thin films appear to be promising candidates for many technological applications due to their stability, band gap energy (about 10.3eV) [1] transparency and photoconductor behavior. A disadvantage of this material is the aging, that is, the slow spontaneous oxidation of porous silicon (PS) [2]. Porous silicon (PS) can be considered as a silicon (Si) crystal having a network of voids in it [3]. This chemical conversation is slow and basically similar to the aging of Si wafer, i.e, a native oxide layer forms on the surface of the pores and the thickness of this oxide layer grows with time. Due to the aging effect, the structural, compositional, electrical and optical properties of PS show continuous change with storage time [2]. That is many of its properties, such as photoluminescence, are age dependent and unstable. Tischier et al. observed that the exposure of PS in different ambient results in a rather rapid decrement of photoluminescence (PL) intensity [4]. One possible way to reduce the aging effect could be "passivation" of PS. Passivation is defined as the process of forming a protective film on an active material surface to reduce the chemical reactivity of the surface and protect it against contamination and increase its stability by isolating the surface from chemical and electrical conditions in the environment. Over the years, many passivation methods, such as anodic oxidation and rapid thermal oxidation, have been attempted to improve the stability, as well as efficiency, of PS. However these passivation methods always carry the danger of a total oxidation of the PS layer and of transforming it into SiO_2. Because of various advantages of LaF_3 like good moisture resistance [5], large bad gap [1], passivation of porous silicon has been investigated for the first time in our previous articles [6]. By reacting $LaCl_3$ with hydrofluoric acid (HF), LaF_3 has been tried to deposit in to the pores of porous silicon (PS) surface with a goal of not to allow the PS sample to be oxidized during transportation and drying for passivation like other deposition techniques [6]. This article reports the influence of light intensity on the I-V characteristics of LaF_3/PS structure.The I-V characteristics of

LaF_3/PS structure for different light intensities are drawn.

2. Experimental

The porous silicon has been prepared in the home made double tank cell by anodic etching of silicon wafer [7]. The anodic etching of Si was done in a 1:1 (for n-type silicon) solution of 48% HF and absolute ethanol and for p-type it was 3:1. The LaF_3 films with different $LaCl_3$ concentration and annealing temperatures were prepared.

Just after the anodic etching the etching solution was drained out and the fresh HF was introduced in the chamber to wash out any remaining etching solution on the chamber. After draining out the washing HF, solution of $LaCl_3$ and 48% HF were introduced simultaneously into the etching chamber to initiate the chemical reaction and produces LaF_3 that deposits on the just prepared PS sample. Thus the PS is never exposed to the environment before passivation and this CBD method of LaF_3 deposition should prevent the PS to be oxidized.

The LaF_3 deposited PS samples have the light effect on its I-V characteristics.

Anodic etching was carried out using an electrolyte of HF (48%) and ethanol (98%) in 3:1 proportion under a constant current density of 15mA/cm^2 for 30 min at room temperature. The electrochemical anodization of Si wafer was done using a double tank cell set-up [6]. The wafer was cut into pieces and these pieces of Si wafer were cleaned by successively immersing in acetone, ethanol and deionized water. The electrolyte consisted of HF: C_2H_5OH in the ratio of 3:1 by volume (for p-type Si wafer). A 100W tungsten lamp was used for illumination from 15 cm distance. After 30 minute anodization, the etching solution and back contact solution was drained out keeping the samples in the etching chamber [7]. Fresh HF was then introduced in the chamber to wash out any remaining etching solution on the chamber. After draining out the HF that used for washing, 0.2 M, 0.4M or 0.6M solution of $LaCl_3$ and 48% HF were introduced simultaneously into the etching chamber through the "HF in" and "$LaCl_3$ in" channels to do the chemical reaction. The chemical reaction that produces LaF_3 is pretty simple, at room temperature, the addition of hydrofluoric acid to an aqueous solution of lanthanum chloride precipitates out lanthanum fluoride, LaF_3 [8]. The formation of white precipitate (LaF_3) confirmed the mechanism of film formation.The basic reaction during LaF_3 deposition is given below:

$$LaCl_3 + 3HF \rightarrow LaF_3 + 3HCl$$

The solution inside the etching chamber was stirred for 10 seconds and resulting LaF_3 crystals were allowed to passivate the PS layer for 4 min. After each cycle of reaction the solution was drained out through the "Solution out" channel and a new solution was introduced into the chamber for the next deposition cycle. In this case, the deposition results from a chemical reaction in solution, which may involve the surface silicon atoms, and in this case, we will speak of chemical grafting of the surface, and why the reaction is limited to the formation of one monolayer [9]. The whole process was repeated to obtain the various thickness of LaF_3 on to PS. After completing the required cycle the wafer was removed from the chamber, rinsed with de-ionized water and dried in air at room temperature.

The compositional investigations have been done by the energy dispersive X-ray (EDX) spectroscopy. For Current – Voltage (I-V) characterization of the lanthanum fluoride deposited PS sample, silver (Ag) film was evaporated onto the front and backside of the sample in a small area by using Edwards E-306A vacuum coating unit. Then the copper wires were connected onto the Ag layer, on both sides with silver paste. The arrangement for I-V characterization is shown in Figure 1.

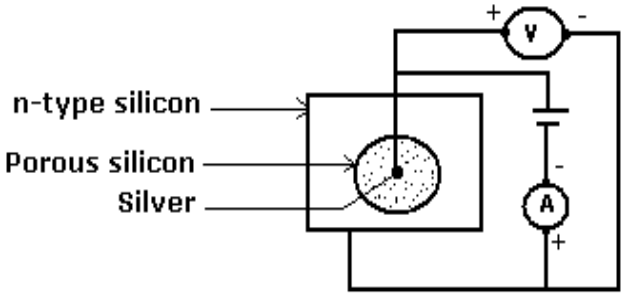
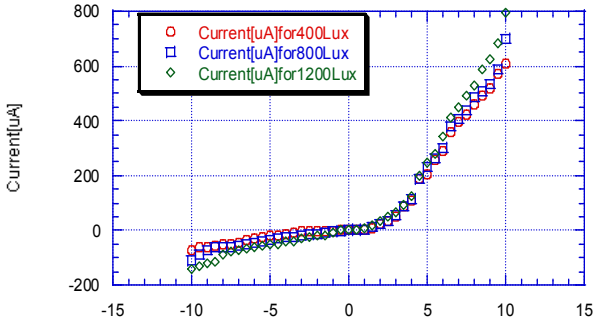
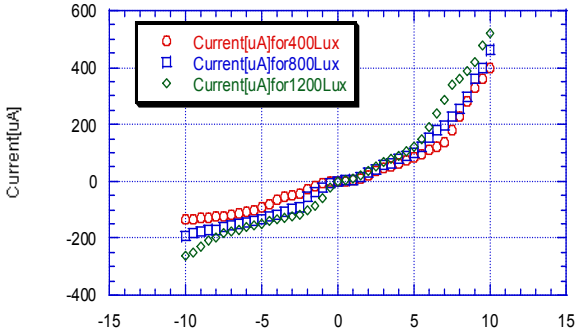


Figure 1. *Arrangement for I-V characterization.*

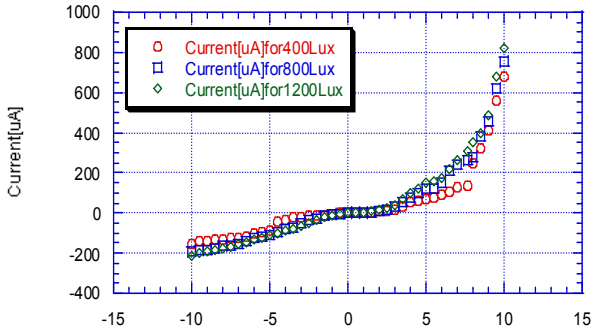
3. Results and Discussion



(a)



(b)

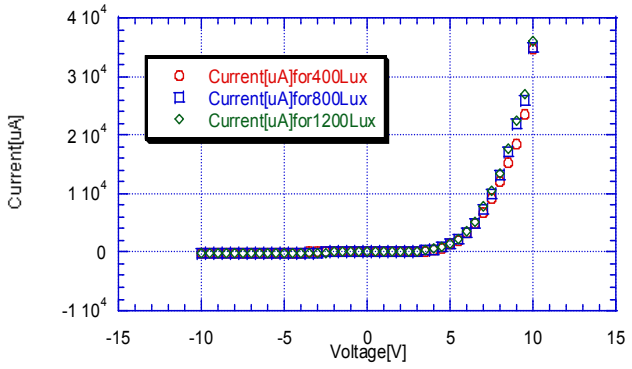


(c)

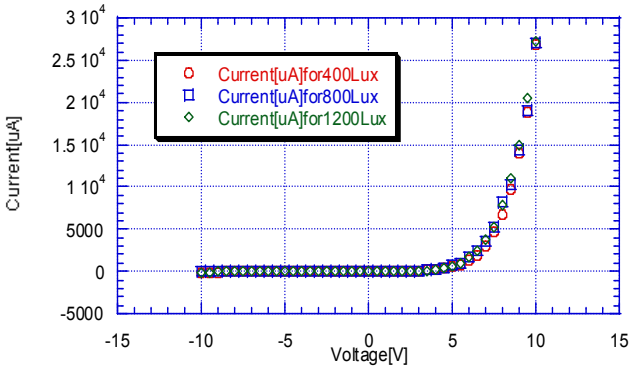
Figure 2. *I-V curve of: (a) 0.2M, (b) 0.4M and (c) 0.6M samples at 200°C annealing temperature for different light intensities.*

The chemical-bath deposited LaF_3 on porous silicon produces a heterostructure system (LaF_3/PS/Si). The effect of light intensity on I-V characteristics of LaF_3 passivated porous silicon structure are shown in Figures 2, 3 and 4. The light intensities were measured by lux meter.

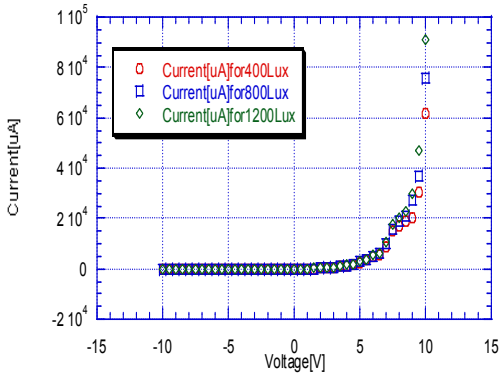
From above Figures (from Figure 2 to Figure 4) it is clear that the forward current as well as the reverse current increases with increasing light intensities for each sample. This variation is shown in Figure 5. It is also noted that for some samples the reverse current is low and for some samples it is very high.



(a)



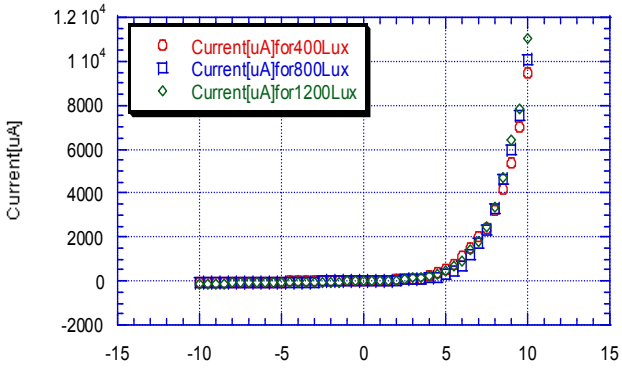
(b)



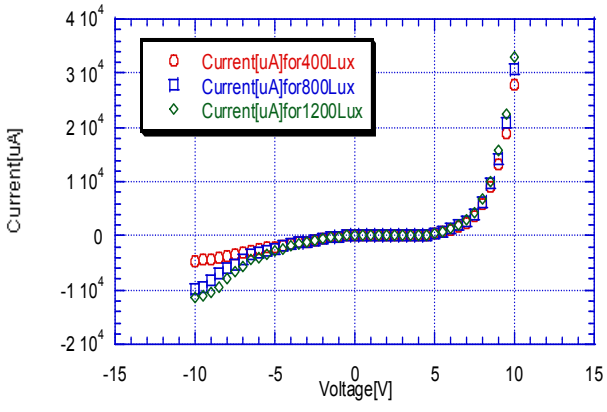
(c)

Figure 3. *I-V curve of: (a) 0.2M, (b) 0.4M and (c) 0.6M samples at 600°C annealing temperature for different light intensities.*

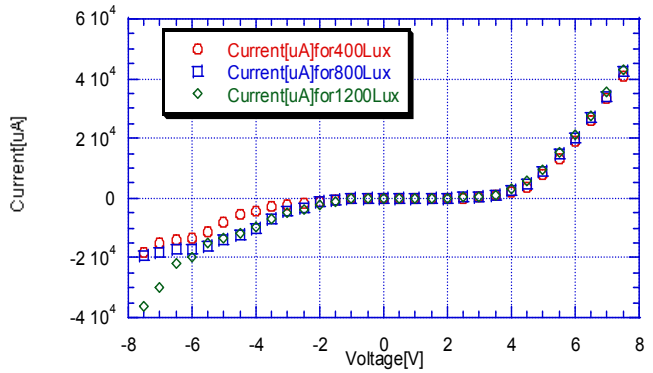
In this report LaF_3 was deposited on PS by CBD technique with a home made double tank cell setup. From the EDX data it was confirmed that the LaF_3 was deposited on PS in the in-situ technique. Later the influence of Light intensity on the I-V characteristics of LaF_3/PS structure has been investigated. The forward current as well as the reverse current increases with increasing light intensities for each sample at any bias voltage.



(a)



(b)



(c)

Figure 4. *I-V curve of : (a) 0.2M, (b)0.4M and (c) 0.6M samples at 400°C annealing temperature for different light intensities.*

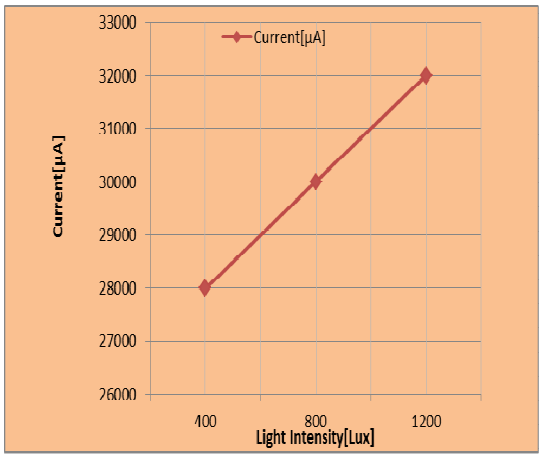


Figure 5. *Variation of forward current with light intensity for 0.4M 400°C annealed sample at the bias voltage of 10V.*

4. Conclusions

Hence, from this research, it can be concluded that LaF_3 can be efficiently deposited on PS by the CBD technique. The aim of this work was to investigate the influence of light intensity on the I-V characteristics of LaF_3/PS structure. The EDX confirmed the deposition of LaF_3 on PS. From these experimental results it can also be concluded that the passivating layer of LaF_3 on PS can be optimized by the $LaCl_3$ concentration and annealing temperature. This optimized layer of LaF_3 can enable the PS to be an important material in electronic and optoelectronic device fabrication.

References

[1] T.Pilvi, E. Puukilainen, K. Arstila, M. Leskela, and M. Ritala, " Atomic Layer Deposition of LaF_3 Thin Films using $La(thd)_3$ and TiF_4 as Precursors" che. Vap. Deposition,14, 85-91,(2008).

[2] Boukherroub R et al. (2000). "Thermal route for chemical modification and photoluminescence stabilization of porous silicon", Phys. Stat. Sol. (A), 182, 117-121.

[3] Andrea Edit Pap, Faculty of Technology, University of oulu, P.O. Box 4000, FIN-90014 University of oulu Finland.(http://herkules.oulu.fi/isbn9514277759/).

[4] Yimin Fan, School of Materials Science and Engineering, Shanghai University Shanghai 201 800, China.

[5] R.H. Hopkins, R.A. Hoffman, W.E. Kramer, Appl.Opt 14, (1975), 2631.

[6] Abdul Al Mortuza, Md. Hafijur Rahman, Sinthia Shabnam Mou, Md. JulkarNain and Abu Bakar Md. Ismail, "Passivation of Porous Silicon by LaF3 Using a Simple Single-Source Chemical Bath Technique", International Journal of Materials and Chemistry, Vol.2, No.4, August 2012, pp 111-115 .

[7] A. Halimaoui 'Porous silicon formation by anodisation'. In: Properties of porous silicon, ed. by L.T. Chanham (IEE INSPEC, The Institution of Electrical Engineers, London) (1997) 12-13.

[8] Patnaik P (2002). "Handbook of Inorganic Chemicals", McGraw-Hill Professional, New York. 448.

[9] Herino R (2000). "Nanocomposite materials from porous silicon", Mater. Sc. Eng. B, 69–70, 70–76.