



ELSEVIER

Contents lists available at ScienceDirect

Materials Letters

journal homepage: [www.elsevier.com/locate/matlet](http://www.elsevier.com/locate/matlet)

# White light from annealed porous silicon: Broadband emission from violet to the near infrared



Oscar Marin <sup>a,\*</sup>, Ana María Gennaro <sup>b,c</sup>, Mónica Tirado <sup>d</sup>,  
Roberto R. Koropecski <sup>b</sup>, David Comedi <sup>a</sup>

<sup>a</sup> CONICET-LAFISO-Nanoproject, FACET, Universidad Nacional de Tucumán, Av. Independencia 1800, 4000 San Miguel de Tucumán, Argentina

<sup>b</sup> IFIS-Litoral (CONICET-Universidad Nacional del Litoral), Güemes 3450, 3000 Santa Fe, Argentina

<sup>c</sup> Departamento de Física, Facultad de Bioquímica y Ciencias Biológicas, Universidad Nacional del Litoral, Ciudad Universitaria, 3000 Santa Fe, Argentina

<sup>d</sup> CONICET-LNPD-Nanoproject, FACET, Universidad Nacional de Tucumán, Av. Independencia 1800, 4000 San Miguel de Tucumán, Argentina

## ARTICLE INFO

### Article history:

Received 4 December 2014

Accepted 2 March 2015

Available online 9 March 2015

### Keywords:

White light emission  
Photoluminescence  
Porous silicon  
Silicon dioxide  
Oxygen-excess defects

## ABSTRACT

We report white light emission under UV excitation from porous silicon (PS) samples annealed at different temperatures and surrounding atmospheres. The photoluminescence (PL) spectra show a broad emission from ultraviolet to near infrared. Annealed PS samples were studied by photoluminescence, FTIR and EPR spectroscopies. The PL spectra were found to include three main components centered at the violet, green and infrared. The FTIR experiments suggest the formation of a system composed by silicon nanocrystals embedded in a nonstoichiometric silicon oxide matrix (nc-Si/SiO<sub>x</sub>). The EPR measurements reveal the existence of the well-know  $P_{b0}$  ( $g \sim 2.007$ ) and  $P_{b1}$  ( $g \sim 2.004$ ) centres, and of a signal at  $g \sim 1.9997$ . The combined PL, FTIR and EPR results suggest that violet and green emissions come from oxygen-excess defects in SiO<sub>x</sub> while the infrared emission is related to defects located at Si/SiO<sub>x</sub> interfaces.

© 2015 Elsevier B.V. All rights reserved.

## 1. Introduction

In the last decade, light emission from porous silicon (PS) and similar systems such as silicon nanocrystals embedded in SiO<sub>x</sub> and silicon nanowires have been subject of extensive investigation. However, a full understanding on the processes and the mechanisms involved in the light emission from these materials have not been achieved and are still under debate [1]. Several models have been proposed to explain the visible photoluminescence (PL) from PS, the quantum confinement (QC) and the quantum confinement/luminescent centers (QCLC) models being the most widely invoked [2]. Depending on the size of silicon nanocrystals and the nature of oxygen species formed during oxidation, different processes may occur. Extensive discussions of the different models that describe the behaviour of the PL from PS and other types of nanostructured Si can be found in references [3–6]. White luminescence from materials and devices is a topic that has attracted great interest due to its relevance for potential applications in white light illumination devices. To our knowledge, white light emission from bare PS has been reported rarely. Tsai et al. [7] and Karacali et al. [8] reported the white PL in the 350–700 nm range

from p-type PS annealed at high temperature and from oxidized/carbonized PS, respectively. The purpose of this work is two-fold: (A) to show that white light emission from n-type PS that extends to a broader range into the near-IR (~900 nm) can be achieved by annealing samples in Ar+O<sub>2</sub>, and (B) to elucidate, combining PL with electron paramagnetic resonance (EPR) and Fourier transform infrared (FTIR) spectroscopies, the physical origin of the components to the broad PL spectra observed.

## 2. Experimental section

The PS samples were obtained from anodization of n-type crystalline silicon. Fabrication details are described in a previous report [9]. The annealing processes were carried out in a quartz tube placed in a horizontal tubular furnace under constant Ar and O<sub>2</sub> flow rates. The as-prepared PS samples were placed at 19.5 and 23.5 cm from the centre of the furnace downstream. The furnace was heated to 1100 °C at a rate of 27 °C/min and then kept at 1100 °C for 20 min. The temperature at the PS substrates positions reached 950 and 840 °C, respectively. In order to study the role of the O<sub>2</sub> flow, two different O<sub>2</sub> flow rates were used (8 and 40 sccm, while the Ar flow rate was kept constant at 125 sccm). PL spectra were excited by illuminating the samples at ambient air with a He–Cd laser set at a wavelength of 325 nm with 15mW power over

\* Corresponding author. Tel.: +54 381 4364093; fax: +54 381 436 4157.

E-mail addresses: [omarin@herrera.unt.edu.ar](mailto:omarin@herrera.unt.edu.ar),  
[alquimarin@gmail.com](mailto:alquimarin@gmail.com) (O. Marin).

an area of  $0.031 \text{ cm}^2$ . All PL spectra were corrected for the detection system response. The FTIR transmission measurements were carried out in a ThermoScientific model 3000 spectrometer. The EPR experiments were performed in a Bruker EMX-Plus EPR Spectrometer in the X Band. The magnetic field was applied parallel to the  $\langle 100 \rangle$  axis of the PS crystalline Si substrate.

### 3. Results and discussion

Fig. 1(a) and (b) show the PL behavior for an as-anodized PS sample and its evolution while being irradiated with the HeCd laser excitation source. As shown, a peak at 637 nm is observed which is initially quenched, reaching a minimum intensity after 8 min, followed by an increase for larger irradiation times. Concomitantly, a monotonic redshift of the PL peak position is observed throughout the experiment. This behavior would be in disagreement with a simplistic interpretation of the QC model, which predicts a blueshift as a result of the reduction of the nanocrystalline size due to photo-oxidation process. Alternatively, the results shown in Fig. 1 may be explained by the QCLC model, which proposes that excitons are created in the nanocrystalline silicon and transported to the c-Si/SiO<sub>2</sub> interfaces to recombine radiatively in specific centers. Taking this into account, it is reasonable to suggest that the UV illumination leads to the creation of silicon dangling bonds (which act as efficient non-radiative recombination centers) by photoinduced hydrogen diffusion and effusion, as previously suggested [10] and, as a consequence, the quenching of PL intensity is observed for short times. This process is counterbalanced by the activation of previously H-passivated luminescent centers at the c-Si/SiO<sub>2</sub> interfaces emitting in the NIR that lead to both, the redshift and increasing PL intensity for longer times.

Fig. 2(a and b) shows the PL behavior of annealed PS at different conditions (varying temperature and O<sub>2</sub> flow rate) and their respective fit with 3 Gaussian components. After the annealing treatment, a broad white light emission from 350 to 900 nm was observed, which can be decomposed in NIR ( $\sim 760 \text{ nm}$ – $E \sim 1.65 \text{ eV}$ ), green ( $\sim 500 \text{ nm}$ – $E \sim 2.47 \text{ eV}$ ) and violet emissions ( $\sim 400 \text{ nm}$ – $E \sim 3.1 \text{ eV}$ ) for all samples. In Fig. 2(c), the relative intensities of these components are depicted. It is seen that PL intensities are greater for samples annealed with higher oxygen flow rate. In addition, the intensity of violet and infrared emissions are strongly affected (the former decreases and the latter increases) when the annealing temperature is increased from

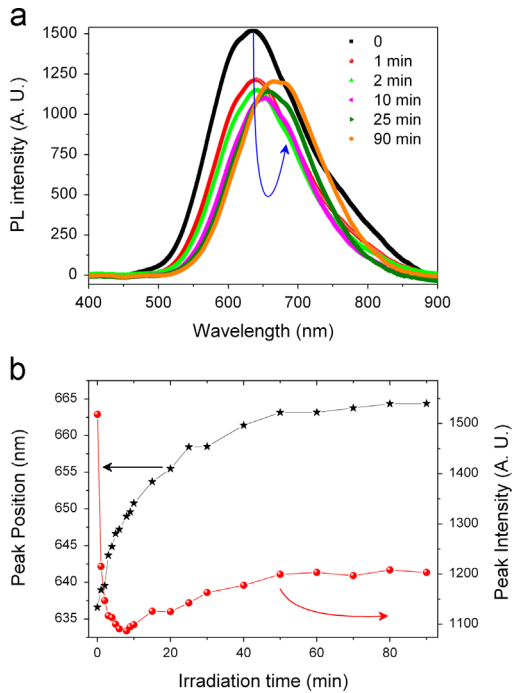


Fig. 1. (a) PL spectra from the as-anodized PS sample (curve arrow shows the evolution of PL peak) while being irradiated with 325 nm photons, (b) evolution of the PL peak intensity and position.

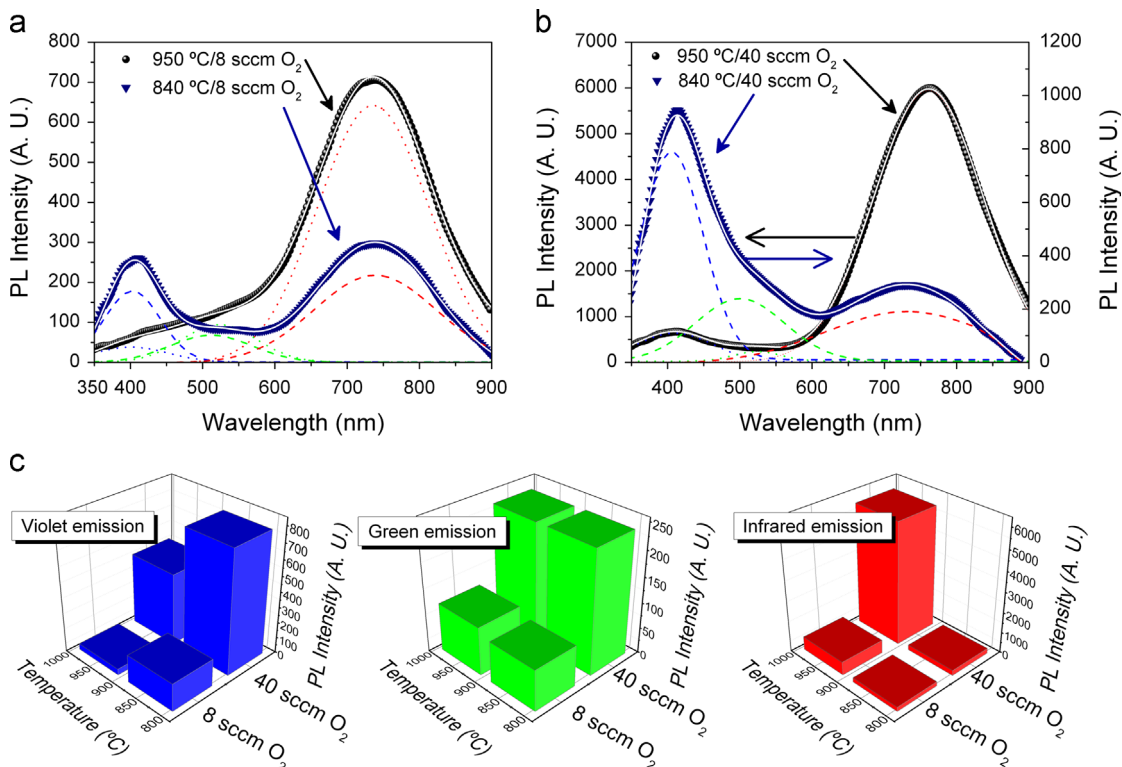


Fig. 2. (a and b) PL spectra from annealed PS at different conditions. (c) Relative intensity of PL components. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Download English Version:

<https://daneshyari.com/en/article/1642646>

Download Persian Version:

<https://daneshyari.com/article/1642646>

[Daneshyari.com](https://daneshyari.com)