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# UV-Vis Photocurrent in SiOx films with Silicon Nanocrystals obtained by HFCVD

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**Abstract**

Actually, optical and electrical characteristics of the SiOx films need to be understood in order to improve and propose optoelectronics devices. Non-stoichiometric silicon oxide ($SiO_x$) films with embedded silicon nanocrystals (Si-ncs) were obtained by hot filament chemical vapor deposition (HFCVD) technique. The authors report high photocurrent of two-terminal metal-oxide-semiconductor (MOS)-like where light is absorbed in the SiOx films with Si-ncs on n–type silicon substrates. Operated at both bias (reverse and direct), where enhanced photocurrent and increased when applied white light, short UV and large UV were observed. The optical properties as photoluminescence and absorption spectra were obtained. Current-Voltage (I–V) measurements in dark and under illumination conditions were realized. The Si-ncs and defects in the SiOx films should have an important role in the high photocurrent. We assume that a high response of the SiOx/Si junction is achieved probably due to a combined effect of the optical down conversion and photo excited electrons in the SiOx films.


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*Keywords:* Non-stoichiometric silicon oxide; Photoluminescence; Transmittance; Current-Voltage; HFCVD.

## 1. Introduction

After discovery of visible light emission at room temperature in the porous silicon by Canham [1] in 1990, many

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researches have studied emission properties of materials that contain Si nanoparticles (Si-nps) as the non-stoichiometric silicon oxide (SiOx), because of their technological importance and its interesting optoelectronic properties. In the SiOx films the absorption and emission properties are correlated with quantum effects in silicon nanoparticles, and also associated with defects [2]. From the technological standpoint, the average size of silicon nanoparticle (Si-np) offers band gap widths, which opens the possibility to tune the emission of light using nanostructured thin films in novel optoelectronic devices.

Si-based photodetectors with a simple and compatible process with a circuit's integrated technology is of high priority. Metal-oxide-semiconductor (MOS) structure is a good candidate for such a purpose. However, the insulating oxide layer blocks the photocurrent to be collected, this problem is solved with a simple SiOx containing Si-ncs films [1], the oxide layer that contains Si-ncs is an approach for high performance photodetectors [2]. Silicon (Si) is a material with low response to ultraviolet (UV) light, but Si carbide, Porous Si and others Si-based materials have been used for UV photoresponse. Therefore, SiOx which is a variation of silicon dioxide, where the content of Si is changed. Depending on the excess of the Si content, Si-ncs appears and the SiOx possesses some special properties such as charge trapping, carrier transportation and photoluminescence. Some novel devices have been proposed using these properties [1-3]. In this work, optical properties of SiOx films with Si-ncs were studied to know its relation with the photodetection of the structures MOS-like realized with these films. The photocurrent range goes from UV to Vis radiation, with high responsivity in whole range. These films with this structure type are compatible with circuit's integrated technology.

## 2. Experiment

SiOx films were deposited on N type Si (100) substrates with resistivity of 1-10 Ω-cm. SiOx films were obtained in a vertical HFCVD hot wall reactor using three different hydrogen flows 25, 75 and 100 sccm using quartz rods (of 5.3 cm length, 2 mm diameter) like source. The filament-source distance (dfs) and the distance source-substrate, which determines the growth temperature, were fixed at 3 mm and 3, 4, 5 and 6 mm, respectively. Table 1 shows the characteristics of the growth films.

Table 1. SiOx Films as-growth.

| Flows (sccm) / dfs (mm) | 25 | 75 | 100 |
|---|---|---|---|
| 3 | A1 | C1 | D1 |
| 4 | A2 | C2 | D2 |
| 5 | A3 | C3 | D3 |
| 6 | A4 | C4 | D4 |

FTO (Fluorine doped tin oxide) circles were patterned on the SiOx films surface. The diameter of the circles electrodes was 1mm. Fig. 1 shows an image of the fabricated structure.

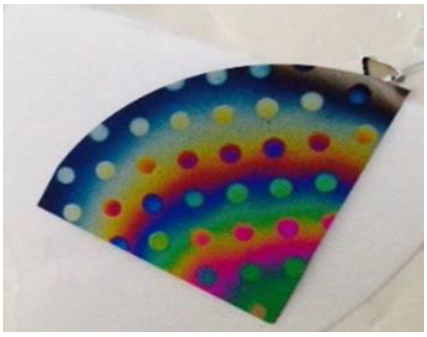

Figure 1. Structure MOS-like with FTO contacts.

## 3. Result

Figure 2 shows the UV-Vis transmittance spectra of the SiOx films as-grown deposited on quartz with three different flows. All the samples exhibited a relatively high transmittance (>70%) between 500 and 1000 nm. The change in the growth temperature produces a shift of the absorption edge towards lower wavelength related to a silicon excess change of the material [3]. The change in the growth temperature produces an increase of absorption coefficient α tending to the absorption coefficient of the silicon.

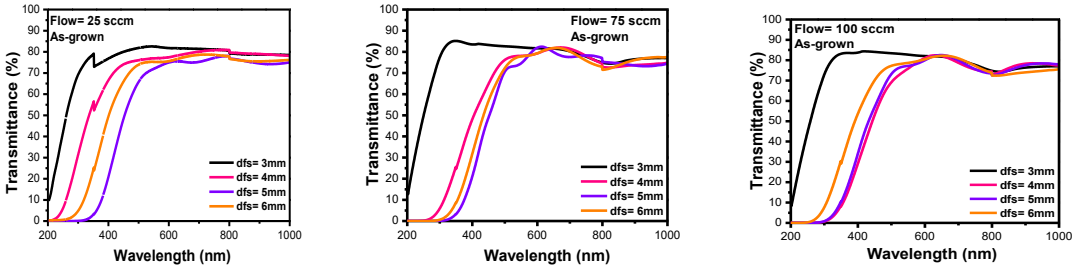


*Figure 2: Transmittance of the SiOx films as-grown to different hydrogen flows.*

Figure 3 shows the photoluminescence spectra of the SiOx films as-grown deposited on silicon with three different flows. A wide PL spectrum centred to 750 nm with a similar shape to a Gaussian curve is observed in all samples, others weak peaks in 470 nm and 700 nm are observed, these peaks are the emission components of the PL spectra, and have different origins.

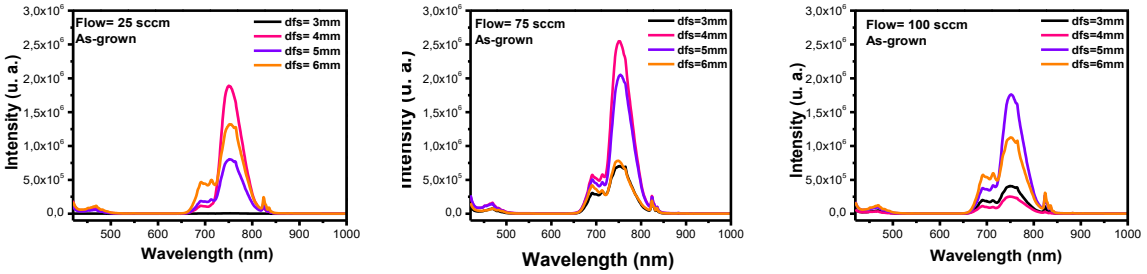


*Figure 3: Photoluminescence of the SiOx films as-grown to different hydrogen flows.*

Figure 4 show the I-V curves of the structures MOS-like obtained with SiOx films as oxide and FTO as metallic contact, in this case FTO is used as a transparent conductive oxide; FTO is an excellent material, transparent and good conductor. The photocurrent of the MOS-like structures were measured in dark and white and UV light, the photocurrent obtained when the illumination is applied is very high in some cases and depends on the hydrogen flow with the SiOx films was growth. We can see that the photoresponse with UV light was very high in all cases, but a more carefully analysis is necessary with all obtained samples, because in some samples with SiOx films the response with white light is high too.

## 4. Discussion

The shift of the absorption edge towards lower wavelength related to a silicon excess change of the material [3] is an interesting optical property. According to the results of the optical properties of the SiOx films, we can correlate the evolution of the intense PL with the shift of the absorption edge (obtained by Transmittance). So, we may assume

that the Si excess increases as the growth temperature increases [6-7]. On the other hand, the mechanism of light emission of the SiOx films is related to some kinds of defects produced during the growth process such as, weak-oxygen bonds (WOB), neutral oxygen vacancy (NOV), non-bridging oxygen hole center (NBOHC), positively oxygen vacancy (E' center), interstitial oxygen molecules and peroxide radicals [4-7]. Some of these defects, such as NOV and NBOHC are the principal radiative recombination centers or the luminescence centers, these centers contribute to light absorption and to improvement the photodetection, which is observed in results of measurements electrics. The I-V curves show a high photocurrent behavior with white and UV light, in this case an analysis to understand this behavior is necessary.

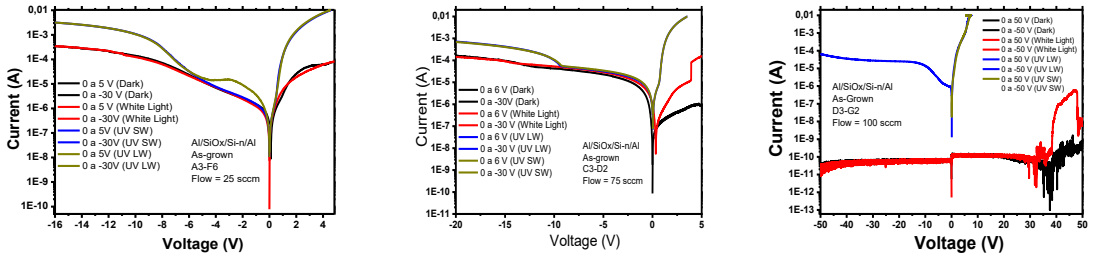


*Figure 4. Dark current and photocurrent under white light and short and large Ultraviolet light of the structure MOS-like with SiOx films as-grown to different hydrogen flow.*

## 5. Conclusions

In this work, the SiOx films have interesting optical properties as a shift of the absorption edge towards lower wavelength and the photoluminescence in the red is due to excitation with light UV. Therefore, when the structure MOS-like are illuminated with white and UV light, the photons are absorbed by SiOx films and electron-hole pairs are produced to generate a photocurrent, the photocurrent increased depend of the type of SiOx films as-growth.

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