UV Silicon Sensor with Si Nanocrystals

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1. ABSTRACT

In this work, it is shown the design, fabrication and characterization of a Silicon/Silicon Rich Oxide (SRO) Ultraviolet sensor. The main characteristic of it is that increases the silicon detection range in the ultraviolet region (200-320 nm). Besides, the fabrication process of this detector is compatible with commercial silicon technology which makes it cheaper than commercial UV ones.

Keywords: SRO, UV, Silicon, Sensor.

2. INTRODUCTION

After the discovery of photoluminescence emission of silicon (Si) nanocrystals embedded in silicon dioxide, efforts have been done to take advantage of such emission. To obtain silicon nC many techniques have been reported [1, 2, 3], however CVD (Chemical vapour deposition) is a simple way to obtain silicon rich silicon oxide (SRO). The SRO normally is modelled as silicon dioxide which contains silicon nC. In other studies, it was shown that SRO obtained by LPCVD (low pressure CVD) radiates intensely when it is illuminated by UV energy [2]. As we can observe in figure 1 the SRO emissions match the wavelength range in which the silicon is very sensible.

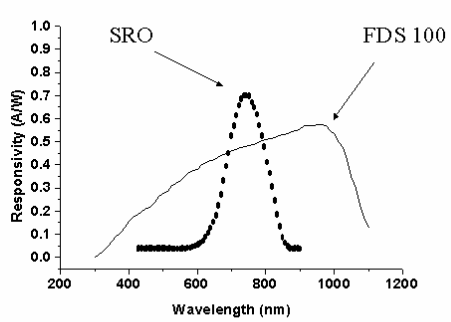

Figure 1. Comparison of the SRO emission with the Silicon diode detection.

Furthermore, UV detectors are, currently, a subject of intense research due to the wide field of applications, as: DVD readers, communications systems, fire detection, UV astronomy, medicine and others [4, 5].

In this paper, an UV silicon detector made of silicon and SRO* is reported. This sensor show high efficiency, and is completely compatible with silicon technology.

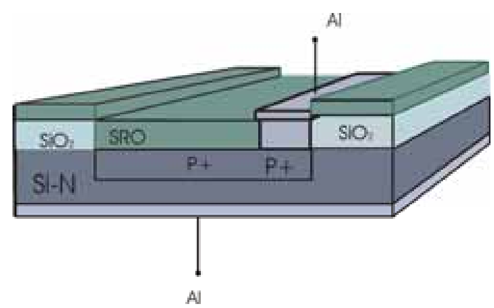

Figure 2. Basic proposed structure sketch of a silicon UV photodetector.

3. SILICON UV DETECTOR

In the figure 2 is shown an idealization of the integration of the SRO with a silicon photodetector that allows the UV radiation detection.

The UV is applied on the SRO film, which radiates emitting infrared and visible light; this emission reaches the silicon photodetector that generates a photocurrent proportional to the UV radiation.

A simple device to detect light is the pn diode. Their main limitation as photodetectors it's the dark current. This current defines the minimum energy detectable for the diode. As the incident radiation exceeds the band gap energy the efficiency to produce electron hole pairs that contribute to the photocurrent is reduced. Even with silicon detectors improved technologically to detect UV energies the responsivity of these devices is too low. However, for the sensor structure here proposed the responsivity is very high.

* Patent pending

4. EXPERIMENTAL METHOD

4.1 Fabrication process

The characteristics of the used substrate are: 8 ohms cm, P type, 10 microns epitaxial silicon wafers. Initially a cleaning process on the wafer is done, and an oxide to define the diffusion region is grown. Then, the oxide is etched and standard phosphorous diffusion was used to form the pn junction. On the top of this structure SRO film, obtained by LPCVD was deposited. Then, a film of PSG is deposited and annealed in H_20 and N_2 during 30 min. Finally contacts were etched and aluminium contacts were patterned. Some of the devices were mounted on IC frames.

4.2. Characterisation

In order to characterize the UV sensor, we use a Perkin Elmer Lambda 3 spectrophotometer with a 190-900nm wavelength range with Deuterium and tungsten bromide lamps. The current was measured using a 617 Keithly electrometer. In figure 3, it is shown the circuit used to measure the device photocurrent. The same circuit was also used to measure the photocurrent of a commercial pn diodes UV enhanced. These diodes were used to compare and to determine the power shining on both devices.

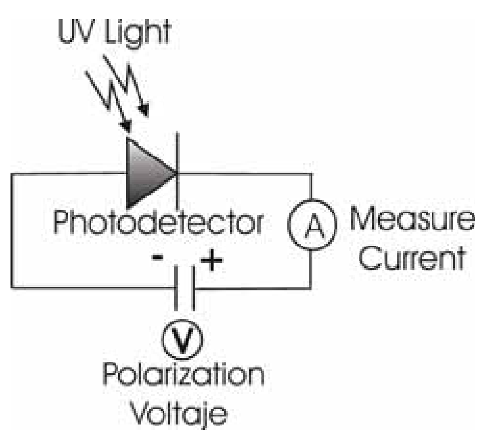

Figure 3. Electrical scheme to characterize the UV sensors

The UV, visible and infrared radiation that is applied on the sensor comes from a LS-50B Perkin Elmer spectrophotometer. When light shines on the sensor it produces a photocurrent in the external polarization circuit, this photocurrent depends on the incident light.

5. RESULTS

In figure 4, it is shown the UV sensor's typical dark current against voltage curve. As we can observed an acceptable rupture voltages and low dark current was obtained.

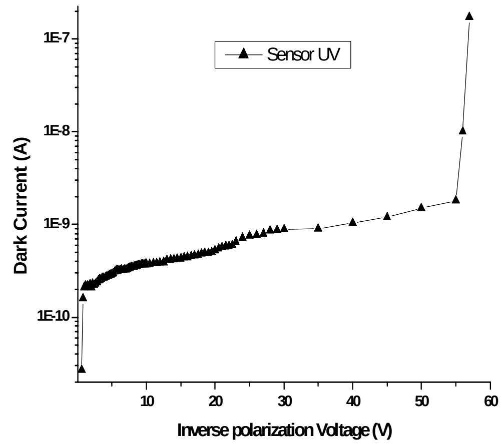

Figure 4. Typical Dark currents against voltage for the UV sensors.

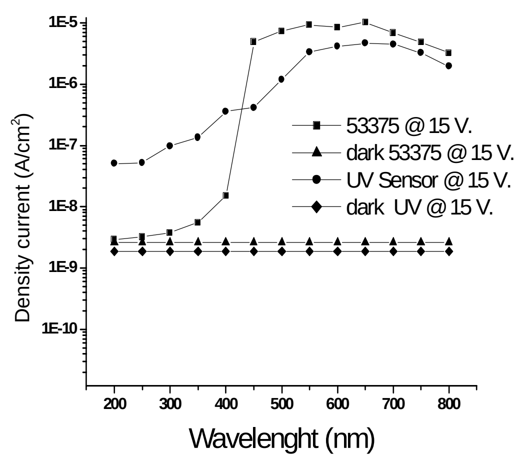

Figure 5. Photo current Density comparison between the UV proposed sensor and a commercial diode (53375).

In figure 5, the current density of a commercial photodetector is compared with that of our UV sensor. From these curves an increment in density current of our sensor of approximately one order of magnitude respect to the commercial silicon photodetector in the UV region (200-350nm) is observed. In the visible and infrared the results are almost the same.
In figure 6 a notably increment of the efficiency (responsivity) of our sensor in the UV region is observed,

compared to the commercial one. The responsivity of the commercial UV enhanced diode typical curve was provided by the vendor.

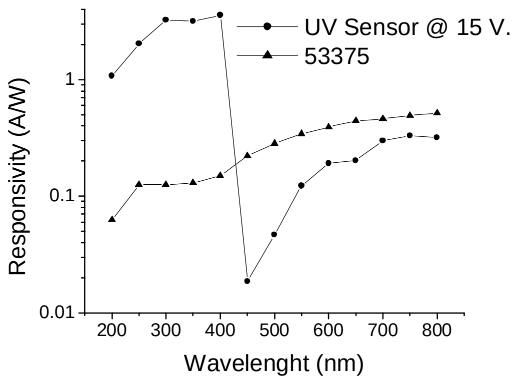

Figure. 6 Responsivity comparison of our UV sensor with the commercial photodetector.

6. DISCUSSION

We have three possible ways to explain the high efficiency show in the figure 6 of the sensor here proposes.

a). UV sensor's responsivity was obtained *by comparison* to a typical one of a commercial diode. In any case, it is clear that the responsivity obtained in the UV region is much higher.

b). Responsivity exceeding 1 A/W could mean that the wavelength shift from the incident UV to detectable wavelength is very efficient and almost UV the incident light contributed the SRO emission. It is, also, probably that light is emitted in the full body of the SRO and all that light contributes to the photocurrent, because the emitted light is in the range of high silicon efficiency, as shown in figure 1. So a double effect is combined to produce so high responsivity.

c). In other studies, it has been observed that when SRO layer are used to produce voltage induced pn junctions used as light detectors, high photocurrents are obtained even when the active area is covered by opaque aluminium [6]. So it is possible that SRO contributes in some way to the photocurrent, and then an extra contribution to the current has to be considered.

7. CONCLUSSIONS.

In this work an UV silicon sensor with high responsivity was proposed and tested. The detector shows higher responsivity than a UV enhanced commercial silicon photodetector.

The UV silicon sensor fabrication process is totally compatible with the silicon technology, and then is extremely economic to implement it in a production line.

Currently, the characterisation of the sensor continue, and efforts towards improve the structure of this are done with the goal to increase even higher the response in the UV region.

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