

Chapter 7 An UV to blue light detector constructed by 3-D Si

Nano-dots/SiO₂ arrays

7-1. Introduction

Mesoporous silica (MS) film naturally has highly surface-areas, contributed from regularly distributed nanopores (2-10 nm) [12], thus being a well three-dimensional (3-D) nanotemplate for Si NCs accommodation. In previous chapters, this constructed enormous Si NCs/silica arrays has been demonstrated as an efficient blue-luminescent nanomaterial. By this characteristic, we also fabricate an UV to blue light photodetector using this nanomaterial [35].

7-2. Fabrication of the photodetector

Molecularly templated mesoporous silica (MS_{as}) films are spin-coated on p-type silicon wafers, using sol-gel-prepared precursors that contain the organic template [15] of the triblock copolymer Pluronic P-123 (P123); they are then baked at 110°C for 1 h. This sample was then doped with Si NCs using high-density inductively coupled plasma (ICP) [14] at 400°C. The thickness was 300 nm and ITO of 1-μm thickness was deposited on the film, as shown in Fig. 7-1.

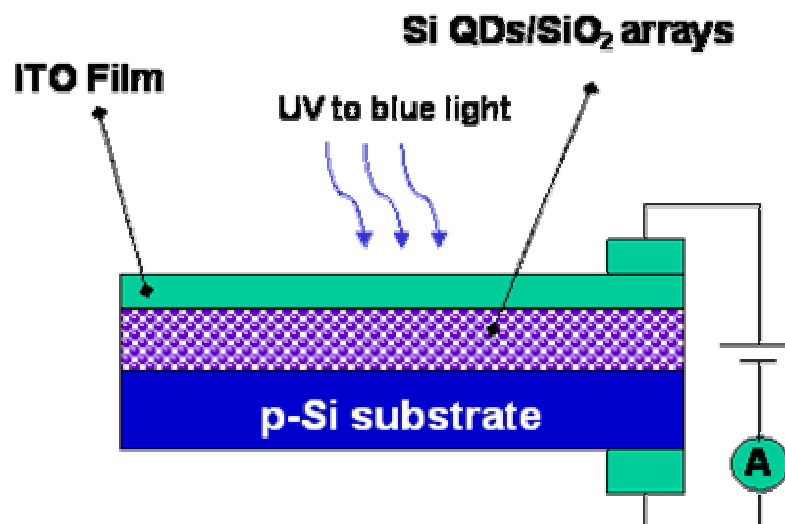


Fig. 7-1: Schematic of the Si NCs/silica arrays UV to blue light photodiode.

7-3. Properties of the photodetector

7-3.1 I-V characteristics

Fig. 7-2 (a) shows the current-voltage (I-V) curve under dark conditions. It shows somewhat rectifying behavior and dark current density as low as 2.3×10^{-5} A/cm² at 3V reverse bias. In photo-responsivity measurement, the He-Cd 325 nm laser at power of 2-10 mW is used as the light source and the spot size is focused to 1 mm in diameter. Fig. 7-2 (b) was taken with 2mW at 325 nm. It shows very strong rectification. The reverse current is enhanced by a factor of 15, while the forward current is almost unaffected. Fig. 7-2 (c) gives the difference of the responses taken with and without 325 nm light. We find curves (b) and (c) have two different slopes and the second slope represents saturated condition. Fig. 7-3 shows the I-V curves under different illuminated powers at 325 nm light. With increasing powers, the saturated voltage also increases. This is due to high power causes larger channel width and yields higher currents.

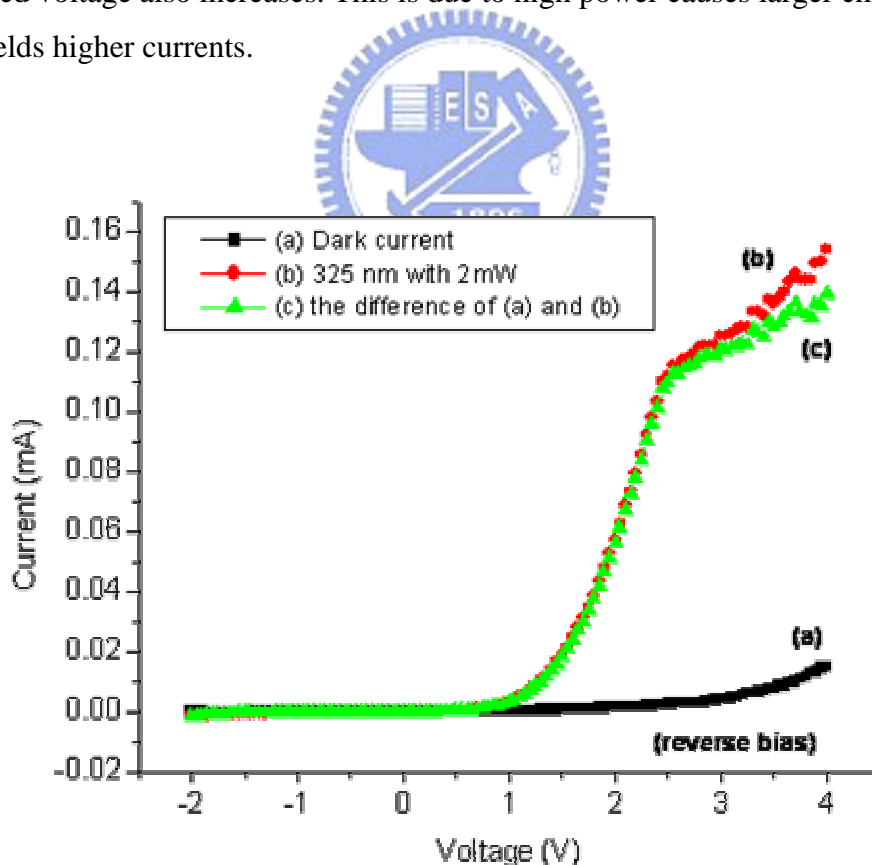


Fig. 7-2: I-V characteristics of a typical diode (a) taken under dark conditions, (b) taken with He-Cd 325 nm light, and (c) the difference of the responses (a) and (b).

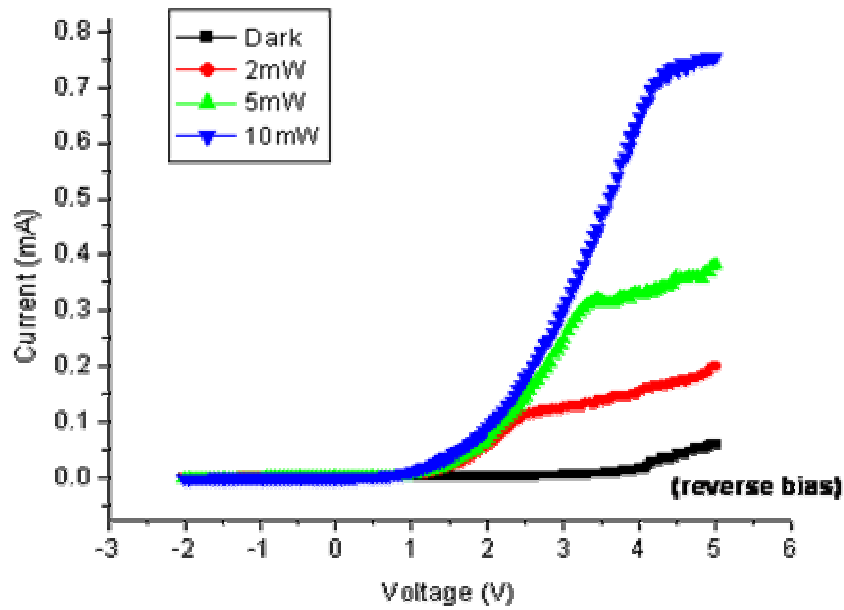


Fig. 7-3: I-V characteristics under different illuminated powers at 325 nm light.

7-3.2 Response versus wavelength

The spectral responsivity R is the product of the quantum efficiency for carrier generation and that of charge collection. The responsivity, measured using Xe lamps (shown in Fig. 7-4) at 3V reverse bias, drops to 0.17 A/W at 500 nm compared to 0.77 A/W at 370 nm.

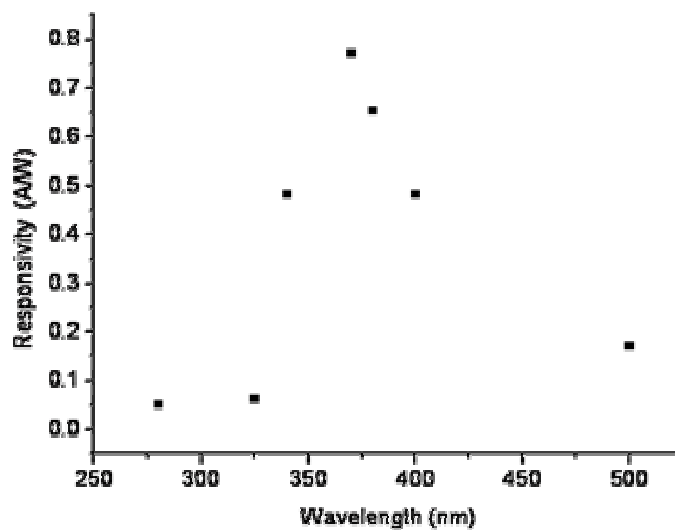


Fig. 7-4: Response versus wavelength at 3V reverse bias.

7-3.3 Comparison with other researches

O. M. Nayfeh, and S. Rao et al. investigated thin film silicon nanoparticle UV photodetector in 2004 [35]. The fabricating process of our photodetector is simpler than their process. And the dark current density of our sample is also lower than their sample. Table II shows the comparison with other researches about UV photodetectors.


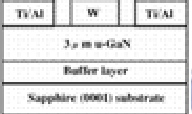
	Process	Dark current (3V)	Responsivity (3V)
Ref. 35	Complex	$6.8 \times 10^{-4} \text{ A/cm}^2$	0.85 A/W (365 nm)
Our sample	Simple	$2.3 \times 10^{-5} \text{ A/cm}^2$	0.77 A/W (370 nm)
GaN UV detector ^[36]		$1.0 \times 10^{-7} \text{ A/cm}^2$	0.01 A/W (350 nm)
GaN UV detector ^[37]		$1.8 \times 10^{-6} \text{ A/cm}^2$	0.15 A/W (360 nm)

Table II Comparison with other researches about UV photodetectors.

The gain and spectral responsivity are related to the uniformity of the particles, quality of particle packing, and thickness of the film [35]. Therefore, the best conditions of the photodetector will be obtained about mesoporous silica pore sizes and thickness.

7-3.4 Reliability

Fig. 7-5 shows the reliability of the photodetector at 2V bias with 370 nm light. During 600s measurement, the responsivity of this photodetector is stable about 0.385 A/W.

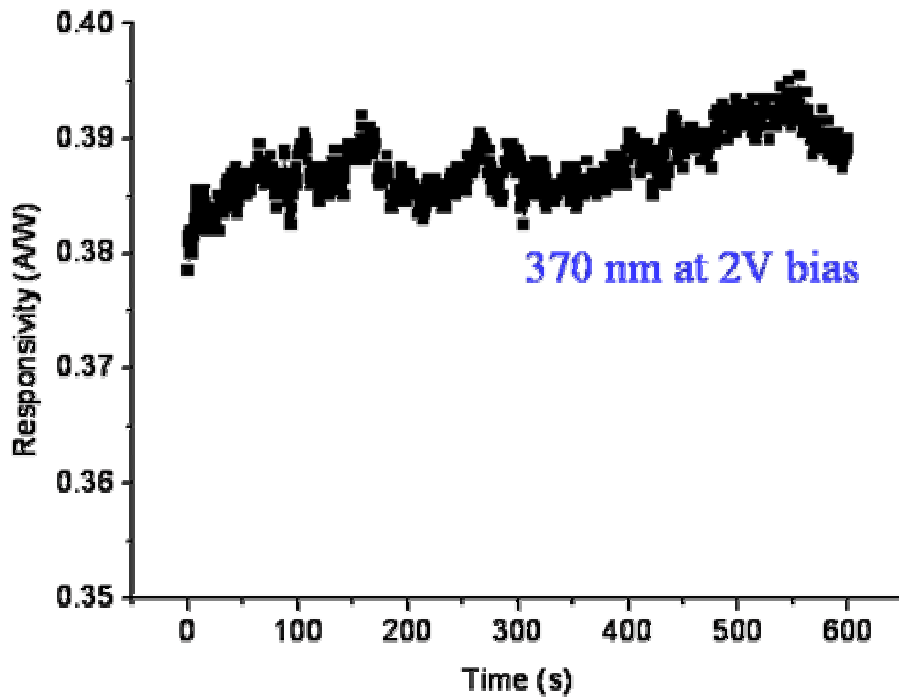


Fig. 7-5: Reliability of the UV to blue light photodetector.

7-4. Conclusion

We demonstrated an UV to blue light photodetector based on Si QDs/SiO₂ arrays. It provides high sensitivity under low biasing voltage. High efficiency allows the study of extremely small samples, and sensor array for high speed screening.