

Ultra Fast Response To Light Radiation In SnO₂ Microrods

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Abstract: SnO₂ microrods exhibited an ultra-fast photo-response when light led 402-940 nm was switched on and off. SnO₂ microrods films were prepared with SnCl₄ as the starting material. We found that increasing light radiation flux decreases the resistance. The effect of radiation on the film will be discussed as function of chemiabsorbed oxygen.

Introduction

Tin dioxide (SnO₂) have been widely used for gas sensor (1-3), transparent conductor (4) and ultraviolet photodetector (5).

Nowadays, ultraviolet photodetector have been fabricated with ZnO (6) and SnO₂ (7). There are a lot of techniques to obtain SnO₂ film such as physical vapor deposition, magnetron sputtering (8), thermal evaporation (9), spray pyrolysis (10), laser pulses deposition (11) and chemical vapor deposition (12).

A new generation of SnO₂ nanostructures have been produced recently, such as nanowires, nanobelts, nanorods, nanotubes and nanowhiskers (13-15). One of the main features of these nanostructures is the relationship surface/volume that makes them attractive to use them as photodetector. The challenge now is to achieve a manufacturing process of nanostructures compatible with micromachining processes.

Commercial semiconductor gas sensors operate at high temperatures (>300° C), because at room temperature the interaction of gas with the sensor surface is negligible.

Some authors demonstrated that illuminating metal oxide gas sensors with ultra-violet light is a viable alternative to activate chemical reactions at their surface without the necessity of heating them (16).

Experimental Procedure

Films growth: SnO₂ microrods were prepared with SnCl₄ and urea as the starting materials (17). Tin tetrachloride (SnCl₄) was chosen as the precursor because they produce a high-purity sol (18). The as-prepared precursor solution was spinner onto a silicon substrate where an interdigital array of gold electrodes had been previously evaporated. The as-coated sensor was then heated at 250° C in air for 2 hs to obtain the film. The surface morphology of the films were examined with X-Ray Diffraction and Scanning Electron Microscope.

The oxides of microstructures materials such as SnO_2 , possess a large surface-to-volume ratios . They can cause molecules to be absorbed or desorbed on the surfaces of the materials, causing the microrods space-charge layer and band to be modulated by the UV- light.

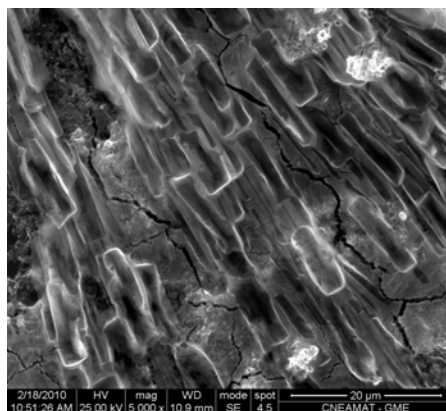


Figure 1. Typical SEM micrograph of the film

Figure 1 shows a typical morphology of the film where a microstructure formed by microrods can be observed. The film shows a high specific surface area, which is a prerequisite for gas sensor and a viable alternative to activate chemical reactions at their surface with UV-light. Fig 2 shows the XRD patterns of the film. The principal phase is cassiterite.

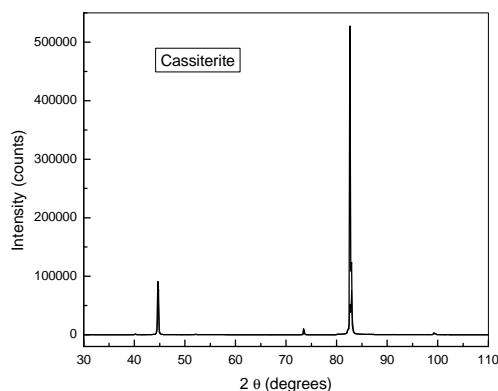
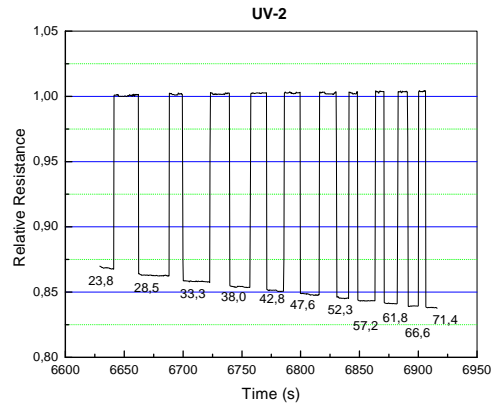


Figure 2. XRD pattern of the SnO_2

Results and Discussion

Electrical measurements were performed to determine the behavior of the film. We used different leds (402 nm, 462 nm, 631 nm, 940 nm). The films were located in a chamber where a led was switched on and off. Changes in resistance film were measured by electrometer Keithley 6514 and oscilloscope Textronix TDS 1012B.

Figs 3 and 4 show the relative resistance vs time with IR and UV illumination. We used LEDs from different powers of 23.8 mW to 71.4 mW in the case of UV and 0.92 mW to 3.22 mW for IR. SnO₂ exhibited significant and reversible responses with characteristic response and recovery time constants of only a few milliseconds under constant illumination.



time

Figure 3. Time dependence of the relative resistance under UV irradiation

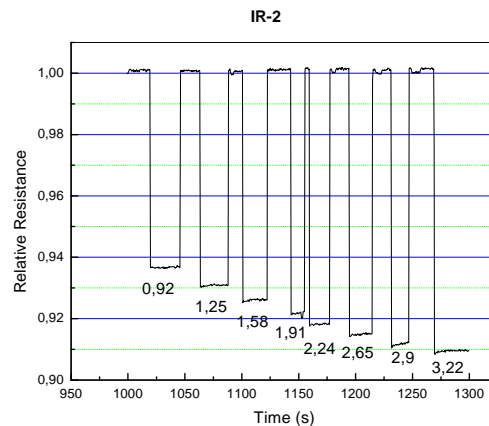


Figure 4. Time dependence of the relative resistance under IR irradiation

The kinetic response: We show a typical photo response as function of time when led was in on and off state (Figure 5). The resistance relative δR is defined as the relative changes in the resistance ($\delta R = R/R_0$). R_0 is the value of the resistance response without light exposure.

The kinetic response of film is ultra fast in the order of milliseconds. In previous work the response UV radiation is very slow in the order of hundred seconds (19).

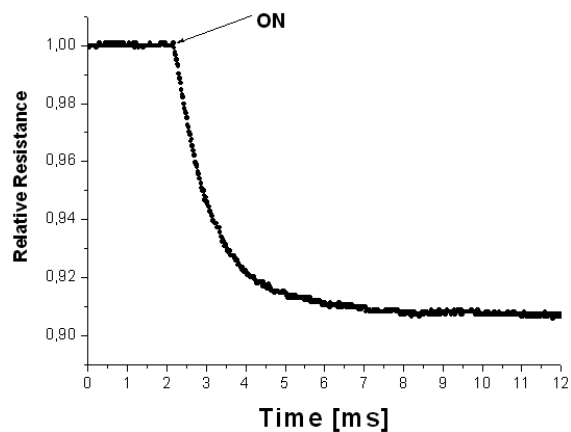


Figure 5. Time dependence of the relative resistance under light irradiation

Light intensity dependence: Figure 6 and 7 show relative resistance under irradiation with different light intensity in air.

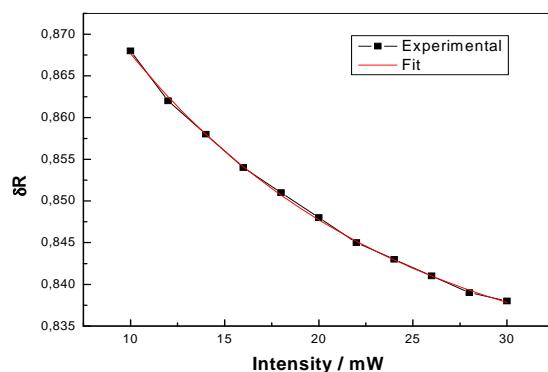


Figure 6. The relative resistance as a function of the UV light intensity. LED 402 nm.

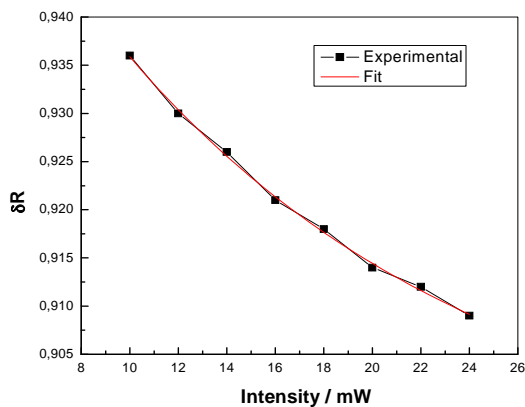


Figure 7. The relative resistance as a function of the IR light intensity. LED 940 nm.

The δR decay follows an exponential behavior. The δR decay of the film increases as the light intensity increases.

When the LED was switched to the on the state and the intensity was increased, the oxygen species (O_2^- and O^- to depending on the temperature) were removed from the surface. Finally, when the LED was switched to the off state, the oxygen species were re-absorbed on the surface.

Conclusion

The results obtained show that SnO₂ thin film have an ultra-fast photo-response for light wave of 402 nm-940 nm.

These results indicate that the photoinduced effect has strong dependency of nano-structures.

Acknowledgements

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References

1. I. Simon, N. Barsan, M. Bauer and U. Weimar. *Sensors and Actuators B* **73** 1-26. (2001).
2. Lamagna et al. *Sensors and Actuators B* **131/1** 121-124 (2008).
3. A. Lamagna, S. Reich, D. Rodríguez , A. Boselli. *Sensor Letter* **4** 253–256. (2006).
4. T.Arai, *J.Phys. Soc.Japan* **15** 916 (1960).
5. G. Brambilla, V.Pruneri, L.Reeki, *Appl. Phys. Letter* **76** 807 (2000).
6. C.X.Xu, X.W.Sun, Z.L.Dong, M.B.Yu et al. *Nanotechnology* **15** 839 (2004).
7. J-Ming Wu, C-H. Kuo. *Thin solid films* **517** 3870-3873 (2009).
8. T. Minami, T. Kakumu, K. Shimokawa, S. Takata. *Thin Solid Films* **317** 318–321. (1998).
9. E.Comini, A.Cristalli, G. Faglia, G Sberveglieri. *Sensors and actuators B* **65** 260-263 (2000).
10. G.Gordillo, L.C. Moreno, W de la Cruz, P.Teheran. *Thin Solid Films*, **252**, N° **1**, 61-66 (1994).
11. T.Starke, G.Coles. *Sensors and actuators B* **88** 227-233 (2003).
12. J. Sundqvist, M. Ottosson, A. Hårsta J. Sundqvist, M. Ottosson, A. Hårsta, *Chem. Vap. Depos.* **10**, Issue **2** 77. (2004)
13. Z.R.Dai, J.L.Gole, J.D.Stout, Z.L. Wang, *J.Phys.Chem B* **106**. 1274-1279. (2002)
14. D.F.Rodríguez, B. Lerner, M.S.Perez, F.A.Ibañez, A.G.B.Leyva, J.A.Bonaparte, C.A.Rinaldi, A. Boselli, and A.Lamagna *AIP* **1137** 377-380 (2009).
15. S.H.Luo, Q.Wan, W.I.Liu. M. Zhang, Z. F. Di, S.Y. Wang, Z.T. Song, C. I. Lin, J. Y. Dai, *Nanotechnology*. **15** 1424 (2004).
16. J.D. Prades, R. Jimenez-Diaz, F. Hernandez-Ramirez, S. Barth, A. Cirera, A. Romano-Rodriguez, S. Mathur, J.R. Morante, *Sensors and Actuators B* **140** 337–341 (2009).
17. H.C. Wang, Y. Li , M.J. Yang, *Sensors and Actuators B* **119** 380–383 (2006).
18. M.S. Mazdiyasi, *Ceram. Int.* **8** 42 (1982).

19. N. Takubo, Y. Muraoka, Z. Hiroi. *Journal of Physics: Conference Series* **148** 012025 (2009).