Effect of N-doped Concentration in SiC Films on Photosensitive Characteristics*

ZHAO Wu[1,2,3], YAN Jun-feng[3], ZHAI Chun-xue[3], DENG Zhou-hu[3],
YUN Jiang-ni[3], ZHANG Zhi-yong[1,2,3]
(1 *Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences, Xi'an* 710119, *China*)
(2 *Graduate University of Chinese Academy of Sciences, Beijing* 100039, *China*)
(3 *School of Information Science and Technology, Northwest University, Xi'an* 710069, *China*)

Abstract: The photosensitivity of SiC films grown under different N concentration has been studied in situ during the growing process of SiC films, which prepared by hot filament chemical vapor deposition (HFCVD). Experiment on photosensitivity characteristics of the samples preformed both at room and high temperature (410℃), respectively. The results show that the photosensitivity of samples is influenced by the processing parameters of preparation and it is almost identical at room and high temperature. There is certain photosensitivity for the SiC films in different wavelength conditions. This indicates that SiC thin films will have a good potential application for high temperature photosensitive sensor.

Key words: SiC thin film; Technical parameter; Photosensitivity
CLCN: TN304　　　　**Document Code**: A

0 Introduction

Silicon carbide (SiC) is a wide bandgap semiconductor material with many attractive features. It crystallizes in many different polytypes, which differ from one another only in the stacking sequence of a double layer. Each double layer consists of two planes of close-packed Si and C atoms (one Si atom lying directly over one C atom) and each successive double layer is stacked over the previous one in a close-packed arrangement. Because there are three different relative positions of the two successive layers, many long-range orders can be found. They correspond, respectively, to cubic, hexagonal or rhombohedral lattice structure arrangements[1-3].

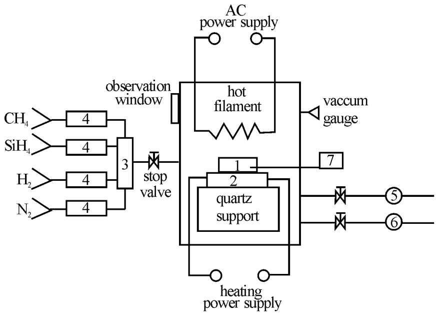
Whatever the polytype, the chemical and physical characteristics of the material[4-5] make it a potential candidate for sensors and devices operating at high temperature, high power, high frequency and in chemically aggressive or nuclear environments[6-8]. Moreover, among the different polytypes, cubic β-SiC is of special interest. Because it crystallizes in a ZnS-type structure, it can be deposited on silicon. Certainly, there is a 21.9% lattice mismatch between SiC and Si, which makes the hetero-epitaxy of SiC/Si very difficult, but with the full potential processing capability of standard silicon-technology lines, the resulting material seems very appealing for smart-sensor applications[9-11]. The silicon-based semiconductor sensors can be used only up to a temperature of about 200℃ because of the small band gap of Si. Therefore, we developed a high temperature sensor based on the large band gap semiconductor SiC.

1 Experiment

A schematic diagram of the HFCVD device is shown in Fig. 1. The HFCVD device consists of a gas providing-system, a growth chamber and a gas pumping-system. The reaction gases were controlled by D07-7A/2M Mass-Flow Controller. The hot filament temperatures were measured by the WGJ-01 optical pyrometer (range 900～3 200 ℃). The substrate temperatures were measured and controlled by DWT-702 Temperature Controller. The growth chamber pressure was measured with the FZH-2B ($20 \sim 1.0 \times 10^{-5}$ Pa) and the SVG-2FM ($1.0 \times 10^{3} \sim 1.0 \times 10^{-5}$ Pa) compound vacuum gauge. The gases used for the experiments are pure methane (99.99%) as the C source, pure nitrogen (99.99%) as the doping N source[12], 5% silane in hydrogen as the Si source, and pure hydrogen (99.99%) as a kind of dilution, protection and etching gas. The substrate was p-type Si, (111) surfaces and its resistivity is 6～9 Ω · cm. Substrate wafers were prepared by general method and the growth procedure of SiC films

---

* Supported by Natural Science Foundation of Shaanxi Province(2003F17 and 04JK256)
Tel: 13572999755　　Email: zhaowu@nwu.edu.cn
Received date: 2006-03-22



1. Si substrate；2. Graphite susceptor；3. Compound gas
room；4. Mass-Flow controller；5. Vacuum pump；
6. High vacuum system (pump，diffusion pump)；
7. Thermocouple

Fig. 1 Schematic diagram of SiC HFCVD device

carried out in a vacuum chamber[13].

Diagram of measuring device was showed in reference[14]. The device has been put into an light-tight box with provided holes where the measuring light ray can get to the surface of the sample. The resistance of different sample was measured with LCR data-bridge 2810A. 12 V and 100 W tungsten-halogen lamp in light source system was provided by direct current supply to get stabilized output of light power. The incident light reaching the silt was splited by WDF type Monochromatic Spectrometer，and the monochromatic light with certain bandwidth could be obtained. Intensity of light was usually detected by radiant power meter，thermoelectric，photo counter and light power meter. Power/Energy Analyzer was used in this experiment.

2 Results and discussion

Relative variation of resistance vs wavelength of different nitrogen doped samples at room temperature is demonstrated In Fig. 2. Vertical axis is relative variation of the film resistance $\Delta R = R_X - R_0$. In the formula，R_X is measured resistance of the sample in light，R_0 is dark resistance of the sample，respectively. Abscissa axis is wavelength of the measuring light ray which ranges from 450 nm to 700 nm. Solid rhombus，hollow circle，hollow triangle and solid triangle represent measuring result of SiC samples with 1%，2%，3% and 4% nitrogen doping content，respectively，at room temperature. The result shows that the highest resistance relative variation of the 1%，3% and 4 % nitrogen doped sample locates at about 500 nm，640 nm and 620 nm，respectively，and their values are correspondingly 0. 942，1. 183 and 1. 301. No other obvious peaks are observed in the given wavelength range. These reveal that the samples have higher sensitivity to the light with wavelength about 500 nm，640 nm and 620 nm，respectively. Namely，these samples have better selectivity to the measuring light.

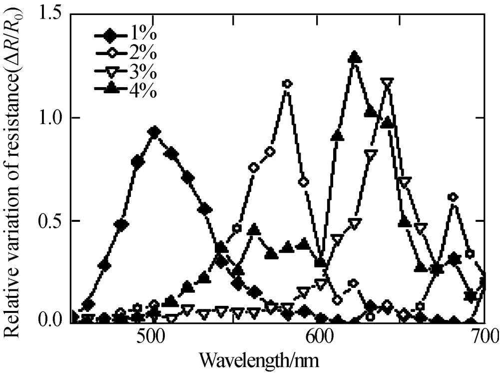


Fig. 2 Relative variation of resistance vs wavelength in different nitrogen doped sample at room temperature

For 2% nitrogen doped sample，the highest peak (1. 173) and secondary peak (1. 621) appear at 580 nm and 680 nm，respectively. This result indicates that the same sample have higher sensitivity to the wavelength of both 580 nm and 680 nm，in other words，the sample has bad selectivity to the measuring light，at least for the former.

Fig. 3 shows relative variation of resistance vs wavelength of different nitrogen doped sample at high temperature (410℃). It shows that the influence of the wavelength on relative variation of sample resistance is approximately in agreement with the results at room temperature in Fig. 2. it means that，the highest resistance relative variation of 1%，3% and 4% nitrogen doped samples appears at about 500 nm，640 nm and 620 nm，respectively，and no other remarkable peaks are observed in the given wavelength scope. These samples have better selectivity to the measuring light. For 2% nitrogen doped sample，there are the highest peak and secondary peak at 580 nm and

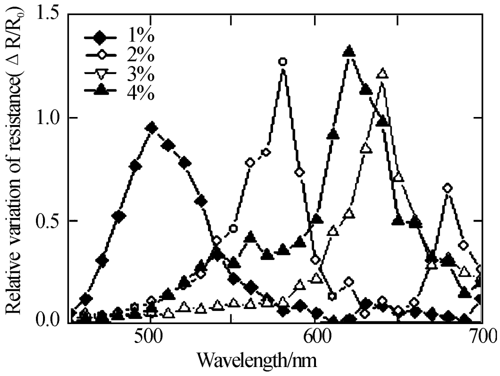


Fig. 3 Relative variation of resistance vs wavelength in different nitrogen doped sample at high temperature(410℃)

680 nm in the given wavelength scope, respectively. Namely, the sample has worse selectivity to the measuring light.

In addition, relative variation of the film resistance was measured in the white light with different power and its value keeps about 0. Namely, the grown samples have no sensitivity to the light power.

3 Conclusion

The investigation on the combined effect of nitrogen impurity and temperature on β-SiC deposited on Si substrate, have revealed that the concentration of the nitrogen impurity during the deposition process of SiC films determines its selectivity to the measuring light; Relative variation of SiC film resistance varies obviously with the wavelength but remains almost constant with the change of light power. The trend of variation at higher temperature (410℃) is almost consistent with that at room temperature. In a word, SiC films have certain photosensitivity to light wavelength, but not to light power. In addition, because of its chemical inertness, SiC will also withstand corrosive environments. No need of using halides makes our technical process simple, convenient and safe.

References

[1] POWELL J A, MATUS L G, *et al*. Recent developments of amorphous and crystalline Silicon Carbide [M]. Berlin: Springer Proceeding in Physics, Springer, 1989, 34:2-7.

[2] RAM U S, Singh G, *et al*. The growth and defect structure of SiC polytypes studied by chemical etching and x-ray diffraction [J]. *Journal of Crystal Growth*. 1976, **32**(2):197-204.

[3] KRISHNA P, MARSHALL R C, RYAN C E *et al*. The discoveryof a 2H-3C solid state transformation in silicon carbide single crystals [J]. *Journal of Crystal Growth*. 1971, **8**(1): 129-131.

[4] DAVIS R F. Thin films and devices of diamond, silicon carbide, and gallium nitride [J]. *Physics* B, 1993, **185**(1): 1-15.

[5] IRMSCHER K. Electrical properties of SiC: characterisation of bulk crystals and epilayers [J]. *Materials Science and Engineering* ,2002 B**91**(3): 358-366.

[6] WANG Ping, ZHOU Jinhui, YANG Yin-tan, *et al*. An ensemble monte carlo study of high field electron transport in 6H-SiC [J]. *Acta Photonica Sinica*, 2004, **33**(3):322-325.

[7] CHEN W, LEEB K, CAPANO M A, *et al*. Growth and characterization of nitrogen-doped C-face 4H-SiC epilayers [J]. *Journal of Crystal Growth* ,2006, **297**(1): 265-271.

[8] CHOLLON G, VALLEROT J M, HELARY D, *et al*. Structural and textural changes of CVD-SiC to indentation high temperature creep and irradiation [J]. *Journal of the European Ceramic Society*, 2007, **27**(6): 1503-1511.

[9] DEZAUZIER C, BECOURT N, ARNAUD G, *et al*. Electrical characterization of SiC for high-temperature thermal-sensor applications [J]. *Sensors and Actuators* A, 1995, **47**(1): 71-75.

[10] WERNER M, VLADIMIR F, ALEXEY V, *et al*. Field-effect sensor for the selective detection of fluorocarbons [J]. *Journal of Fluorine Chemistry*, 1999, **93**(2): 61-67.

[11] JIN Rui-ying, CHEN Zhi-ming, PU Hong-bin, *et al*. Photoelectric characteristics of siC1-xGex / SiC heterojunction diode [J]. *Acta Photonica Sinica*, 2005, **34**(2):205-208.

[12] ZHU Yong, SHEN Wei-dong, YE Hu, *el at*. Silicon nitride thin films deposited by R F magnetron sputtering [J]. *Acta Photonica Sinica*, 2005, **34** (1) :154-157.

[13] ZHANG Zhi-yong, ZHAO Wu, WANG Xue-wen, *et al*. Epitaxial monocrystalline SiC films grown on Si by HFCVD at 780℃ [J]. *Material Science and Engineering*, 2000, B**75**(1):177-179.

[14] ZHAO Wu, DENG Zhou-hu, YAN Jun-feng, *et al*. Deposition of SiC thin film and its photosensitive characteristics [C]. Optoelectronics & Information Technology Doctoral Forum of China, 2006, Wuhan. Paper Collection I:2006:437-441.

掺杂N的浓度对SiC薄膜的光敏特性影响

赵武[1,2,3],闫军锋[3],翟春雪[3],邓周虎[3],贠江妮[3],张志勇[1,2,3]

(1 中国科学院西安光学精密机械研究所,西安 710119)

(2 中国科学院研究生院,北京 100049)

(3 西北大学 信息科学与技术学院,西安 710069)

收稿日期:2006-03-22

摘 要:在热丝化学汽相沉积(HFCVD)法制备SiC薄膜过程中,研究不同的N掺杂下制备样品的光敏特性.对薄膜在室温和较高温度(410℃)下进行光敏特性测试,结果表明,薄膜的制备工艺参量对其光敏特性有较大影响;较高温度下其敏感特性和室温下测试的结果大体一致;在合适条件下制备的薄膜对不同波长的光有较好的敏感特性.可以看出,SiC薄膜在研究高温光敏器件领域具有很好的应用前景.

关键词:SiC薄膜;工艺参量;光敏特性;

ZHAO Wu associate professor, was born in Shan'xi Province, China on Oct. 30 1970. He graduated from the Electronics Department of Northwest University in 1995 and received master degree from there in 1998. Now he is a Ph. D. candidate at Xi'an Institute of Optics and Precision Mechanics, CAS. His research interests are semiconductor material and semiconductor device.