극한 환경 마이크로 화학센서용 다결정 3C-SiC 다이오드 제작과 그 특성

심재철, 정귀상
울산대학교

Fabrication of polycrystalline 3C-SiC diode for harsh environment micro chemical sensors and their characteristics

Jae Cheol Shim and Gwiy-Sang Chung
University of Ulsan

Abstract : This paper describes the fabrication and characteristics of polycrystalline 3C-SiC thin film diodes for extreme environment applications, in which the this thin film was deposited onto oxidized Si wafers by APCVD using HMDS In this work, the optimized growth temperature and HMDS flow rate were 1,100°C and 8sccm, respectively. A Schottky diode with a Au, Al/poly 3C-SiC/SiO_2/Si(n-type) structure was fabricated and its threshold voltage (V_d), breakdown voltage, thickness of depletion layer, and doping concentration (N_D) values were measured as 0.84V, over 140V, 61㎚, and 2.7×10^{19}㎝³, respectively. To produce good ohmic contact, Al/3C-SiC were annealed at 300, 400, and 500℃ for 30min under a vacuum of 5.0×10^{-6}Torr. The obtained p-n junction diode fabricated by poly 3C-SiC had similar characteristics to a single 3C-SiC p-n junction diode.

Key Words : Polycrystalline 3C-SiC, MEMS, APCVD, Schottky, Ohmic, p-n junction

1. Introduction

Schottky barrier diodes offer unique advantages over conventional p-n rectifiers in terms of lower resistance, faster response, and negligible transient reverse current during switching. In addition, the reverse saturation current of Schottky diodes is larger than that of p-n junction diodes. Therefore, a Schottky diode requires less forward bias voltage to achieve a given current than does a p-n junction diode. Schottky diodes based on silicon carbide (SiC) are of special importance owing to their capability of handling high voltages and high temperatures.

SiC possesses exceptional chemical and physical properties such as high thermal conductivity, a wide band gap, high breakdown field, high saturation velocity, and chemical stability [1]. Therefore, metal-SiC, Schottky contacts are suitable electrical devices for harsh environments such as high voltage rectifiers, UV radiation detectors, signal mixers, and high temperature gas sensors [2].

In this work, poly 3C-SiC thin films were grown on p- and n-type Si substrates by APCVD. Next, Schottky and ohmic contacts were fabricated with Au and Al, respectively, and deposited on the poly 3C-SiC thin films. The electrical characteristics were investigated by I-V and C-V curves to demonstrate potential MEMS applications.

2. Experimental

Poly 3C–SiC thin films weregrown on n- and p-type Si (100) substrates using Ar_2, H_2, and HMDS {$Si_2(CH_3)_6$} gases by using APCVD for 30minutes. The growth temperature and HMDS flow rate were varied from 1,000 to 1,200℃and from 6 to 8sccm, respectively.

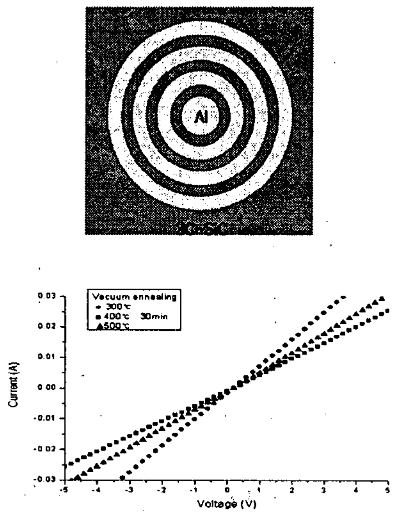

Fig. 1. (a) Schematic view of ohmic contact and (b) I-V characteristics of ohmic contact as a function of the annealing temperature.

Ohmic and Schottky contacts were fabricated to study the electrical properties of poly 3C-SiC thin films. In Fig. 1 (a), ohmic contacts were prepared by the deposition of Al electrode on poly 3C-SiC surfaces. The diameters of the circle pattern contacts were 250, 500, 750, and 1,000μm. The thickness of Al was 5,000Å. These devices were annealed at 300, 400, and 500℃ for 30 min under vacuum (5 × 10^{-6}Torr) and the current -voltage (I-V) characteristics were measured as a function of annealing temperature to investigate their electrical properties.

3. Results and Discussion

Fig. 1 (b) shows the I-V characteristics of the Al/3C-SiC ohmic contact as a function of the annealing temperature. The samples were annealed at 300, 400, and 500℃ for 30min, and the resistances were observed to be 204, 59, and 111Ω respectively. The optimal properties of the ohmic contact were observed at 400℃. The ohmic contact characteristics of Al/poly 3C-SiC annealed above 400℃ gradually became worse.

In order to obtain the electrical properties of poly 3C-SiC, the I-V and C-V characteristics were investigated. We measured capacitance by HP4192A and calculated the carrier density and thickness of the depletion layer with equations (1) and (2), respectively. K_s is the dielectric constant of the 3C-SiC thin film and A is the area of the electrode. Fig. 2 shows the C-V characteristics of the Schottky contact calculated by equation (1). The thickness and threshold voltage (V_d) of the poly 3C-SiC thin film were measured to be 6,000Å and - 0.84V, respectively.

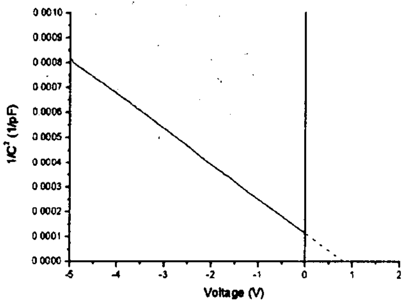

Fig. 2. C-V characteristics of Schottky contact.

The I-V characteristics of the poly 3C-SiC thin films were studied using a Keithley 207 programmable voltage source and a Keithley 2001 digital multimeter. Fig. 3 shows the I-V characteristic of the Schottky diode of the 3C-SiC thin film as observed in a traditional diode diagram. The diode of Fig. 7 achieved a breakdown voltage of over 140 V. However, a high leakage current occurred. Random grooves were observed suggesting the existence of anti-phase boundaries (APB) in the poly 3C-SiC film. Therefore, it is suggested that the APB is a possible leakage site of the poly 3C-SiC film [8].

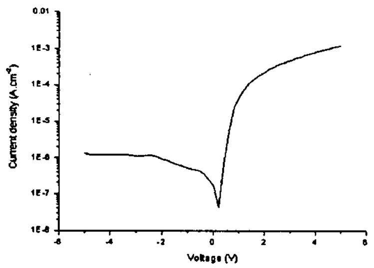

Fig. 3. J-V characteristics of Schottky contact.

4. Conclusions

In this work, poly 3C-SiC thin films were deposited on oxidized Si substratesby APCVD using HMDS. In order to investigate the electrical properties of poly 3C-SiC, we evaluated the characteristics of the Au/poly 3C-SiC/SiO_2/Si (n-type) Schottky contact such as the threshold voltage (V_d) and the breakdown voltage, which were 0.84 V and over 140V, respectively. In addition, the thickness of the depletion layer of the poly 3C-SiC thin film using doping consistence (N_D = 2.7 × $10^{19}$$cm^{-3}$) was calculated to be 61 nm. The Au/poly 3C-SiC/SiO_2/Si (n-type) Schottky diode had a high breakdown voltage. Therefore, Schottky diode utilizing poly 3C-SiC thin films can be applied to MEMS applications.

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