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Schottky-barrier diamond photodiode using thermally stable WC-based contacts

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1. Introduction

Photodetector with solar blindness (λ<280 nm) can find a number of applications including missile plume detection, flame control, and bio-chemical agent sensing. Diamond possesses the highest figure-of-merit for high-temperature, high-power and high-frequency operation. The wide-band gap (5.5 eV) has the potential deep ultraviolet (DUV) solar-blind photodetectors. Up to date, little work has been concerning on the single Schottky-barrier diamond photodiode. A fundamental issue on the photodiode is the development of thermally stable electrical contacts. A guideline for a Schottky contact with good performance is to search an intermetallic compound nonreacted with diamond at elevated temperatures. Tungsten carbide (WC) is a promising choice due to its good electrical conductivity, high melting point, high mechanical hardness, and good chemical inertness at elevated temperatures. The purpose of this work is to develop the visible-blind DUV diamond photodiode with excellent thermal stability. Along this purpose, we select WC and Ti/WC for the Schottky and ohmic contacts, respectively.

2. Experiments

The starting B-doped diamond epilayer was grown by a microwave-plasma chemical vapor deposition technique on an Ib (100) diamond substrate. The metallic contacts were deposited by sputtering in a UHV chamber. The device structure consisted of a 420 μm diameter WC Schottky dot separated by 10 μm radially from the Ti/WC ohmic contact. In order to investigate the thermal stability of the electrical and photoresponse properties, an isothermal annealing of the photodiode was performed at 500°C in an argon/air ambient for 5 h with an interval of 1 h. Measurements of the I-V characteristics were conducted by a two-point probe method, which was used to evaluate the ideality factor n, Schottky barrier height $q\phi_B$, and the leakage current. The photoresponse spectra were measured in the range of 215 to 630 nm.

3. Results and discussion

The photodiode shows a rectifying ratio of 10^8 with leakage current lower than 10^{-14} A at the reverse biases 0-30 V regardless of annealing for 4 h, as shown in Fig.1. The influence of isothermal annealing on the n and $q\phi_B$ values of the diamond/WC photodiode is depicted in the insert of Fig.1. A nearly ideal diode with $q\phi_B$ of 1.4 eV was obtained after annealing for 1 h. On the other hand, annealing improves the photoresponsivity at 220 nm dramatically by a factor of about 10^3, which is illustrated in Fig.2. The photocurrent saturates with increasing the bias for both the as-fabricated and annealed photodiodes.

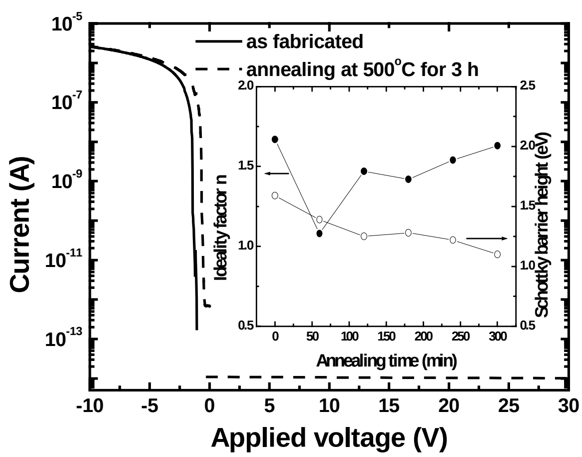

Fig.1 Dark I-V characteristics of the diamond/WC photodiode before and after annealing at 500°C for 3 h. Inserted plots are the ideality factor and Schottky barrier height as functions of annealing time at 500°C.

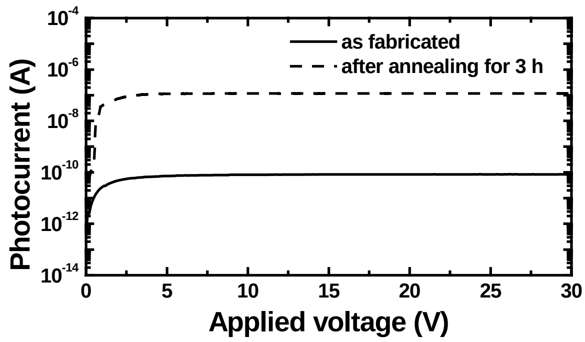

Fig.2 Reverse I-V characteristics under 220 nm illumination with an intensity of about 20 μW/cm^2 for the diamond/WC photodiode before and after annealing at 500°C for 3 h.

The photodiode after annealing for 2 h or longer time exhibits a blind ratio as larger as 10^6 between DUV and visible light and an internal gain at a reverse bias as small as 2 V, as shown in Fig.3. No degradation in the photoresponsivity was observed upon 5 h's annealing. The enhancement of the photoconductivity was considered to result from the modification of the diamond surface. From these results, we conclude that the WC-based Schottky and ohmic contacts are thermally stable. The work opens up a way for developing thermally stable diamond devices.

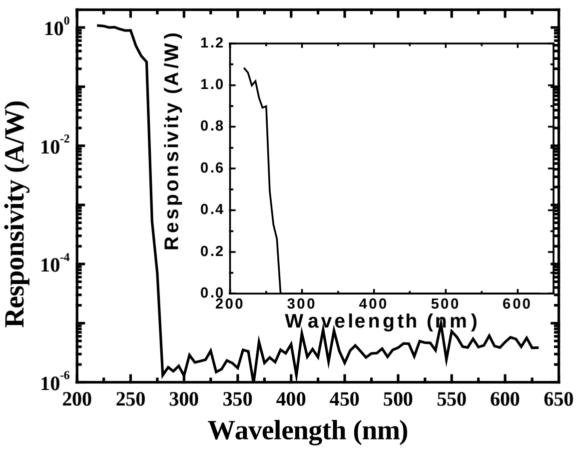

Fig.3 Spectral photoresponse at 2 V of the diamond/WC Schottky photodiode annealed at 500 ^{o}C for 3 h.