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Deep-ultraviolet detectors based on oxygen-/fluorine-terminated (100) diamond

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ABSTRACT

In this study, deep-ultraviolet detectors based on oxygen-/fluorine-terminated (100) diamond (O-/F-diamond) have been fabricated. Both of the O-/F-diamond surfaces have been formed on different areas of one (100) diamond sample by O_2 and CF_4 plasma. Pd has been evaporated on the O-/F-diamond surfaces to form Schottky contact, whose barrier heights have been investigated by X-ray photoelectron spectroscopy technique. Deep-ultraviolet detector based on F-diamond shows lower dark current than that based on O-diamond.

1. Introduction

Deep ultraviolet (DUV) detectors can find various applications, such as environment security, information technology, medical treatment and astronomical observation [1]. Diamond exhibits attractive intrinsic properties, such as wide gap energy (5.47 eV), high electric breakdown field (10 MV cm^{-1}), and high carrier mobility (3800 and 4500 cm^2 V^{-1} s^{-1} for holes and electrons, respectively) [2,3], which makes it to be suitable for making DUV detectors, and satisfies the 5S requirements such as high sensitivity, high signal-to-noise ratio, high spectral selectivity, high speed, and high spectral selectivity [4].

The type of surface termination strongly influences the properties of diamond surface, such as electron affinity, surface conductivity, and work function, as shown in Table 1 [5–7]. Due to high energy of C—F bonds, surface fluorination of diamond can be considered as very promising technique for electronic applications [8]. The formation of C—F bonds at the diamond surface may lead to a reduction of surface oxygen and the related electronic states in the bandgap of diamond [9]. The reduction of surface states at the fluorinate interface can improve carrier mobility in the field effect transistor [10].

Usually, diamond DUV detectors have been mainly fabricated on hydrogen-/oxygen- terminated diamond (H-/O-diamond) [1,4]. Few groups have reported research results about diamond DUV detectors fabricated on fluorine-terminated diamond (F-diamond). In this work, DUV detectors based on O-/F-diamond have been fabricated, respectively. The properties of the two kinds of DUV detectors such as barrier heights for contacts, dark currents, responsivities, and response time etc. will be discussed.

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Table 1
Electron affinity, surface conductivity, and work function for H-diamond, O-diamond and F-diamond.

	Electron affinity	Work function	Surface conductivity
Hydrogen-terminated [5]	−1.3 eV	4.9 eV	p-type
Oxygen-terminated [6]	1.7 eV	6.3 eV	none
Fluorine-terminated [7]	2.56 eV	7.24 eV	none

2. Experimental details

The IIa-type high-pressure high-temperature diamond (100) substrates ($3 \times 3 \times 0.5$ mm^3) were used in this experiment. Before growth, the substrates were cleaned in a nitric and sulfuric acids mixture solution at 250 °C for 1 h. Then, they were cleaned ultrasonically by deionized water, ethanol, acetone, ethanol and deionized water sequentially. The diamond epitaxial layers with a thickness of 100 nm were grown by microwave plasma-enhanced chemical vapor deposition. Then, these samples were treated in a nitric and sulfuric acids mixture solution at 250 °C for 1 h.

For sample-I, in order to form O-/F-diamond on one diamond sample, the diamond surface of sample-I was treated by reactive ion etching (RIE) in an O_2 atmosphere. Then, half of the diamond surface was treated by RIE in a CF_4 atmosphere, as shown in Fig. 1(a). The O_2 (CF_4) flow rate, RIE chamber pressure, radio frequency power, and treating time were 100 sccm, 10 Pa, 50 W, and 60 s, respectively. Then, the sample was treated in a nitric and sulfuric acids mixture solution at 250 °C for 1 h again to investigate the stability of the F-diamond. For sample-II, the diamond epitaxial layer was treated to O-diamond and F-diamond by using the same methods. Then, Pd layers with the thicknesses of 3 nm and 100 nm (Thin-Pd and Thick-Pd) were deposited by evaporation on the diamond surface, respectively, as shown in Fig. 1(b). For sample-III, two pattern area were treated to O-diamond and F-diamond by RIE, respectively. Then, Pd was evaporated to form Pd/O-diamond contact and Pd/F-diamond contact, as shown in Fig. 1(c). The finger width and spacing of DUV detectors are 30 and 30 μm, respectively. The optical area is about 1.8 mm^2.

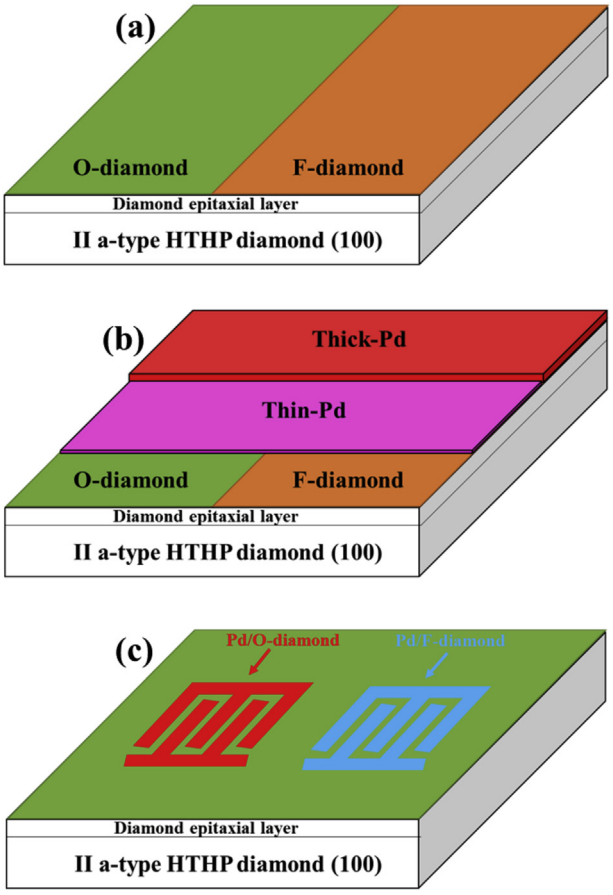

Fig. 1. The schematic diagrams for samples. (a) The schematic diagram of sample-I with different terminations. (b) The schematic diagram of the sample-II with different terminations and Pd layers. (c) The schematic diagram of the sample-III with two kinds of DUV detectors. The pattern area were treated to O-diamond and F-diamond by RIE, then were covered by Pd layer. The residual area was O-diamond.

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