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Reprint of "Palladium Ohmic contact on hydrogen-terminated single crystal diamond film"☆

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ABSTRACT

Contact properties of Palladium (Pd) on the surface of hydrogen-terminated single crystal diamond were investigated with several treatment conditions. 150 nm Pd pad was deposited on diamond surface by thermal evaporation technique, which shows good Ohmic properties with the specific contact resistivity (ρ_c) of 1.8×10^{-6} Ω cm^2 evaluated by Transmission Line Model. To identify the thermal stability, the sample was annealed in Ar ambient from 300 to 700 °C for 3 min at each temperature. As the temperature increased, ρ_c firstly decreased to 4.93×10^{-7} Ω cm^2 at 400 °C and then increased. The barrier height was evaluated to be −0.15 eV and −0.03 eV for as-deposited and 700 °C annealed sample by X-ray photoelectron spectroscopy analysis. Several surface treatments were also carried out to determine their effect on ρ_c, among which HNO_3 vapor treated sample indicates a lower value of 5.32×10^{-6} Ω cm^2.

1. Introduction

Diamond appears promising for high-power and high-frequency devices, since it has remarkable properties, such as wide band gap (5.47 eV), highest thermal conductivity (22 W/cm K), high breakdown field (>10 MV/cm), high carrier mobility of electron (4500 cm^2 V^{-1} s^{-1}) and hole (3800 cm^2 V^{-1} s^{-1}), and high saturation velocity (10^7 cm/s) [1–2]. Recently, applicability of semiconducting diamond films to electronic devices has been extensively studied by fabricating Schottky diodes [3–7] and field-effect transistors (FET) [8–15]. One of the most essential topics to be studied for the diamond applications is the contact properties between the electrode metal layer and the diamond film. Up to now, many refractory metals such as Ti, Mo and Ta, which are capped by Au [12,16,17], are used as contact material for p-type diamond, on account of carbide formation at the interface with the annealing temperature higher than 400 °C. Au [18], a non-carbide-forming metal, was also used as contact metal, whereas the adherence of Au on diamond film is quite poor and could peel off easily even during lift-off process without ultrasonic. However, few investigations on Pd Ohmic contact to hydrogen-terminated single crystal diamond film were reported.

In this study, contact properties of Pd on hydrogen terminated diamond surface were investigated. The specific contact resistivity (ρ_c) was evaluated by Transmission Line Model (TLM). Then, annealing process was performed to examine the thermal stability of the contact. Furthermore, the X-ray photoelectron spectroscopy (XPS) technique was used to identify the contact barrier height at the interface. For comparison, before Pd TLM patterns deposition, the other diamond samples were treated by several kinds of solutions and vapors.

2. Experiment

Undoped homoepitaxial diamond films were grown by microwave plasma assisted CVD onto high pressure and high-temperature synthetic Ib diamond (100) substrates with the dimension of $3 \times 3 \times 0.5$ mm^3. The total flow rate of the reaction gas was 500 sccm, and the ratio of CH_4/H_2 was 1%. The process pressure, growth temperature and microwave power were 100 Torr, 900 °C and 1 kW, respectively. After growth, hydrogen plasma was kept for 10 min to form the hydrogen termination, and the samples were cooled down in pure hydrogen ambient. The Hall measurement, Raman spectra, X-Ray Diffraction (XRD) and Atomic Force Microscope (AFM) were carried out to evaluate the epitaxial diamond film. After 3 nm Pd being evaporated on diamond surface, the fabrication process was implemented in two different ways, which is shown in Fig. 1. In one way, 150 nm Pd TLM configuration with an area of 100×100 μm^2 and space ranging from 5 to 30 μm was firstly formed on diamond film by using the lithography and thermal evaporation method. A negative photoresist (PR) of Az5214 was used, whose prebake and reversal bake temperature were 95 °C and

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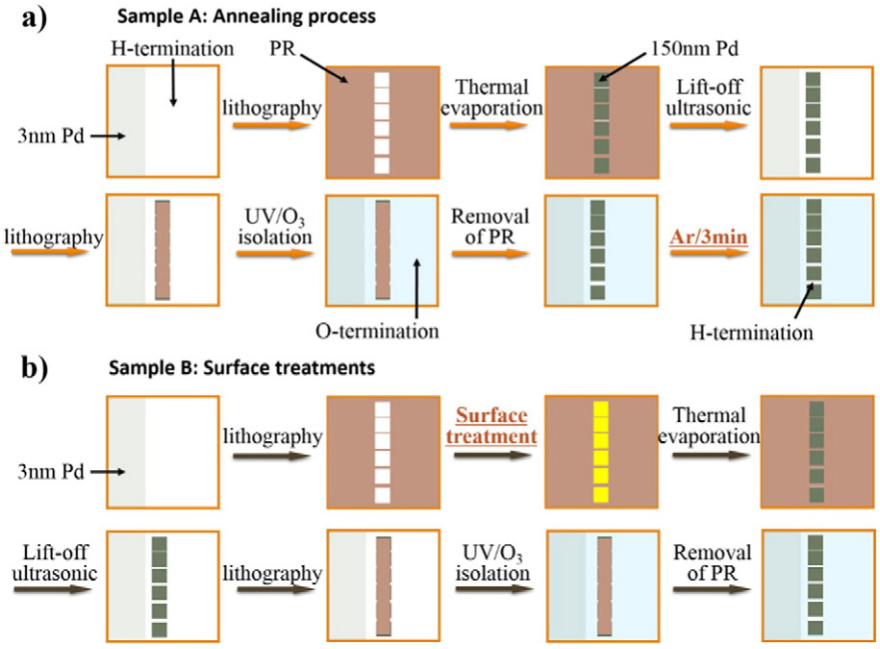

Fig. 1. The fabrication process flow of the TLM configuration, a) sample A for annealing process, and b) sample B for surface treatment.

110 °C, respectively. Secondly, the sample was treated by UV/ozone for isolation. Thirdly, the sample was annealed to investigate its thermal stability in Ar (5 N) ambient at several temperatures from 300 to 700 °C during which Ar flow rate was set to 2 L/min and the pressure was kept at atmospheric pressure. Finally, XPS was utilized to determine the barrier height of the Pd contact on hydrogen-terminated diamond. This sample was denoted as sample A. In another way, samples were firstly treated by different kinds of solutions and vapors after lithography, including HCl, $NH_3 \cdot H_2O$ and HNO_3. Secondly, 150 nm Pd TLM pads were evaporated onto the diamond film. Thirdly, samples were treated by UV/ozone. These samples were named as sample B group.

3. Results and discussion

The sample morphologies were investigated by optical microscope (OM) and AFM. The typical images are shown in Fig. 2. Fig. 2(a) shows the full-scale OM image, illustrating a smooth

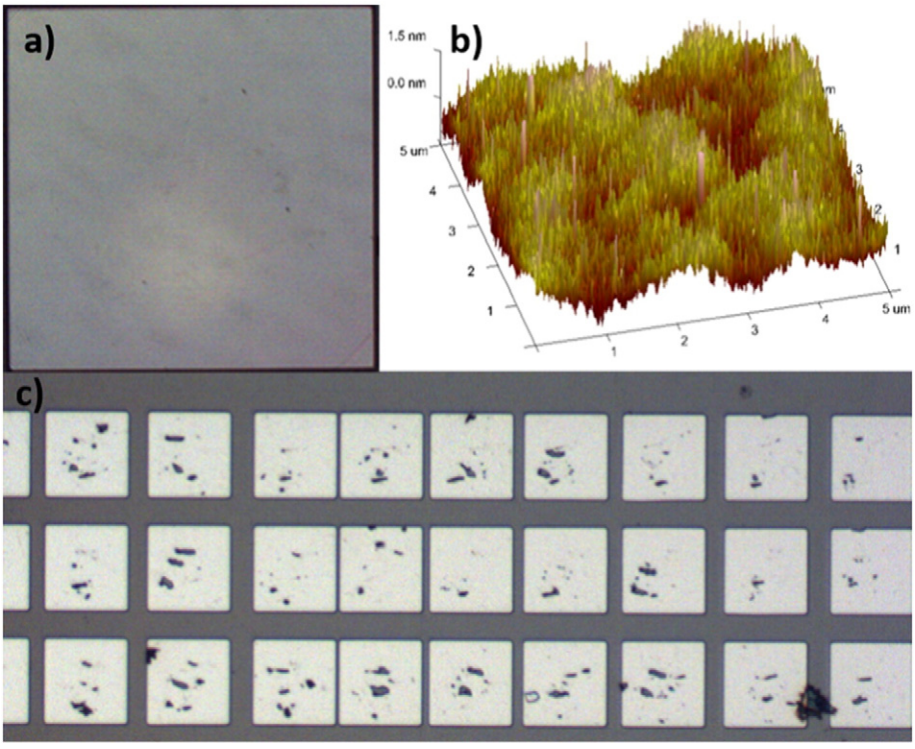

Fig. 2. a) The optical microscope image of as-deposited single crystal diamond film with the dimension of 3×3 mm^2, b) AFM image with the area of 5×5 μm^2, c) the optical microscope image of TLM configuration after annealing at 700 °C in air for 3 min.