

Diamond surface conductivity after exposure to molecular hydrogen

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Abstract

We report experimental evidence of a substantial reduction of the sheet resistance of a commercially available (110) oriented natural diamond surface after exposure not to atomic but to molecular hydrogen. In a conventional CVD reactor, we have merely exposed the sample to high purity molecular hydrogen fluxes at 800 °C. After exposure to air, the surface conductivity increased several orders of magnitude as measured by a professional collinear four-point probe head with tungsten carbide tips. After annealing at 900 °C in vacuum ($P < 10^{-5}$ Pa) the conductivity dropped at least 4 orders of magnitude; repeatability tests on the measurements of the surface conductivity after thermal hydrogenation and subsequent air exposure were conducted in order to avoid systematic errors. Similar experiments were conducted at different process temperatures in order to evaluate the best process conditions. Thermal hydrogenation appears to be ineffective at increasing the surface conductivity of (100) homoepitaxial CVD diamonds.

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1. Introduction

It is well known experimentally that hydrogen termination of diamond induces a p-type conductive surface layer. This two dimensional hole conductivity, achieved without conventional doping of diamond, has attracted a lot of interest both from the viewpoint of basic surface science [1] and for the fabrication of electronic devices such as field effect transistors, chemical sensors and biosensors [2,3].

Among several models proposed in the literature to explain the surface p-type conductivity, the ‘electrochemical transfer-doping model’ [4,5] has attracted the most attention. It is based on the observation that negative electron affinity of the hydrogen-terminated diamond surface induces a low ionisation energy which favours the electron transfer from the valence band to physisorbed adsorbates. The surface conductivity is then promoted by exposing the hydrogen-terminated diamond surface to humid air; a slightly acidic (due to the presence of carbonic acid) water layer, which spontaneously forms on any

surface, is then sufficient to induce a sub-surface hole accumulation layer of up to 10^{13} cm⁻².

The hydrogenation process is then a key step for the realisation of the hole conductive layer; it can be obtained by atomic hydrogen dosing using a hot filament or plasma process [6]. This commonly used procedure entails exposing the diamond surface to pure hydrogen plasma and then cooling it down to near room temperature in pure hydrogen ambient.

However, Ando et al. [7] demonstrated the possibility of hydrogen chemisorption on diamond surfaces without resorting to plasma process. In this research, carried out by exposing diamond powders to a pure molecular hydrogen flow in the temperature range 400–1100 °C, they reported experimental evidence of hydrogen chemisorption through infrared/Raman spectroscopy and temperature programmed desorption. This hydrogenation method has been used in very few other works for treating diamond powders, but, to the best of our knowledge, no examples of thermal hydrogenation of single crystal diamonds, nor measurements of the relevant surface conductivity, have been documented.

In this paper, we show that thermal hydrogenation is an effective method to induce a hydrophobic and conductive surface of a (110) natural diamond. This is quite similar to what

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