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Photocurrent study of beta-ray priming in CVD diamond

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Abstract

Priming by X-rays or by beta-rays is generally needed in order to qualify CVD diamond for nuclear detection or for dosimetry. The priming effect is usually attributed in filling the hole traps, which are responsible for the charge collection efficiency of the detector. Emptying the filled traps can be easily detected by Thermoluminescence (TL), which is considered to be a measure of the absorbed dose. In this work, we prove that below-gap photocurrent (BGPC) can also be used in the same way and it is dominated by the optical detrapping of holes from the same centers. Time dependence of this beta-rays induced persistent photocurrent (PPC), which in fact, depends only on the total number of photons impinging onto the sample. In fact, at long times or for large number of photons, the photocurrent approaches to the same limit of PC for a null dose. The hole trapping centers distribution seems to extend from 1.25 to 2.5 eV valence band.
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Keywords: CVD diamond; Persistent photocurrent (PPC); Below-gap photocurrent (BGPC); Priming; Dosimetry

1. Introduction

In the previous article [1], both the X-ray and the beta-ray primed state of CVD diamond was investigated by light with respect to the performances in alpha particle spectrometry and in thermoluminescence (TL) dosimetry. The results showed that: (1) performances were better in the case of blue illumination (or illumination above 2.5 eV); (2) under the same conditions TL signal was almost erased; (3) the carrier transport was due to electrons in this case. In the same article, the photocurrent spectra carried out over a primed CVD diamond sample (beta priming in this case) displayed a large ' bump ' between 2 and 2.5 eV, but only when the measurement was carried out starting form lower energies: starting from energies of 3–4 eV the bump disappeared. At the top of the bump, the photocurrent gain with respect to a no-priming case was in the order of 100–200, depending on the dose. In fact, 2 years before, Nebel and collaborators [2] found what they called persistent photoconductivity (PPC) after UV illumination at 5.5 eV, and noticed a strong increase of photocurrent (two orders of magnitude or much more) in the energy region between 1 and 3 eV. They attributed the origin of PPC to the trapping of holes in 'save traps' at approximately 1.4 eV above the valence band and spatially lying in the grains. Electrons, on the contrary, were supposed to be captured later at the grain boundaries in P1 centers lying 1.7 eV below the conduction band. In a more recent article, Alvarez and collaborators [3] measured the long term decay of the photocurrent in an UV irradiated CVD diamond sample under red light illumination and found that it could be described by a stretched exponential function.

In this article, we present a detailed investigation concerning the wavelength dependence and the time behaviour of BGPC after beta-ray irradiation, in order to better understand the phenomena, which controls the relaxation of the photocurrent in CVD diamond. Moreover, we prove that PPC, in the same way as TL or TSC (thermally stimulated current), can be used for beta-ray dosimetry—and also for X-ray dosimetry—at relatively low doses.

2. Experimental

The measurements were carried out on a polished $10\times10\times0.4$ mm^3 CVD diamond sample produced by Norton. Titanium/gold electrodes were evaporated on

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