DIAMOND NANOPARTICLES TO DETECT HIGH ENERGY ELECTRON RADIATION

G. Boka[1], Y. Dekhtyar[2] and M. Rocca[3*]
[1] Oncological Center of Latvia, Hipokrata str 4, Rīga, LV1038, Latvia
[2,3]Riga Technical University, Kipsala str 6B, LV1048, Latvia
[3] Mirko.Rocca@edu.rtu.lv

ABSTRACT

Since diamond is used for dosimetry of ionizing radiation, the diamond nanoparticles (DNPs) could be employed as nano-detectors. DNPs will allow a dose detection in the nano-volumes, helping to determine the absorbed radiation dose at the scale of a single DNA structural unit that is important for radiobiology. The use of DNPs to measure radiation is demonstrated. Radiation electrically charges the DNPs' surface. As a result, the electron work function of DNPs emission change. DNPs' work function, sized 140 nm, are correlated with the dose and energy of electrons. The dose was delivered in a range of 1 to 30 Gy, with the electrons having energy of 6 to 20 MeV. The dose range was variated from 1 to 6 Gy/min. The results demonstrate that DNPs could become a possible working substance for ionizing radiation nano-dosimeters.

Keywords: diamond nanoparticles, photoemission (PE), electron radiation, nano-dosimeter.

INTRODUCTION

Nowadays to detect and monitoring possible exposure to ionising radiation, increasing the labourer's working safety conditions who has to deal with radioactive materials or techniques [1]. Dosimeter is a device which can relate the quantity of ionizing radiation impacting on the detection volume of the dosimeter [2]; this mean that the quantification of the radiation is due to the detector surface, making possible a correlation between volume, considered by the detector, and the radiation quantity which it will be exposed. Introduced by H.H. Rossi (1950), who introduce the concept of micro-dosimetry [3]. The concept of dosimetry now is related to the "stochastic variables", which take into consideration internal and external scattering event of the sensor expose to a radiation source [4]. Generally, the micro dosimetry is based on two different devices, which could be a solid or gas state detector [5;6]. In this case it was chosen to work with a solid-state diamond-based detector [7;8]. The motivation behind this choice is because diamond could be easily related to the human tissue [9]; in addition, in their nanoscale structure they will have a significant band gap, thanks to the presence of nitrogen vacancy in the chemical structure of the diamond. DNPs have a well-known structure stability and still have a good tissue equivalence; these characteristics made them the best candidate to work with as sensor for dosimeter [10;11]. The aim of this article is to prove that the DNPs have sensibility for the electron beam radiation in a dose range between 1 to 30 Gy. The use of nanoscale materials increases their importance, because the diamond nanoparticles can be related to the DNA, this is possible thanks to the range size of the nanoparticles and their reactivity [ref]. They can also easily interact with the DNA strand and let us understand if the ionization process could directly damage the DNA strand letting know if it is dealing with a Double Stand Breaks (DSB) [12]. It could be already considered a substantial damage if the DSB event deletes or damages a region of 50 pair, approximately 15 nm, from the DNA [13].

MATERIALS & METHODS

The samples are made Considering synthetic diamond nanoparticles powder (140 nm raw DND-15mV, Zeta 2,0% ash from Adamas Nano), which were pressed with 5 bars of pressure using a modified mould and a hydraulic press to obtain a tablet with thickness of 1 mm. Using DNPs tablet simplify the work in terms of sample's structural stability, transport, exposition to the radiation treatment and for data collection through photoemission (PE) technique. The PE measurement was taken using an exoemission spectrophotometer located in the Biomedical engineering and nanotechnology institute (BINI). The PE works at a low-pressure condition, 6,58 x 10^{-6} atm. Regarding the radiation process, it was considered a "VARIANT TrueBeam" linear accelerator located in the Latvia Oncology Centre, used as electron beam radiation source.

For the experiment was considered an amount of 31 samples, divided in two groups considering two different dose rates of 1-6 Gy/min, with dose from 1 to 30 Gy and energy from 6 to 20 MeV. Considering the presence of 1 reference samples, which was taken as refence for the PE emission signal of the tablet without any radiation treatment. Once the tablets were ready, they were divided by dose rates and brought to the Latvia Oncology Center for the radiation treatment with electron beam radiation. The radiation was delivered only once per sample and the source of the radiation was located at 100 cm from the samples, with an exposition field of 10x10 cm; furthermore, a bolus was located on the sample, to insure to deliver the maximum of dose to the samples. After the radiation treatment the PE technique was performed for each sample to obtain information about the work function depending on the dose exposition, allowing to understand the possible presence of variation relate to the electron emission current from DNPs tablet 's surface caused by the electron functionalization.

RESULTS AND DISCUSSION

3.1 PE Results after Radiation Treatment

To understand if the radiation treatment can introduce modifications to the DNPs' electron emission behaviour, it would be necessary to use the PE technique to monitor the number of electrons emitted from the DNPs tablet's surface. The electron emission current in PE technique is proportional to the amount of energy delivered to the DNPs tablet by the photons [14], using a UV source to provide the require energy at a specific wavelength range. Radiated DNPs were then expose to a wavelength range of 310 to 200 nm for the PE technique to collect data about the surface electron functionalization.

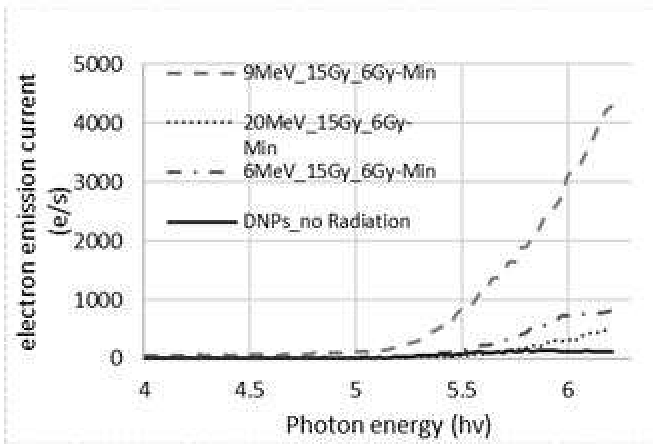

Fig. 1: PE spectra of tableted diamond nanoparticles tablet, dose rate of 6 Gy/min.

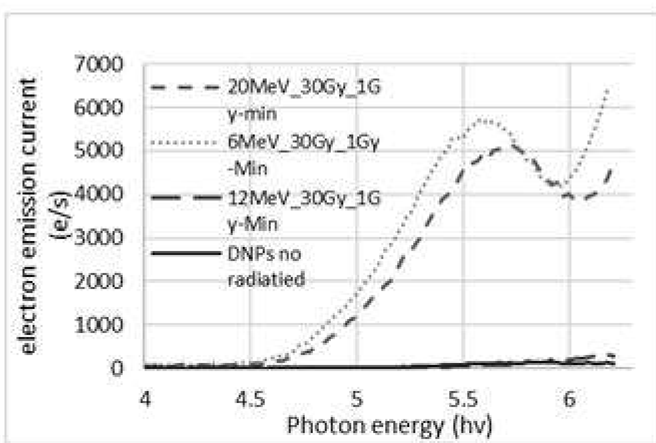

Fig. 2: PE spectra of tableted diamond nanoparticles tablet, dose rate of 1 Gy/min.

From the signals reported in fig. 1 and fig. 2 is possible to calculate the work function [14]. The work function value is obtainable considering the number of emitted electrons from DNPs tablet surface as linear regression of the signals crossing the X-axis value, thanks to the linear regression is possible to interpret it as a linear function of N=f(E) and report it as y= ax+b [15;16].

$$\varphi = N_{E=0} = \frac{b}{a} \quad (1)$$

From eq. 1 is possible to obtain the work function value which promote the electron emission. Once obtained the work functions, it's possible to plot them in a graph taking into consideration the influence of the radiation treatment on the work function.

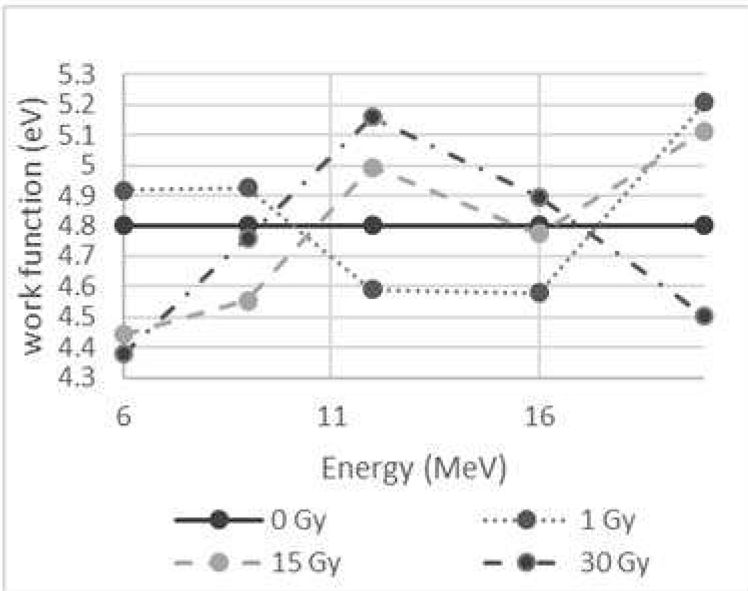

Fig. 3: shows the work function value depend on the energies delivered to the DNPs samples.

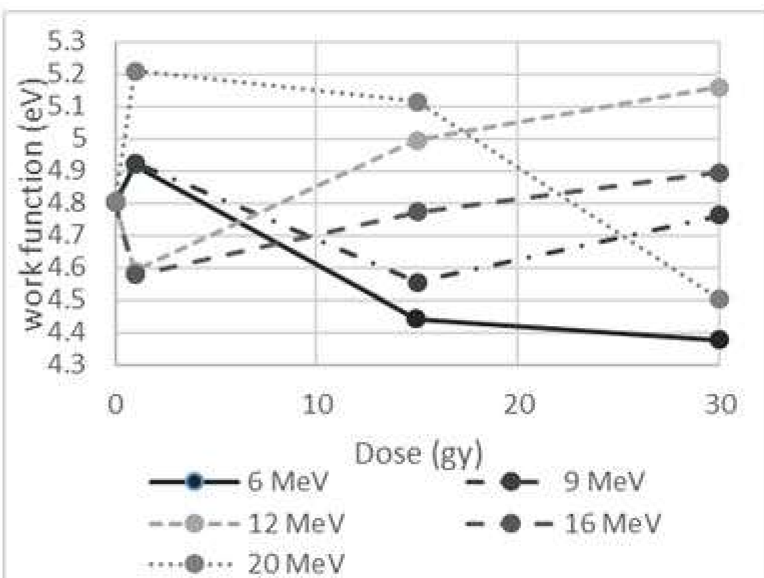

Fig. 4: shows the work function value depend on the dose delivered to the DNPs samples.

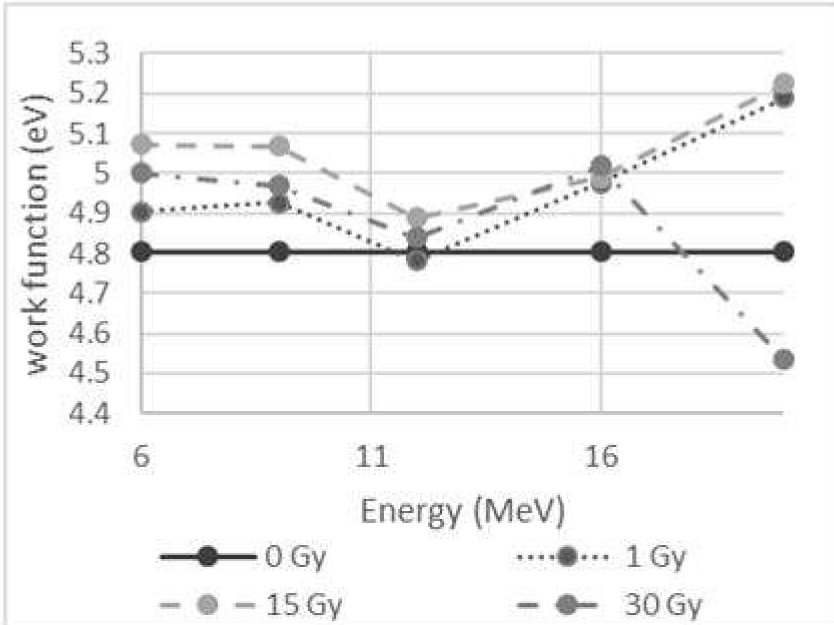

Fig. 5: shows the work function value depend on the energies delivered to the DNPs samples.

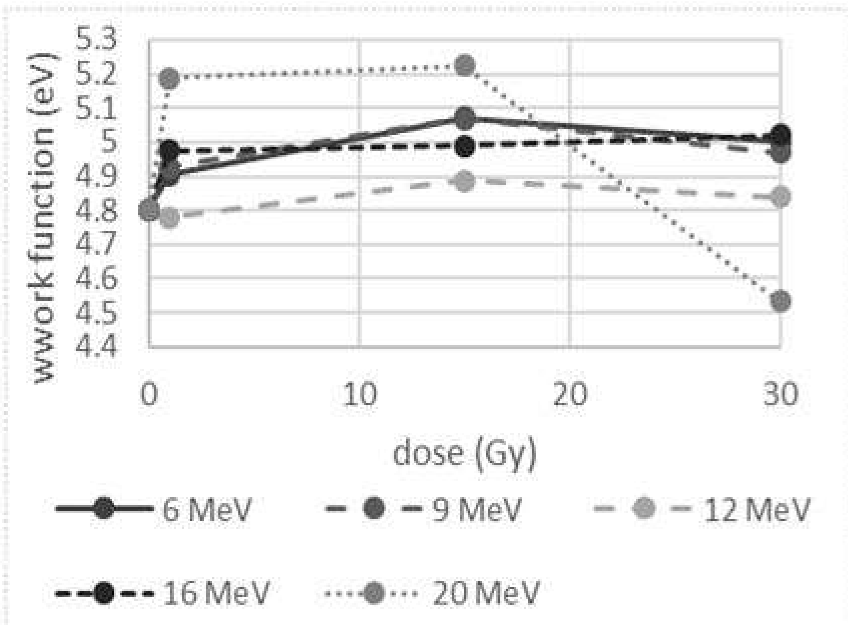

Fig 6: shows the work function value depend on the energy delivered to the DNPs samples.

From fig. 3 and fig. 5 is possible to compare the work function different response, based on the energy, between radiated samples to the non-radiated one, highlighting that DNPs show higher response to specific radiation allowing us to select them between all the radiation treatment considered. The selected dose and energy for 1Gy/min is 30 Gy considering energies of 6 MeV, 12 MeV and 20 MeV; instead, for 6 Gy/Min 15 Gy and energies of 6 MeV, 9 MeV and 20 MeV. The selection of that doses (Gy) and energies (MeV) could be related to a possible differentiation during the electron functionalization of the DNPs' surface which cause a higher electron emission current compared to the other radiated and non-radiated DNPs tablets.

CONCLUSION

As result:

- DNPs show to have sensibility for doses from 1 to 30 Gy and energies between 6 to 20 MeV, taking into consideration a dose rate of 1-6 Gy/min.
- The DNPs' work functions highlight to have a higher response to 1 Gy/min 30 Gy with energies of 6, 12 and 20 MeV, 6 Gy/min 15 Gy and energies 6, 9 and 20 MeV.

DNPs' surface functionalization can cause a different respond when DNPs are expose to different amount of energies. For this reason, these parameters have been selected for additional analyses relate to the possible changing in DNPs' behaviour, caused by the electron functionalization provide by the electron beam radiation, like the possibility to show toxic behaviour towards eukaryotic cells.

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