EXPLORING GAMMA RADIATION EFFECT ON EXOELECTRON EMISSION PROPERTIES OF BONE

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Abstract: *Gamma radiation is used for radiation therapy to treat carcinogenic diseases including bone cancer. Ionising radiation kills carcinogenic calls. However, there are side effects of the gamma radiation on the bone surface electron structure. One of the effects is in the form of altering electron density of states of bone that, with time, influences biomedical reactions on bone life condition.*

Key words: *gamma radiation; exoelectron emission; bone; radiation effects*

I- Introduction

Gamma radiation is used for radiation therapy to treat carcinogenic diseases, including bone cancer. However, there are side effects by radiation on structures of bones. Structure alters electron density of states that, in time, influences biomedical reactions on bone life condition.

Gamma radiation used by therapy has the energy of photons (1-20 MeV) to damage bone molecular/atomic bonds coupled with (0.1-10) eV [1]. Because of the bone semiconductor properties [2], its structural features affect electronic behaviour of bone too [3]. Due to this reason, biochemical reactions between the bone and the surrounding cells targeted to remodel tissue could be influenced [4]. A bone surface, where the cells are coming to be adhered [5] with the aim to supply biochemical reactions [6], provides the greatest impact.

Exoelectron emission (EEE) phenomenon underlies an electron spectroscopy to explore alteration of the electronic structurally dependence properties of different materials [7, 8]. It is the only physical method to explore defects of surface giving information on stability of concentration with time.

Gamma radiation used for radiation therapy has the energy of photons (1-20 MeV), and therefore penetrates the bone of the human organism and damages its atomic/molecular structure. Because of the bone semiconductor properties, the behaviour of its atomic/molecular structure affects electron structure and this in turn could provide an impact on biochemical processes within the organism. EE is a powerful tool to investigate a wide range of structural imperfections at the surface layers of solids, bone being one of them.

The main objective of this paper is to develop EE E measurement technique to be in use for investigating gamma radiated bones. The: developing technology for specimen preparation; Optimisation for EEE measurement; validation of measurements; Estimation of EE analysis.

II- Theoretical background

Ionising radiation passing through living cells will initiate a chain of chemical reactions, mediated through cellular water, leading to ultimate biological damage (indirect effects).

Bone is the main component of the skeleton in the adult human. Like cartilage, bone is a specialised form of dense connective tissue. Bone gives the skeleton the necessary rigidity to function as attachment and lever for muscles and supports the body against gravity [8]. Bone is composed of collagen, water, hydroxyapatite mineral, and small amounts of proteoglycans and noncollagenous proteins [8]. Some data in the literature for the composition of adult human and bovine cortical bone are given in Table 1.

Table 1. Composition of Adult Human and Bovine Cortical Bones [10].

Component	*Bovine*	*Human*
Water	*9.1%*	*7.3%*
Apatite mineral	*67.4 %*	*67.4%*
Organic matrix	*21.5%*	*21.4%*

The electron structure of bone and its surface vary under different treatment. Several electron canters with maximums at -5.0eV, -5.3eV, -5.7eV were found in bone tissue [8].

Because gamma radiation is widely used in therapy as well as in bone cancer therapy, the effects of gamma radiation on human bones should be investigated. The bovine cortical bone specimens can be used as prototype of adult human bone because of similarities in compositions of adult human and bovine cortical bones.

EEE was developed as an electron emission for different materials. This technique is extremely sensitive to structural imperfections in material surface [8]. EEE is a radiation of low-energy electrons from the surface of a firm body being in the non-equilibrium excited by any way condition [9]. The common advantage of all EE phenomena must be the influence of structural changes in the surface and subsurface region (depth of about 10 nm or less) [9].

EEE is a powerful tool to investigate a wide range of relaxation processes in the surface layers of solids: strain relaxation, oxidation and other chemical reactions, annealing of point defects, re-coupling of destroyed bonds, phase transformations, etc. This method is widely used for investigation of biological objects [7, 8, 9].

III- Instrumentation and Method

Good instrumentation is very important in for obtaining reliable results. At the realization of the experiments the device of the exoemission control was used. Such a spectrometer was discussed in details in the thesis. The device consists of a vacuum system, a complex of electronic devices for the PTSE intensity registration and the record of the received information blocks of a photo- and thermo-stimulation.

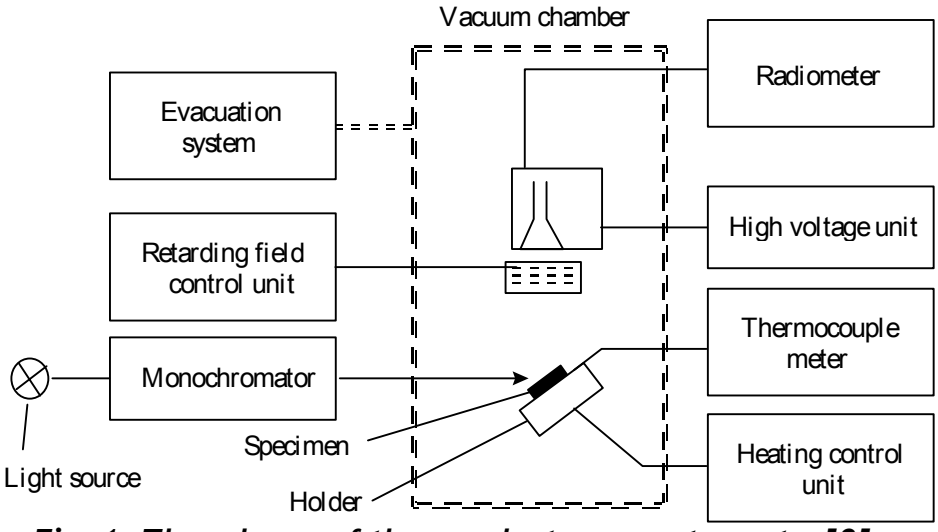

Fig. 1. The scheme of the exoelectron spectrometer[8]

Bovine tibia bone of slithered 1.5 years old cow was used as a material for the experiments. The bovine bone was bought after two days the animal was slithered. Then, it was cleaned mechanically from muscles, fat and bone marrow. Specimens were cut transversally to the bone longitudinal axis using the stainless steel surgical saw or facing tool. Specimens were cut in a way so that they have the same physical parameters: thickness (A) of 0.2 cm, surface area (B) of 0.36 cm^2, volume of 0.36cm^3 and mass density of 0.9g/cm^3.

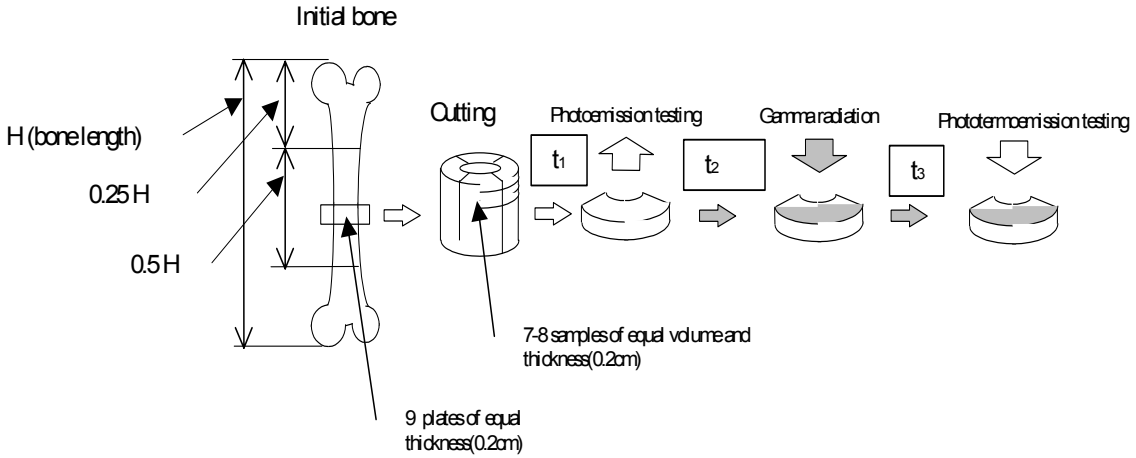

Fig.2. Technology of preparation and emission testing of the model specimens

Some factors were considered and discussed since they could affect exoemission measurement results. These factors were: duration of storage, anisotropy of bone energy, heating conditions, and photon energy.

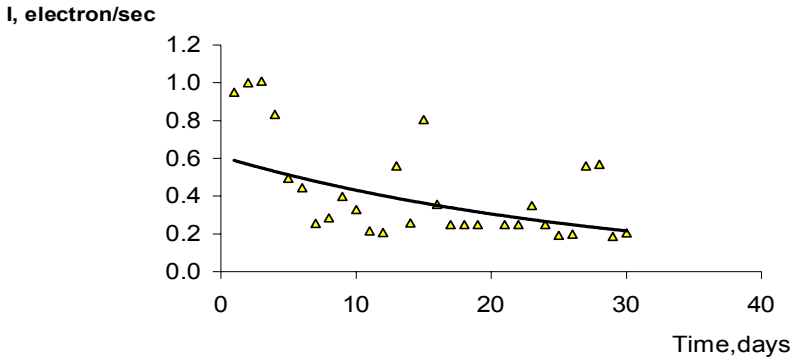

Fig.3. Storage - time induced decay of photoemission

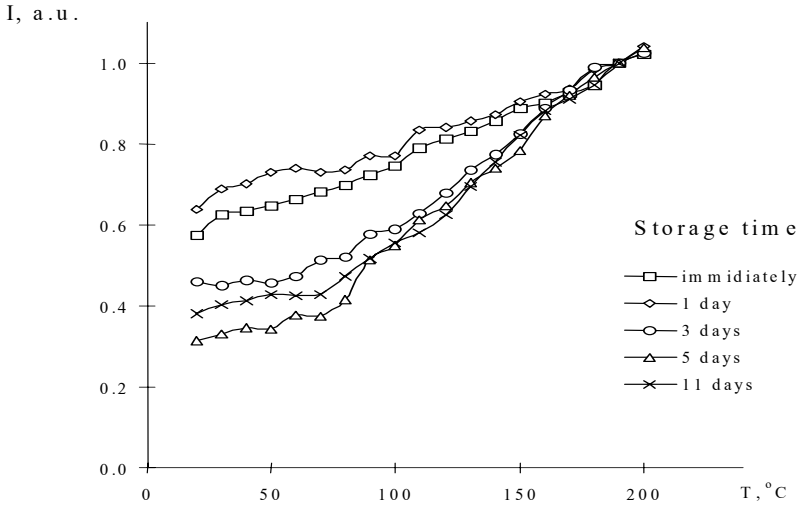

Fig.4. Temperature dependence of the emission current at different storage time

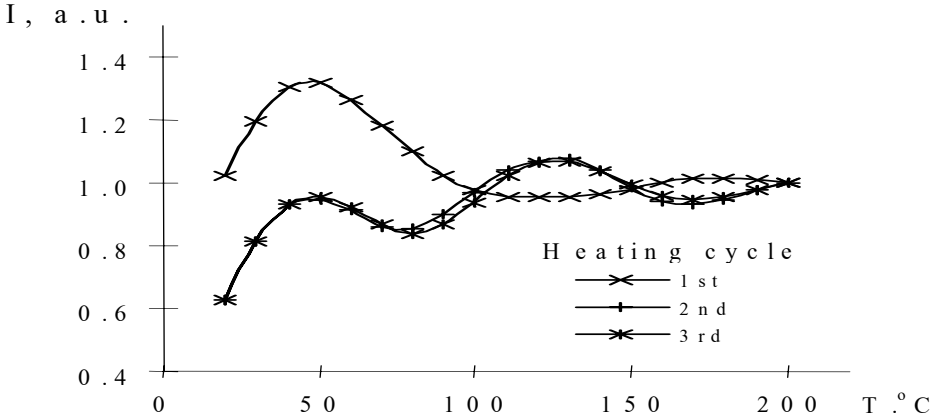

Fig.5. Affection of multiple heating on I(T) regularities [8]

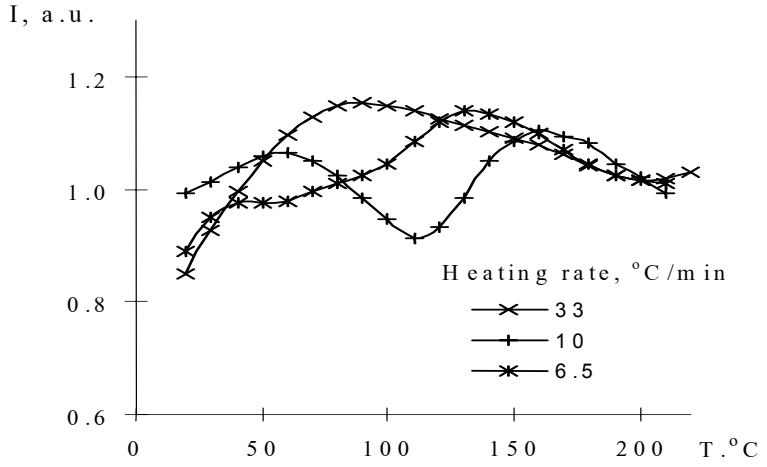

Fig. 6. EE spectra recorded at different heating rates [8]

Gamma radiation was delivered from the linear accelerator SL75-10. Gamma radiation doses were applied to the bones in both modes: fractional and non fractional (Table 2).

Table 2 Applied fractional and non- fractional irradiation.

Irradation mode	*Number of experiments*	*E, Mev*	*D, Gy*	$\dot{D}$, *Gy/min*
Fractional				
1	*27*	*8*	*2,4,6,8,10*	*2*
Non-Fractional				
2	*69*	*6*	*2,4,6,8,10*	*2,3,4,6*
3	*27*	*8*	*2,4,6,8,10*	*2*
4	*27*	*8*	*1,2,3,4,5,6,7,8,9,10*	*2*
5	*69*	*18*	*2,4,6,8,10*	*1,2,4,6*

It was found that:
1. Exoemission measurements should be carried out after the 10^{th} day of storage of the samples at room conditions;

2. The I(T) regularities for both groups of the transversal and longitudinal patterns cut off were placed within the range of the I measurement error;
3. The energy of photons should be equal to 5.6 eV;.
4. The measurements cannot be provided after 1st heating cycle;
5. Heating rate, being equal to 10^0 C/min, provided the necessary sharpness of I(T) regularity;
6. The measurements should be performed in a time less not more than five days after gamma irradiation;
7. Errors for the total emitted charge not more than 4% with the level of significance equal to 95%.

IV- Results and discussion

Fractional and non-fractional irradiation effects

Figure 8 demonstrates typical PTSE spectra of bone after gamma irradiation meaning that radiation inserted imperfections in the bones. Two typical maximums of I placed at +50 C and ~ +150 C were manifested. This meant that two types of imperfection were detected. The discovered imperfections were considered too. The defect centre detected at +50C was situated at the collagen mineral interface, however the one of ~+150 C dealt with the hydroxyapatite phase. Because the height of the peaks became greater, both kinds of centres were affected by radiation. Moreover, the concentration of imperfections estimated by Q rose under D (Fig.7).

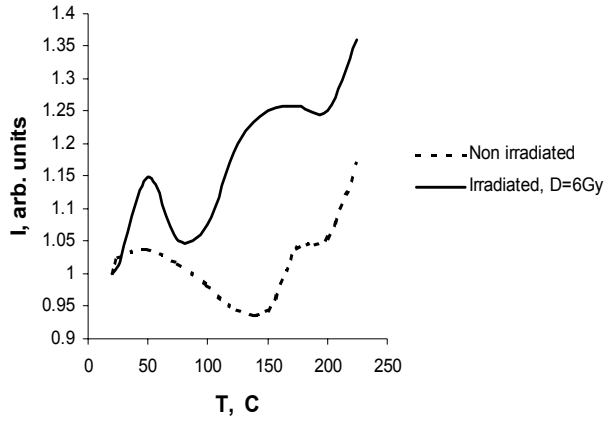

Fig.8. Typical PTSE spectra of bone after photon irradiation.

There is a difference in the effects of radiation on magnitude (Q) whether the application of radiation dose is fractional or non-fractional. The

higher the effect of radiation on Q is more evident in case of fractional radiation.

Non - fractional mode

Figure (Fig.9a) shows the EE structural induced changes inserted in bone material by gamma photons with Energy E= 6MeV, irradiation had been performed with different absorbed dose rate (2 Gy/min and 6 Gy/min respectively).

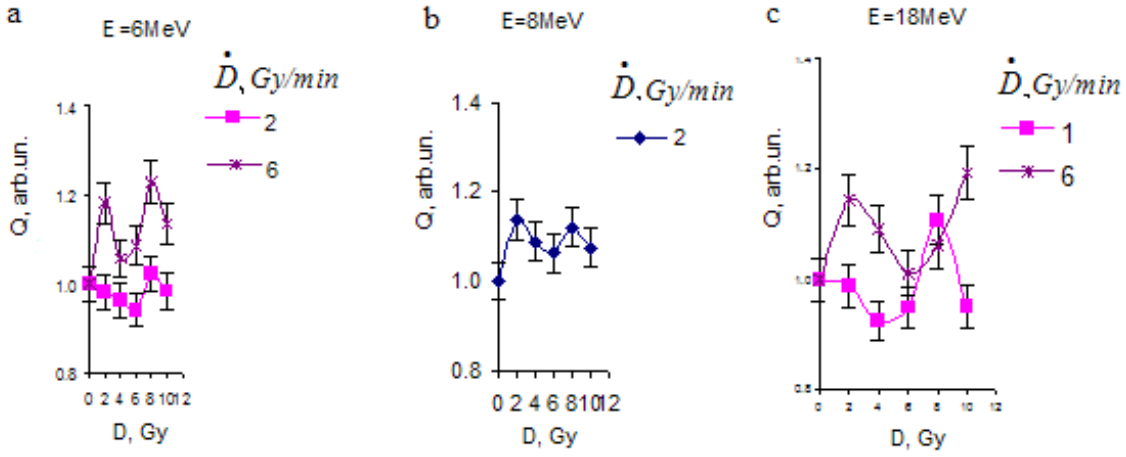

Fig. 9. Dependence of total emitted charge (Q) on gamma radiation absorbed dose (D) of gamma photon for:

a. Energy E = 6 MeV and Absorbed dose rates ($\dot{D}$min= 2Gy/min and $\dot{D}$max= 6Gy/min)

b.E = 8MeV and Absorbed dose rates ($\dot{D}$min= 2Gy/min)

c.E = 18 MeV and Absorbed dose rates ($\dot{D}$min= 1Gy/min and $\dot{D}$max= 6Gy/min)

It demonstrates a non-linear behaviour of Q from dose. Non-linearity increases with rising dose rate.
Figure 9b shows the EE structural induced changes inserted in bone material by gamma photons with gamma radiation photon energy of E= 8MeV where irradiation had been performed with different absorbed dose rate (2 Gy/min and 6 Gy/min respectively).
Figure 9c shows the EE structural induced changes inserted in bone material by gamma photons with Energy E= 18 MeV, where irradiation had been performed at different absorbed dose rate (1Gy/min and 6 Gy/min respectively).

Irradiation with different photon energies demonstrated non-linear behaviour of Q after constantly increasing exposure. The two peaks located around 2 Gy and 8 Gy of exposures are visible for the applied energies. The tendency of peaks magnification affected by higher dose rate is found. One can assume that the bone EE response is not linear on

the dose exposed and probably is connected with interaction of radiation induced centres responsible for EE process.

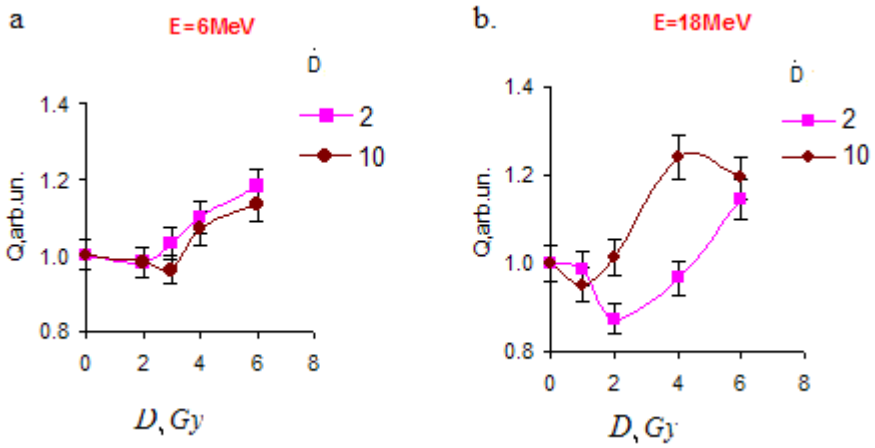

Fig. 10. a. Energy of gamma photon E(E=6 MeV) influence and dependence of Q on absorbed dose rate
b. Influence of gamma photon Energy (E =18MeV) influence on dose rate affection

Figure 10a shows the structural changes inserted in bone material by gamma photons with Energy E= 6MeV, irradiation had been performed with different gamma radiation doses (2 Gy and 10 Gy respectively).
Figure 10b shows the structural changes inserted in bone material by gamma photons with Energy E=18MeV, irradiation had been performed with different gamma radiation doeses (2 Gy and 10 Gy respectively).

Irradiation with different photon energies demonstrated non-linear behaviour of Q after constantly increasing absorbed dose rate (Irad). The tendency of peaks magnification affected by higher dose rate is found for E=18MeV. One can assume that the bone EEE response is not linear on the dose rate and probably is connected with interaction of radiation induced centres responsible for EEE process.

Fractional mode

Fig.11 shows the structural changes inserted in bone material by gamma photons with Energy E= 8MeV where irradiation had been performed with fractional gamma radiation doses dD of 1 Gy and 2 Gy respectively.

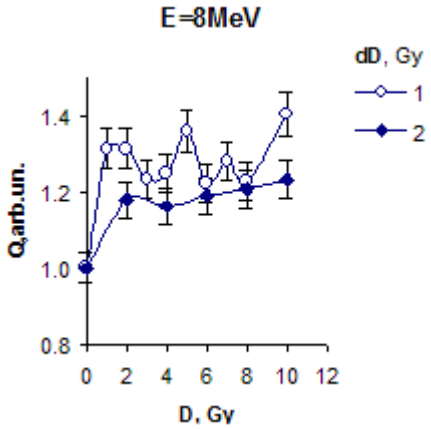

Fig.11. Dependence of total emitted charge (Q) on gamma fractional gamma radiation dose dD.

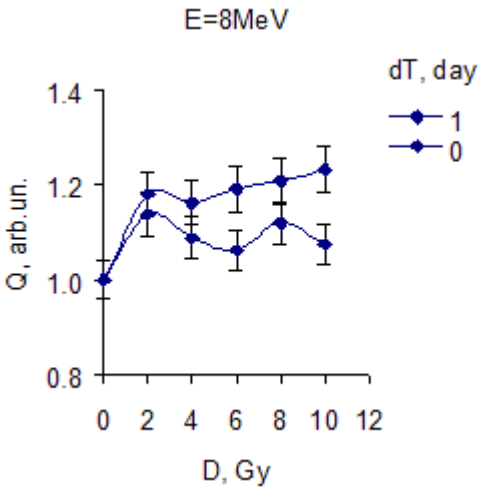

Fig.12. Dependence of total emitted charge (Q) on fractional gamma radiation dose D

There is a difference in the effects of radiation on factor Q whether the application of radiation dose is fractional or non-fractional. The higher the effect of radiation on Q is more evident in case of fractional radiation (Fig.11 and Fig.12).

V- Conclusion

1. The higher the effect of radiation on Q is more evident in case of fractional radiation.
2. Irradiation with different photon energies demonstrated non-linear behaviour of Q after constantly increasing exposure. The two peaks located around 2 Gy and 8 Gy of exposures are visible for the applied energies. The tendency of peaks magnification affected by higher dose rate is found. One can assume that the bone EEE response is not linear on the dose exposed and probably is connected with interaction of radiation induced centres responsible for EEE process.

VI- REFERENCES

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