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Evaluation of Lead Nanoparticles Usability for Gamma Radiation Sensing

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Abstract

This paper presents the detailed studies of the current-voltage (I-V) characteristics of a compressing thick disc pellet of lead nanoparticles which it is exposed to gamma radiation. The I-V characteristics are carried out for the pellet as exposed to a disc-type ⁶⁰CO radiation source with an activity of 370KBq. The data analyzed to obtain current versus dose plots at different applied voltages. These plots are clearly showing that, the induced current increases quite linearly versus radiation dose. The interaction of the gamma rays with the Pb nano matter can produce charge-hole pairs leading to the generation of electronic current. Nevertheless the nano lead enhances sensitivity to gamma-radiation, it may be used to improve and develop units and devices for radiation detection for environmental safety and effectiveness of nuclear power engineering.

1. Introduction

Nanoparticles may exhibit interesting and technologically important properties which are not possessed by bulk materials [1, 2]. Already it has been accepted that small clusters of metal atoms have unique optical, electrical, physical and properties [3, 4, 5]. When the particle dimensions become less than 100 nm, the average concentration of these defects (i.e. the number of the surface atoms with respect to the total amount of the atoms in the particle) exceeds 1 %. This value is much higher than the average concentration of point defects which can be created in the bulk by radiation. [6]

On the other hand the ionization means separation of positive and negative electric charges which is the basis of any kind of generation of electrical energy. These phenomena can be used for direct conversion of radiation energy to electricity in composite structures when one of the components is characterized by much stronger absorption of ionizing Radiation than the other. In this case the radiation will produce separation of electric charges.

The prevalence of heavy elements (tungsten, lutecium, lead, etc.) enhances sensitivity to hard gamma-radiation [7], that can be applied of nanostructures and shaped crystals

in radiation safety and protection.

Studies of the prospects of application of lead nanostructures and shaped solids demonstrate that lead nanoparticles are capable to improve essentially either the ecological safety or the effectiveness of Nuclear power plants (NPP). Such improvements are based on development of units and devices for, operative differential monitoring of radiation flows inside active reactors zones for instantaneous detection of damages of fuel rod cladding inside nuclear reactors. [8]

2. Material and Method

Our method divided into three main parts:

Part 1: The DC conductivity of the disc pellet of Pb nanoparticles sample is measured by holding the sample between two electrodes (made of thick brass discs) in a laboratory-fabricated conductivity cell and using a Keithley (Model 617) & electrometer at the room temperature. In this method a constant voltage source, V, is connected in series with the plate sample, and the electrometer. Since the voltage drop across an electrometer is negligible, essentially all voltage appears to cross the sample. The resulting current is measured by the electrometer. Resistance is calculated using the Ohm's law. The current-voltage characteristics are recorded without γ irradiation. Basically, the relations used are:

$$R = \frac{V}{I} \quad (1)$$

The resistance is the ratio of the potential voltage to the current as in equation (1). It has the unit of ohms (Ω). The resistivity (ρ) relates the resistance to the volume of the medium (cross-section area A with length d) and is given by the equation (2).

$$\frac{1}{\rho} = \frac{d}{RA} \quad (2)$$

Part 2: At room temperature, a disc-type ^{60}Co gamma radiation source with an activity of 370KBq is used to expose this thick disc to various levels of gamma radiation dose by changing the exposure time. I-V characteristics for as-printed and gamma irradiated specimens are recorded after each exposed dose.

Part 3: The XCOM code is a data base to be run on a PC and it uses pre-existing data bases for coherent and incoherent scattering, photoelectric absorption, and pair production cross - sections to calculate mass attenuation (μ/ρ) coefficients at energies of photon KeV. The photon attenuation coefficients have been evaluated comparing A and A_0 which are the measured count rates in gamma detector, respectively, with and without the absorber of thickness x

$$\mu = \frac{1}{x} \ln \frac{A_0}{A} \quad (3)$$

where

A = intensity transmission

A_0 = incident intensity

μ (cm^{-1}) = linear attenuation coefficient

x (cm) = thickness of absorber.

The fact that the linear attenuation coefficient varies with the density of the absorber limits its use, even if the absorber material is the same.

3. Results and Discussion

3.1. Using Lead Nano Particles Pellet with Diameter, 4.95mm and 0.250mm Thickness

The current versus applied voltage plots are obtained whole the measurements have been carried out with and without γ radiation. Figure.1, shows the plot of I-V characteristics that a recorded for the sample disc with thickness 0.25mm Without irradiation γ at room temperature, the inverse of slope is the resistance $R = 0.109 \times 10^6 \Omega$ from equation (2) we can calculate the resistivity at room temperature $\rho = 8.4 \times 10^6 \Omega\text{mm}$.

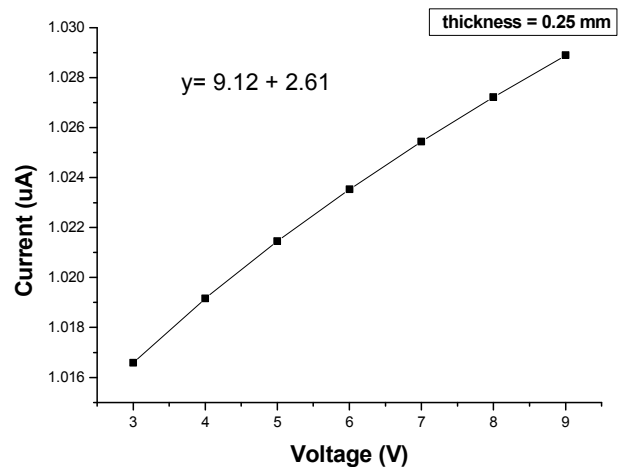


Fig. 1. Currents values of the sample is directly proportional to the voltage and the values are obtained at room temperatures $R=0.109 \times 10^6 \Omega$.

Figure 2. shows plots of I-V characteristics with and without gamma radiation, The typical plots of the current versus applied voltage are recorded for the disc pellet as well as for the disc exposed to different level of gamma radiation dose. It is shown in fig. 3. these plots are analyzed to obtain variations of the current density with gamma radiation dose at applied voltage 5V. The current density has been found to increase quite linearly with gamma radiation dose over the dose range. The induced current increases quite linearly with radiation dose because the interaction of the gamma rays with matter can produce charge pairs leading to the generation of electronic current under an applied voltage across the absorbing material. In order to understand relative change in

the current due to gamma radiation exposure of different levels, a quantity called normalized current, I_N , is defined as:

$$I_N = \frac{I - I_0}{I_0} \tag{4}$$

Where: I and I_0 are the currents with and without radiation respectively. The normalized current I_N increases quite linearly with the gamma radiation dose up to a dose of 1 Gy. The experiment has provided that the material got effectiveness of direct conversion of radiation to electrical current. The detector should be fabricated with a material that must absorb the gamma ray energy to generate charge pairs with appropriate transport properties enabling the read-out electrodes to acquire the signal containing the information of the incident radiation.

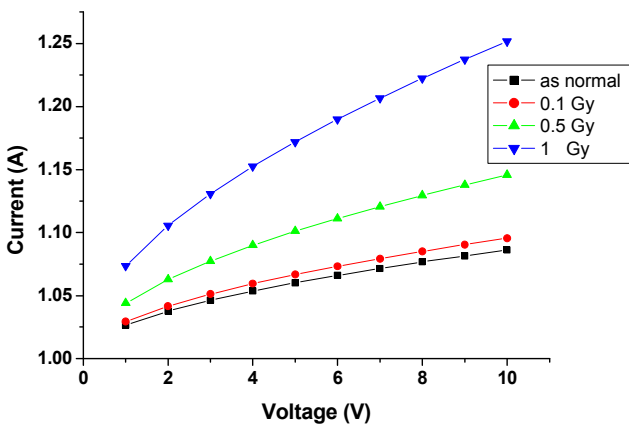


Fig. 2. Plots of current – voltage characteristics that were recorded for normal and with radiation the lead nanoparticles sample with 0.5 thickness at 25 °C.

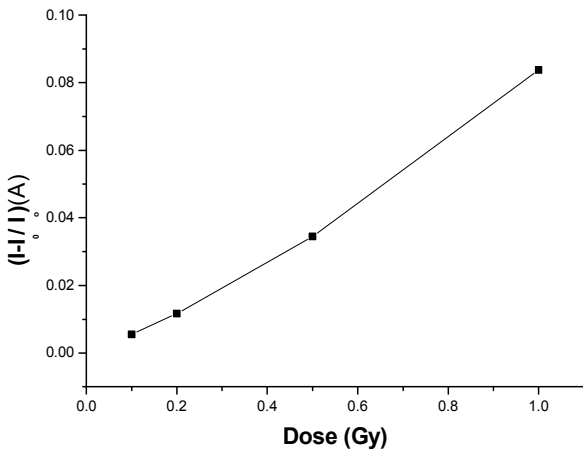


Fig. 3. Normalized current $(I - I_0)/I_0$ with radiation dose under an applied voltage of 5V.

The linear attenuation coefficients (μ) for bulk lead and for lead nanoparticles have been measured at the photon energies of range (600KeV-1600KeV). The obtained results are displayed in Fig. 4. It can be seen that the measured results decrease with increasing photon energy, and also the attenuation of the lead nanoparticles is higher than the attenuation of the bulk lead.

The photon attenuation coefficients have been evaluated

comparing A and A_0 which are the measured count rates in detector, respectively with and without gamma radiation absorber of thickness x (cm) as shown in equation (3).

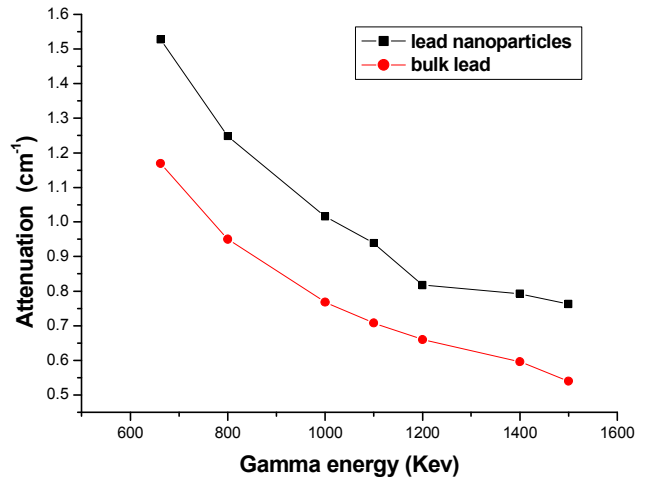


Fig. 4. Attenuation of gamma radiation versus gamma energy of the two types of lead material.

Fig. 5. shows that comparing between the output intensity and input intensity is increasing with high gamma energy and indicate to the count rates and it is constant at the low energy, so lead nanoparticles can be using for radation detection.

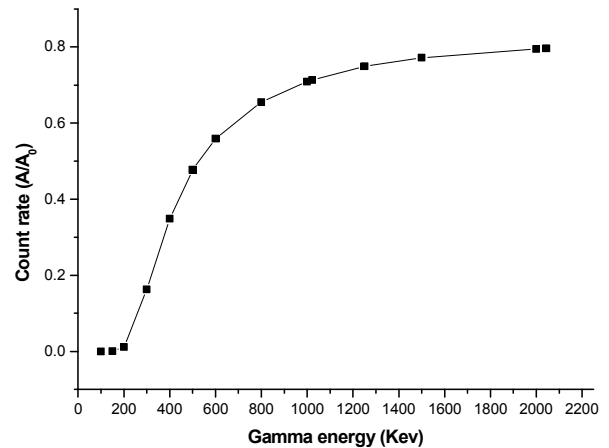


Fig. 5. (A_0/A) versus gamma energy at high energy.

3.2. Discussion

The idea is to explain the changes in the electrical behavior using a limited amount of reactions between radiations induced defects and impurities. [9]. The identification of the stable defects responsible for these changes and the knowledge of the kinetics of their formation should suggest the species and the concentrations of the impurities that are suitable for improvement of the radiation tolerance of lead nanoparticles. The aim is to induce alternative reactions to the current – voltage characteristics for the Pb nanoparticles disc clearly show that the current increases quite linearly with the increase in gamma radiation dose up to a certain critical dose. Exceeding this dose results in unstable dissymmetric characteristics. Performance parameters of the devices. Such as

sensitivity to γ -radiation exposure and working dose region are dependent on gamma energy. The above mentioned direct charging detectors can be classified as a type of low-efficiency radiation electricity converted, which is required for a good room temperature nuclear detector [10]. such type is showing which high resistivity results in a decrease of the leakage current in the material. It is observed that, the lead nanoparticles have unique electrical properties.

4. Conclusion

It may be concluded that Pb nanoparticles can be considered as effective materials for environmental real time γ - radiation sensing. Also it may be used as a base material on development of units and devices for operative differential monitoring of radiation flows inside active reactors zones for instantaneous detection of damages of fuel rod cladding tubes and optimization of regulation of reactor functioning. It has a lot of potential applications in the industries of optoelectronic and other semiconductor devices. This work throws some light on and helps further research on nano-sized lead powder.

References

- [1] El-Sayed M. El-Refaie, El-Gamel A. A., A. H. Gepreel M. (3) Kandil M., Hussein A. Z., " Electrical Properties of Electrorefined Nanostructured Lead (Pb) for Enhancing Radiation Safety" International Journal of Materials Science and Applications, July 2015. [http://www. Science publishing group. com/ijmsa](http://www.Sciencepublishinggroup.com/ijmsa).
- [2] DOE Fundamental Handbook. Nuclear Physics and Reactor Theory. Vol. 1 of 2. DOE-HDBK-1019/2-93, January 93.
- [3] Ibrabim AM and Soliman L I 1998 Rad. Phys. Chem. 53469.
- [4] Y. Ronen, A. Hatav, N. Hazenshrung, "242 m Am-Fueled Nuclear Battery, Nuclear Instruments and Methods in Physics Research a, vol. 531, Oct. 2004, pp. 639-644.
- [5] T. Yoshida, T. Tanabe, A. Chen "Method for Generating Electrical Power and Electricbattery" United States Patent Application, Pub. No. US 2005/0077876 A1, Apr. 14, 2005.
- [6] L. Popa-Simil "Pseudo-Capacitor Structure for Direct Nuclear Energy Conversion", United States Patent Application, № US 2010/0061503 A1, Mar. 11, 2010.
- [7] L. Popa-Simil, Advanced Nano-Nuclear Program Proposal, LAVM LLC, Los Alamos, 2011.
- [8] N. V. Klassen, A. E. Ershov, V. V. Kedrov, V. N. Kurlov, S. Z. Shmurak, I. M. Shmytko, O. A. Shakhray and D. O. Stryukov Additional information is available at the end of the chapter [http://dx. doi. org/10.5772/55205](http://dx.doi.org/10.5772/55205).
- [9] Bonnie C Baker: " Temperature Sensing technologies" AN 679 Microchip Inc (1998). SushmaBhat, S K Khosa, P N Kotru, R P Tandon, Material Science and Engineering. B 309,7-11, 1995.
- [10] .W C Michels: Electrical Measurements and their applications, Van Nostrand, New York (1957).