# Effects of Ionizing Radiations on the Resistances of Locally Available Brand of Ceramic Resistors

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**Abstract**

*In this research work the resistances of ceramic resistors ranges from, low, medium and high were observed for cumulative doses of gamma radiation of Co-60 and 6Mev electrons. The resistors post exposure to ionizing radiations have showed fluctuating behavior in their resistances for different cumulative doses. It is observed that the radiations of Co-60 and 6 Mev electrons have shown almost the same pattern of responses. Low range resistances have shown increment in its resistances after the very first dose of 10Gy. Medium range resistances initially showed fluctuating behavior, but the overall the resistance was observed to be declined. The high range resistances have also shown fluctuating behavior with two peaks for different cumulative doses of Co-60 photons and 6Mev electrons, then attained the resistance almost the same as initial unirradiated sample.*

***Keywords*****:** Ceramic Resistors; Ionizing Radiations; Radiation Induced; Resistance, Co-60 Radiation, 6-Mev Electrons

## Introduction

Resistances are mainly used to control or reduce the flow of electric current, voltage division, adjustment and maintenance of signal levels, biasing of active devices, terminating transmission lines etc. In context of functionality, resistors are mainly classified into two types which includes fixed resistors and variable resistors, as the variable resistors could be controlled over a range of resistances (Williams, 1992; Zandman et al., 2001). The basic resistors physically appeared as the two-legged electronic device with colored stripes that defines the amount of resistance that each resistor holds by revealing the color-coding. The resistors are made up of different conducting materials with compromising efficiencies in order to obstruct the flow of electrons i.e., electric current via atomic structures of the chosen materials. Hence, by controlling certain factors such as conducting ability of materials, surface area and length, the resistance can be varied according to the requirements. Williams, 1992; Zandman et al., 2001) differentiate types of resistors based on different materials used, their construction, tolerance abilities, power dissipation and their functionality required for different purposes. The present

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research is focused on the change in resistances of locally available brand of ceramic resistances with the cumulative doses of ionizing radiations of gamma radiations of Co-60 photons and 6Mev electrons. The resistances are categorized with low (Ω), medium (kΩ) and high resistances (MΩ) ranges.

Ceramic is a heat resistive material which is hard and brittle in nature. It is divided into three main categories, the earthenware, stoneware and porcelain. We can use ceramics in making cement, bricks, tiles etc. Ceramic can be produced either by metals or non-metals. In contrast with other metal, they have high melting point. The density of ceramics lies 2-6 $gm/cm^3$ between polymers (lower) and metals (higher). Porcelain is a type of ceramic which is smooth but breakable. It becomes denser because of its clay. They are identical in nature, but it is more costly than ceramic. Earthenware is an ancient material used in the field of pottery and for decretory purposes. It can be made porous with low temperature range (1000-1150 $^0$C), to control its porosity the fired material is enfolded with finely ground glass powder sling in water and again return back to fire for predetermined time (Treccani, 2023; (Subedi, 2013; Quesada et.al., 2019).

In this research work ceramic based locally available brand of fixed resistances were used to study the effects of ionizing radiations on their resistances for cumulative doses of Co -60 gamma radiations and 6Mev electrons. When ceramics exposed to Ionizing radiations it's physical and chemical properties can be changed depending on the type and dose of radiation. When ceramic resistors are exposed to ionizing radiations its properties like di-electric breakdown, thermal conductivity, electrical resistance, may alter (Zinkle, 1999; Zinkle & Hodgson, 1992). It has been established that even the efficient semiconductor radiation detectors TIBr was reported stable till the cumulative dose of 45kGy of gamma radiation of Co-60 (Matsumura et al., 2016). The interaction modes of different types and energies of radiations may lead to modification of the physical, electrical, chemical or other properties (Gu et al., 2017). It has been tried to made IC's, OP amplifiers and different circuitry more radiation resistant, which was termed as 'Radiation hardening'. Since different radiation types and their cumulative doses affects differently on the electrical components, there are number of techniques which are used to make Radiation hardening effect for electronic components and circuitries , such as ,by changing total dielectric isolation in place of $SiO_2$ in CMOS and radiation hardening over temperature protection circuit using dynamic comparison technique. Such techniques were already presented, and progress has been made in this direction (Manzi et al., 2022; Ray, 2023; Dang et al., 2024).

It is thought that the instantaneous increase in the conductivity of ceramic resistors is due to the valence band electron excitation. Dose dependent degradation in ceramic materials were also reported. The damages which may include displacement of ceramic material atoms, defect clustering, cavity formation, may produce micro evolution in ceramics at different cumulative doses of different types and energies of radiations. These changes in ceramic material was thought to be the reason of this fluctuating behavior of different ranges resistances , post irradiation. The study of two types of radiations effects on the most basic type of electronic circuit, the ‘ceramic based resistors of three different categories’ was not found to be studied categorically. Hence this research has provided the basic information’s of cumulative dose vs resistor’s responses.

## Material and methods

Ceramic resistors of same brand have been purchased from the local market. Three categories of resistors, low, medium, high have been made, with each category having 20 resistors of identical resistances. Resistances were tagged uniquely under the categories of low, medium and high resistances as, 1Ω, of 47kΩ, and 2.2MΩ respectively (Figure 1). Two sets of identical category resistances have been made to expose it with Gamma radiations of Co-60, and 6Mev Electrons. The base line resistances of these fresh (unexposed) samples have been measured thrice and recorded. The average values thus obtained were used. The tagged resistances as per categories were kept in zip lock airtight bags.

The fresh categorized resistors were exposed with Co-60 gamma radiation using SSD (source to skin distance) technique, with 80 cm SSD on Cobalt-60 radiotherapy machine. The resistors were placed uniformly on 10 cm plastic phantom with 0.5 cm bolus on it to ensure $D_{max}$ (the calibrated max dose) is on the resistors. The doses were given 10Gy per session per week, till the cumulative dose of 30Gy. Then the doses per session reduces to 5Gy till the cumulative dose of 175Gy had achieved. Post irradiated samples resistances were measured after 48 hrs. The whole data collection was taken at room temperature.

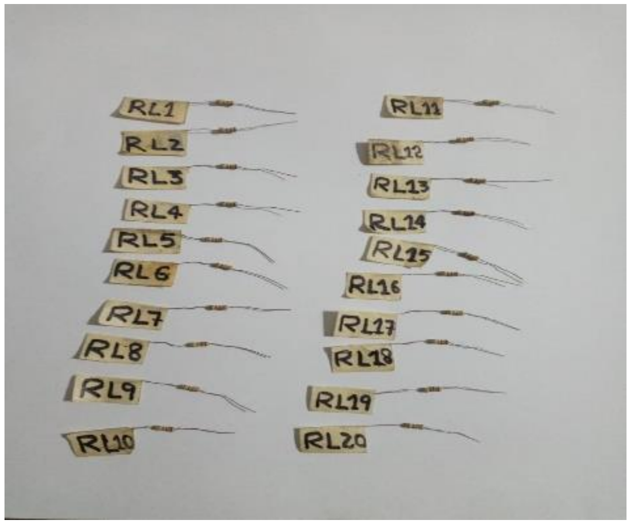


***Figure 1 Tagged resistances***

The other same set of fresh (unexposed) samples labelled uniquely in the same way were exposed with 6Mev electrons on Medical Linear Accelerator. The resistors were irradiated using SSD technique with 100 cm source to surface distance. The resistors were placed uniformly on 10 cm thick plastic phantom and a bolus of 1.0 cm was used over it to give the $D_{max}$ (maximum dose) to the resistors. A cumulative dose of 30Gy with 10Gy steps were delivered, then with 5Gy steps the cumulative dose of 115Gy was achieved. Post irradiation, the sample resistances were observed after 48 hrs with multimeter.

## Results and Discussion

This section gives details with the changes in different category resistances with cumulative doses from Gamma radiation of Co-60 and 6Mev Electrons.

### *Gamma radiation of Co-60*

*High resistance (MΩ)*: With Co-60 radiation, the high resistance (MΩ) has initially shown a slight increase of approximately 1.6% post 30Gy of the cumulative dose. Two peaks of resistance increments of approximately 139% was observed post 75Gy and 85Gy. Post 90Gy the samples retained their approximately its pre- irradiated resistance in the observed dose range (Table 1, Figure 2).

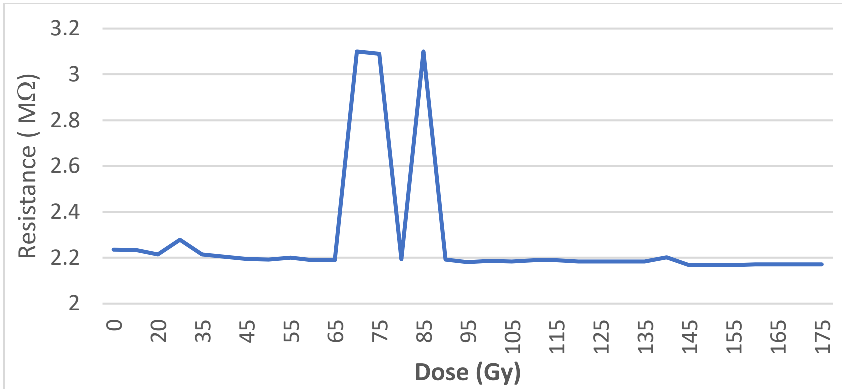


***Figure 2. Mega Ohms vs CO-60 dose***

*Medium Resistance (KΩ)*: In kilo ohms, the first dose of 10Gy of Co-60 radiation, reduces the resistance to about 0.6% and gives the deepest ditch of the graph. The cumulative dose ranges where resistances had shown declining behavior were observed from 20Gy to 50Gy , 90Gy to 95Gy , 140Gy to 145Gy, and 155Gy to 160Gy. Stable resistances ranges were observed for dose ranges from 70Gy to 80Gy, 105Gy to 135Gy, 145Gy to 155Gy, and 160Gy to 170Gy. The overall resistance decreasing behavior was observed in the observed range of doses (Table 1, Figure 3).

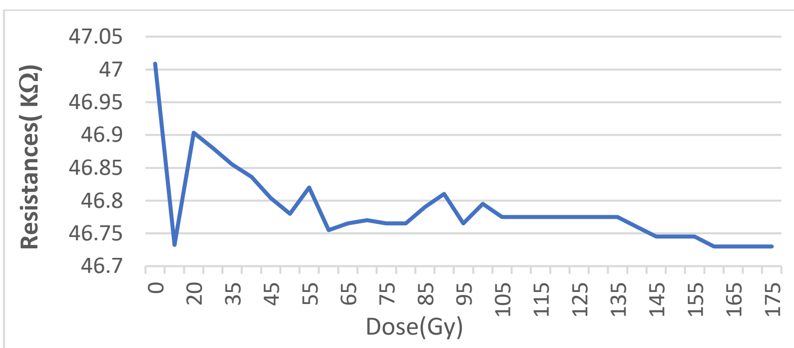


***Figure 3. Kilo Ohm vs CO-60 doses***

*Low Resistance (Ω)*: In the low resistance (1Ω) post irradiation of 10Gy of Co-60 radiation is found to give very high enhancement of approximately 146%. This behavior of enhancement in resistance was observed to continue with minor fluctuation from maximum (approximately) 150% at 20Gy. In the dose range from 135Gy to 165Gy the resistance was found to retained the enhancement. The resistance again gets another peak of 170% at 170Gy (Table 1, Figure 4).

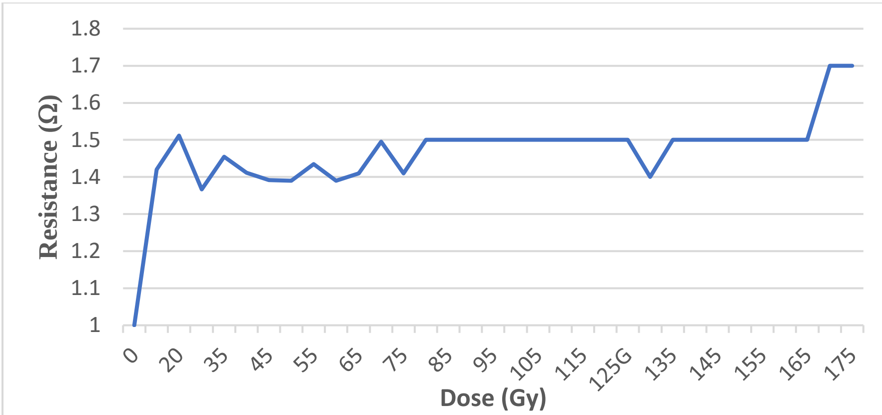


***Figure 4 Resistances in Ω vs Co-60 doses***

***Table 1 : Resistances VS Cumulative doses of Co-60 gamma radiation***

| Doses (Gy) | Low Resistance (Ω) | Medium Resistance (KΩ) | High Resistance (MΩ) |
|---|---|---|---|
| 0 | 1.0 | 47.00 | 2.23 |
| 20 | 1.51 | 46.90 | 2.21 |
| 35 | 1.45 | 46.85 | 2.21 |
| 45 | 1.39 | 46.80 | 2.19 |
| 55 | 1.43 | 46.82 | 2.19 |
| 65 | 1.41 | 46.76 | 2.18 |
| 75 | 1.41 | 46.76 | 3.09 |
| 85 | 1.5 | 46.79 | 3.1 |
| 95 | 1.5 | 46.76 | 2.18 |
| 105 | 1.5 | 46.77 | 2.18 |
| 115 | 1.5 | 46.77 | 2.18 |
| 125 | 1.5 | 46.77 | 2.18 |
| 135 | 1.5 | 46.77 | 2.18 |
| 145 | 1.5 | 46.74 | 2.16 |
| 155 | 1.5 | 46.74 | 2.16 |
| 165 | 1.5 | 46.73 | 2.17 |
| 175 | 1.7 | 46.73 | 2.17 |

### *6 Mev Electrons*

*High resistance (MΩ)*: In the Mega ohms resistance, the first 10Gy dose of 6Mev electron was found to enhance 138%. A dip in the resistance, post irradiation of 20Gy was found, which was approximately the same as its initial un-irradiated sample resistance. At 30Gy the samples were found to regain their maximum enhanced resistance.

Post 35Gy the resistance was found to be stable and approximately equal to the same as its un-irradiated sample. This behavior continues for the rest of the observed dose range (Table 2, Figure 5).

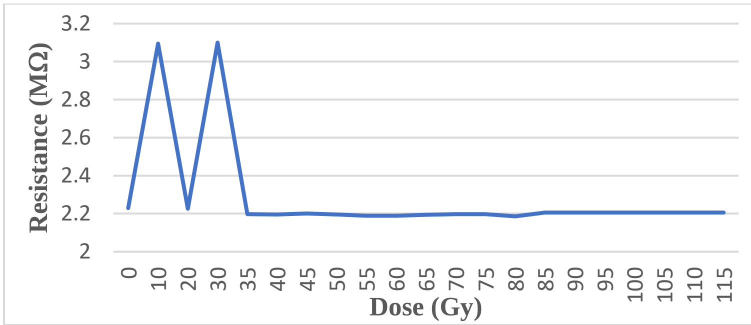


***Figure 5. Mega Ohm vs 6Mev electron doses***

*Medium Resistance (KΩ)*: In kilo ohms resistance, the first doses of 10Gy of 6 Mev electrons reduces the resistance to 0.6% and gives the deepest ditch of the graph. There are dose ranges where resistance declining behavior were observed such as from, 20Gy to 50Gy , 90Gy to 95Gy , 140Gy to 145Gy and 155Gy to 160Gy. Stable resistances ranges were observed for dose ranges 70Gy to 80Gy, 105Gy to 135Gy, 145Gy to 155Gy and 160Gy to 170Gy. Overall the resistance decreasing behavior was observed (Table 2, Figure 6).

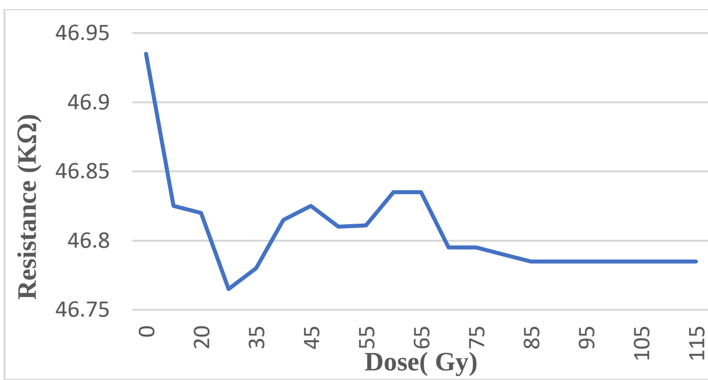


***Figure 6. Kilo Ohm VS 6MeV electron doses***

*Low Resistance (Ω)*: In low resistance, post 10Gy dose of 6Mev electrons enhanced the resistance to 146%. Dips of 142% and 140% at 20Gy and 35Gy was observed respectively. Afterwards from 40Gy to 105Gy the sample maintained at150% enhanced state. Post 105Gy the resistance enhanced to 170% and retain its value at dose range from 110Gy to 115Gy (the observed dose range) as shown in Table 2 and Figure 7.

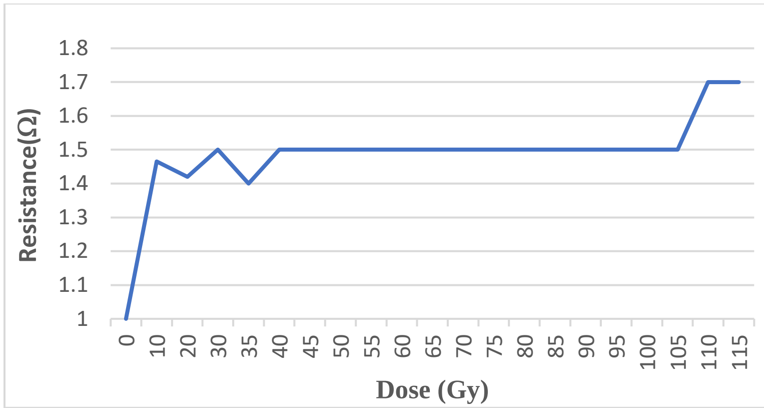


***Figure 7. low Resistances in Ohm vs 6 MeV electron doses***

***Table 2: Resistances VS Cumulative doses of 6 Mev radiation***

| Doses (Gy) | Low Resistance (Ω) | Medium Resistance (KΩ) | High Resistance (MΩ) |
|---|---|---|---|
| 0 | 1.0 | 47.00 | 2.23 |
| 20 | 1.42 | 46.82 | 2.26 |
| 35 | 1.4 | 46.78 | 2.19 |
| 45 | 1.5 | 46.82 | 2.20 |
| 55 | 1.5 | 46.81 | 2.18 |
| 65 | 1.5 | 46.83 | 2.19 |
| 75 | 1.5 | 46.79 | 2.19 |
| 85 | 1.5 | 46.78 | 2.20 |
| 95 | 1.5 | 46.78 | 2.20 |
| 105 | 1.5 | 46.78 | 2.20 |
| 115 | 1.7 | 46.78 | 2.20 |

## Conclusions

In low resistance (1Ω), a drastic increase in the resistance post first dose (i-e,10Gy) with both gamma radiation and 6Mev electrons was observed .The overall behavior was found to be increased. In the Medium range resistance (47 KΩ) post first dose of (10Gy) the resistance decreased with both types of radiations, and with fluctuating behavior the resistance was found to be decreased in the observed range of cumulative doses. In the high resistance (2.2MΩ), both type of radiations were found to give two peaks of high increment. With 6Mev electrons, the peaks were appeared post 10Gy and 30Gy and attained enhanced resistance to approximately 138% with respect to unirradiated sample. On the other hand with Co-60 gamma radiation two peak resistance enhancements of approximately 139% at 70Gy 75Gy and 85Gy were observed. In high resistance (MΩ), regardless of the type of radiation, the pre and post peaks were found to be almost the same as unirradiated samples. The results observed in this research has shown fluctuating behavior for different cumulative doses of Cobalt 60 gamma radiation and 6Mev electrons. The peaks and the dips for different cumulative doses have shown similar behavior both for Co-60 and 6Mev electrons. It is required to further investigate the irradiated samples for noticeable changes at different cumulative doses by breaking it and analyzing the composition of resisting material to get further insight into physical and chemical changes.

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