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EFFECTS OF GAMMA IRRADIATION ON ELECTRICAL PROPERTEIS OF POLYVINYL CHORIDE (PVC) SAMPLES

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ABSTRACT

The electrical properties that are of major importance to the operation and lifetime of many electrical components and systems include the relative dielectric constant and relative permittivity, these properties are dependent on the chemical composition of the dielectric, they usually suffer degradation after electrical deterioration has taken place. The aim of this paper is to use the change in electrical properties with radiation dose to design polymer dosimeter. The experimental results show an improvement the relative permittivity of the medium decreased except for PE sample which increased when the total irradiation dose of gamma rays was increased whereas the relative dielectric constant increased for all PVC samples. The predominance of cross-linking results shows linear relations between relative permittivity and relative dielectric constant versus absorbed dose of gamma rays source. These relationships between these properties and dose level can be utilized as measuring tool (Dosimeter) for radiation exposure that incident on the PVC samples.

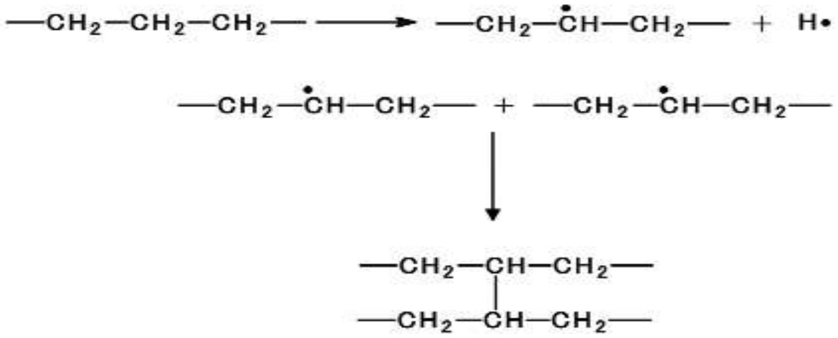
Keywords- *The electrical properties, dielectric and relative permittivity.*

I. INTRODUCTION

The majority of polymeric materials are electric insulators in nature [1]. However, they can be rendered conductive by different methods: Creation of conjugated double bonds in the backbone chain of polymers [2,3]. Introduction of donor-acceptor complex in the polymer matrix [4], and adding conductive fillers such as metallic powders and carbon black [5-8]. One of the goals of materials research is to create new materials with physical properties tailored to a particular application and to understand the mechanisms controlling these properties. Irradiation of different types of polymer was early studied by Tarssova et al [9]. The effect of the polymer composition on radiation induced crosslinking was studied by many workers [10-12]. It is well known that electrical conduction in polymers can be considerably enhanced by irradiation [13]. The increase in conductivity of irradiated polymers may be attributed to the formation of conjugated structures [14]. Also, the irregularity in the polymer chain may give rise to a hopping mechanism that will enhance the conductivity [15]. The present investigation aims to clarify the effect of γ-radiation on both the electrical and thermal properties of styrene butadiene rubber (SBR) loaded with mixed concentration ratio of Cu and Fe metal fine powder. Moreover, the filler-filler interspacing distance is calculated empirically as a function of both γ- dose and filler content.

. In general, Eq. (1) and (2) shows the reaction between free radicals, illustrate the process of permanent cross-linking and main-chain scission respectively:

The cross-linking process is:-



(1)

Whereas scission chain processing we can obtain by:-

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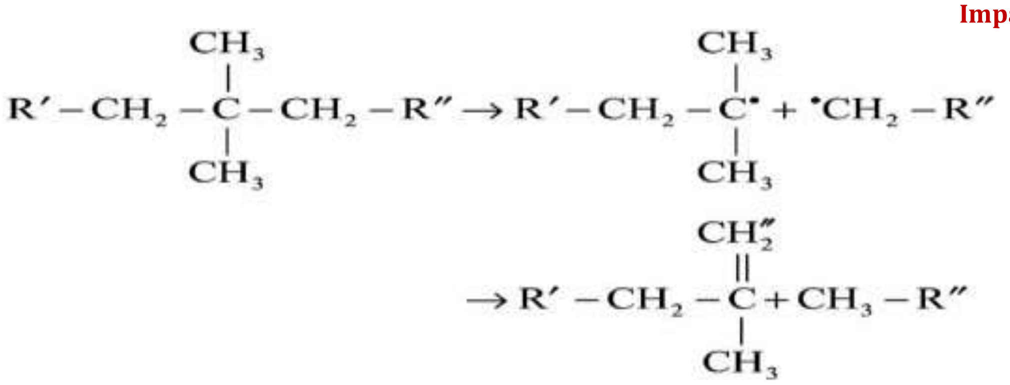

(2)

II. EXPERIMENTAL WORK

2.1 Samples Preparing

The PE and PVC samples were prepared as sheets with thickness ranging between 2 to 4 mm. Tables (.1, .2.) illustrate the physical properties of PVC and black PVC samples respectively.

2.1.1 Cs110275 granulated PVC compound (PVC)

Mixture of suspension of PVC, stabilizers, plasticizers, fillers, lubricants and other additives. Any good extruder designed for PVC, may be suitable for this type extrusion that it is equipped with convenient heat and screw having a good homogenizing capacity.

Table1. Physical, mechanical and electrical properties of PVC sample

Property	Test Method	Unit	Typical Value
Density	ASTM D792	g/cm^3	1.51
Hardness A 15	ASTM D2240	Shore	72 (±3)
Tensile Strength	ASTM D638	Kg/cm^2	50
Elongation at Break	ASTM D 638	%	100
Volume resistivity	ASTM D 257	Ohm. Cm	$>10^{13}$
Min. Thermal Stability	ASTM D 2115	Minutes	>50

2.1.2 Black PVC

Black PVC is new the code of s97v, a good high heat stability at200^{0}C light fastness and food application [16].

Table 2. Physical, mechanical and electrical properties of black PVC sample

Property	TEST Method	Unit	Typical Value
Density	ASTM D792	g/cm^3	1.51
Hardness	ASTM D2240	Shore A	72(±3)

Tensile Strength	ASTM D638	Kg /cm^2	90
Elongation at Break	ASTM D638	%	41
Min. Thermal Stability	ASTM D2115	Minute	50
Volume Resistivity	ASTM D257	Ohm. Cm	10^{13}

2.2 Samples Irradiation

The samples above which were irradiated by different doses (10,30,50,75,108 KGY) of gamma rays emitted from^{60} Co with an activity of (37GBq) in room temperature ,the dosimetry calibration is using reference standard dosimeter Fricke(Fricke is chemical dosimeter consists of ferrous ammonium sulphate ,sulphuric acid and sodium chloride.) and lifetime of(2.27years) it is produced by the following reaction :

$$^{b59}Co + \ ^{1}_{o}n = \ ^{60}Co + \gamma \qquad (3)$$

^{60}Co is primarily a β^- emitter (0.311Mev) , which decays into an excited state of ^{60}Ni .The excited nucleus of ^{60}Ni gives up its excess energy by emitting two gamma photons in cascade with energies of (1.17) and (1.33) Mev as shown in fig 1:,the medium energy being (1.25Mev). The source of ^{60}Co is housed in protective container called the treatment heat, which reduces the exposure rate of the radiation to a low level everywhere outside the useful beam. The treatment heat also contains a shutter for "shutting off" the useful beam and an adjustable collimator to control the size and shape of the beam .The importance of ^{60}Co source is obtain gamma rays with energy of (1.25Mev) [17].

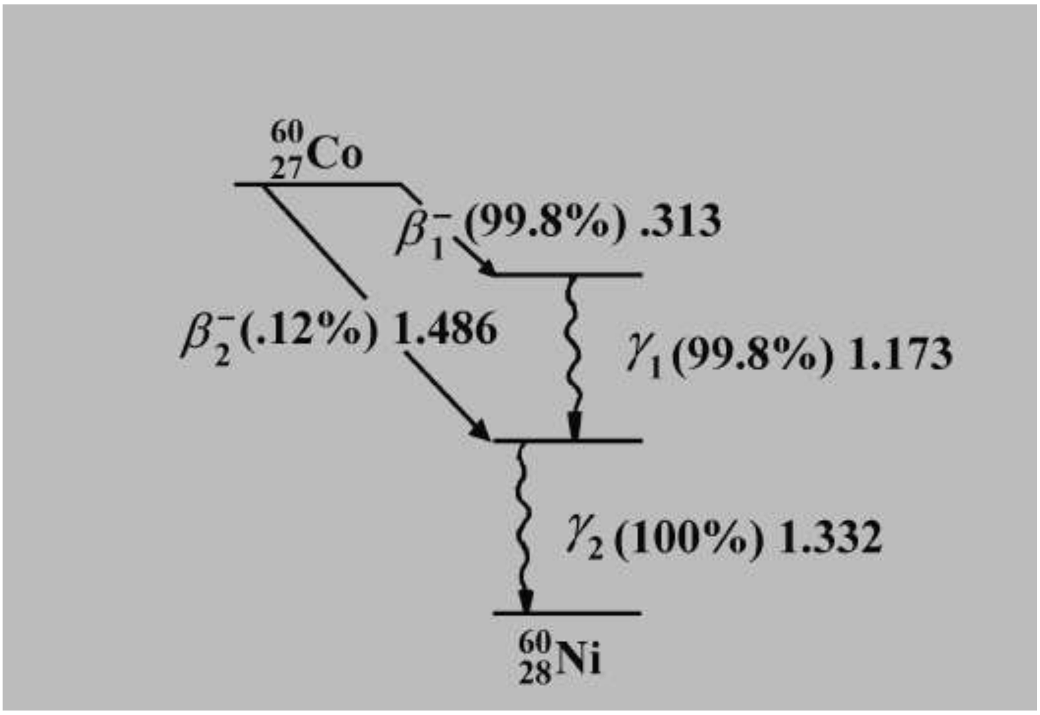

Fig. .1. Decay scheme of radionuclide cobalt-60

2.3Determination of Dielectric Constant:

2.3.1 Equipment Used:

Two plates and Digital AVO-meter model DT9205A.

2.3.2 Theory:

Dielectric constant is ability of material when placed between plates of capacitor, to cause an increase in the capacitance over that when the plates are separated by vacuum. Principle of the capacitor, use of the equation:

$$Q = CV \quad (4)$$

Dielectric constant is expressed as the ratio of capacitances [`18]:-

$$\text{Dielectric constant } \sigma = \frac{\text{capacitance with Dielectric between plates}}{\text{capacitance with vacuum between plates}}\frac{C_r}{C_0} \quad (5)$$

Then we can obtain the relative permittivity ε_r by using this equation:

$$\varepsilon_r = \frac{1}{4\pi\sigma} \quad (6)$$

Where σ is relative Dielectric constant ε_r is capacitance with Dielectric material between plates is ε permittivity of Dielectric material.

III. RESULTS & DISCUSSION

Different electrical properties of a given insulator or dielectric material can respond differently to radiation. In general, the influence of radiation on these properties of a particular dielectric constant depends greatly on the chemical transformations that take place within it or its surroundings. For polymeric materials, in particular, cross linking and chain scission are believed to play an influential role on the rate of deterioration of these dielectrics.

Electrical properties of PVC which were changed by radiation are most useful in the electrical aspect of application of dielectric polymer. These properties include relative dielectric constant and relative permittivity as shown in Fig.2 and Fig 3

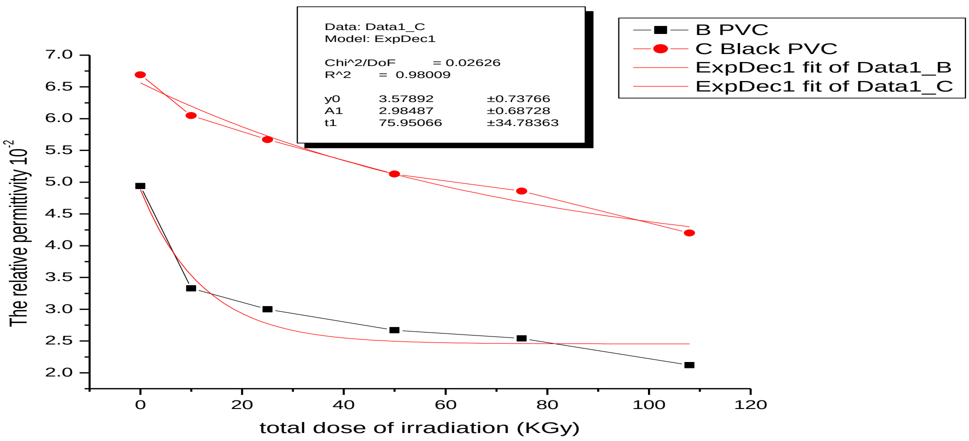

Fig.2: Plot of the relative permittivity at different gamma doses for PVC and black PVC

In view of Fig 2, and Fig.3 it is clear that the relative permittivity of medium decrease and whereas the relative dielectric constant increase when the total irradiation dose increase of gamma rays for all PVC samples..

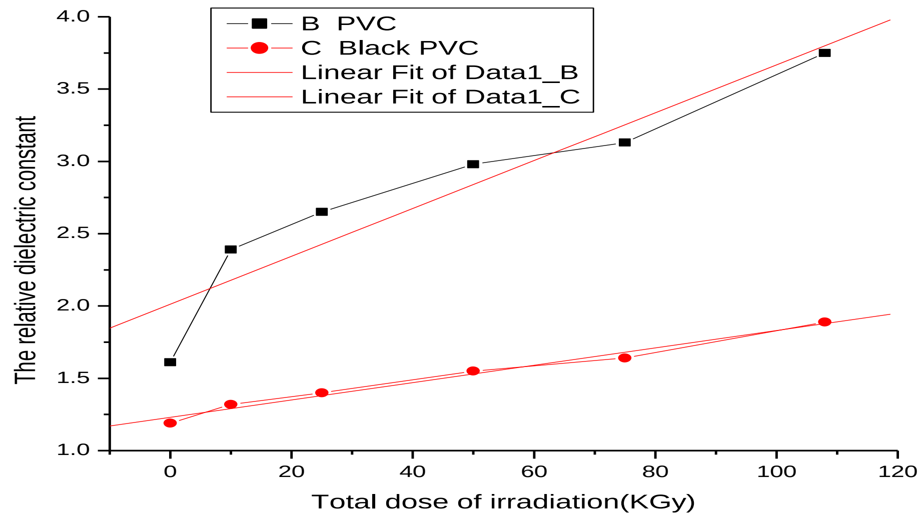

Fig.2: Plot of the relative dielectric constant at different gamma doses for PVC and black PVC

These decrease in relative permittivity and increase in relative dielectric constant for all PE and PVC samples, due to the permittivity inversely proportional to dielectric constant which described in equation (6). For increase and decrease in relative permittivity and relative dielectric constant may be attributed to the formation of conjugated structures which described by equation (1) and (2). Also, the irregularity in the polymer chain may give rise to a hopping mechanism that will enhance then conductivity which proportional to these properties, in accordance to Nouh et al. [19] and Toka et al. [20]. .

By fitting Figs 2, (using the Origin6.1 program), shows the relation between the relative permittivity of medium and absorbed dose of gamma rays source follows: -.

For PVC Sample:-

$$y_1 = 2.45 + 2.43\, e^{\frac{-x}{12.3}} \qquad (7)$$

For Black PVC

$$y_2 = 3.58 + 3\, e^{\frac{-x}{76}} \qquad (8)$$

Where y_1 and y_2 permittivity for PVC and Black PVC respectively x is total absorbed dose of Gamma ray which emits from ^{60}Co.

From mathematical models we can predict to the electrical permittivity decrease by rate of 43 and 222 times for the samples of PVC and Black PVC respectively as compared to samples before irradiation by gamma ray at dose of 200KGY.

By using the Origin 6.1 program on the fig 3 shows the relation between the relative Dielectric constant of medium and absorbed dose of gamma rays source follows:

For PVC:-

$$y_{3}= 2.01211 + 0.01656x \quad (9)$$

For Black PVC:-

$$y_{4}=1.23+0.006x \quad (10)$$

Where x is total absorbed dose of Gamma ray which emits from ^{60}Co and y_3 andy_4 are Dielectric constant for PVC and Black PVC respectively.

By using the equation (9) we can predict to dielectric constant for the sample of Black PVC increase when it , exposed to gamma –ray- irradiation of dose magnitude 200KGY by the rate of 21838 times for original property before irradiation.

IV. CONCLUSIONS

Analysis of the changes in the electrical properties of the PE and PVC samples submitted to gamma irradiation shows that:-

(i) The relative permittivity of all PVC samples decrease, whereas the relative dielectric constant increase, when the absorbed doses of Gamma radiation increases depend on the types of interaction cross linking and chain scission.

(ii) The depending of electrical properties on gamma dose shown on equations (6.) to (9) for relative permittivity of PVC and black PVC samples respectively can be used to measure the absorbed dose of Gamma radiation emitted by sources.
.(iii) By the same way equation (7) to equation (11) reflect the relationship between relative dielectric constant of black PVC and black PVC samples respectively can be used to measure the absorbed dose of Gamma radiation emitted by sources.

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