

Study of Shielding Properties for NBR Rubber /Nano Silica Composites Against Gamma Radiation

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Abstract: This study aimed to investigate the influence of adding Nanosilica (NS) to Nitrile Butadiene Rubber (NBR) as shielding materials for gamma radiations at minimal cost. Rubber silica nanocomposites were prepared by mixing nitrile rubber with surface modified and unmodified nanosilica. The Linear attenuation coefficient was measured experimentally and calculated for NBR rubber with different concentration of nano silica. It is concluded that the addition of nanosilica particles improves the mechanical and nuclear properties of NBR rubber. The increase of modified nanosilica particles increases the total γ -ray attenuation coefficient μ for all energies.

Keywords: NBR, NS, Mechanical properties, gamma shielding.

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I. Introduction

With the increasing use of gamma radiation in various applications in industry, medicine, agriculture, nuclear reactors, gamma irradiators and particle accelerators, the exposure for longer duration to these radiations can cause very harmful effects on human health. Therefore, the usage of shielding becomes of a paramount importance for using this radiation without a risk [1]. Many research workers have determined the values of different shielding parameters in various ways (2-10) to know the shielding effectiveness of the shielding materials developed with time.

To design and choose an appropriate biological shielding, it is necessary to have known its nuclear, structural and physical properties and also the characteristics of radiation impinging on it. The nuclear parameters that must be known to design and choose a shielding material is linear attenuation coefficient (m). The linear attenuation coefficient is the probability of interaction of gamma-rays per unit of length of a given absorber characterizes and it's an important parameter for characterization of the penetration and of interaction of gamma-rays with materials.

Acrylonitrile-Butadiene Rubber (NBR), is a synthetic Rubber, widely used as seals, gaskets, rollers, and other products in which oil resistance is required along with heat resistance properties. The mechanical properties of polymers are changed considerably by high energy radiation. Properties such as tensile strength, hardness, modulus and elongation at break are decreased as a result of chain scission, while crosslinking has the opposite effect on these properties [11, 12].

One of the important application of nanosilica is its use as a filler in rubber matrix for reinforcement. Nano silica has more prominent reinforcing effect over commercial micro silica owing to its better dispersion capability in rubber matrix. However, they have tendency to form agglomerate due to high surface energy and ability to form inter particle hydrogen bonding via the hydroxyl (silanol) groups present on the surface [13-14]. The greatest challenge in polymer nano technology is to uniformly disperse these nano dimensioned fillers which offer numerous advantages over conventional micron-sized fillers. This problem can be treated via surface modification of the silica particles. Silane coupling agents are the most used type of modifier agents. Organic-modification of nanosilica surface with organic silanes can efficiently improve its compatibility with organic matrix and also increase the degree of dispersion. Silane is a monomeric silicon compound used in a wide range of applications because of their unique ability to chemically bond organic polymers to inorganic materials. Silane monomers improved the mechanical and electrical properties of polymeric materials. These improvements are often retained even after severe environmental aging [15]. Silane coupling agents belong to a class of organo-silane compounds having at least two reactive groups of different types bonded to the silicon atom in a molecule. These materials are used as promoters, dispersing agents, cross-linking agents, surface modifiers, etc [16-17]. Organo-modification of nanosilica surface with organosilanes can efficiently improve its compatibility with organic matrix and also increase the degree of dispersion. As a result, thermal and mechanical properties of the composite are improved.

In this work, the effect of surface modified nanosilica on the mechanical and gamma shielding properties of the nitrile rubber (NBR) has been studied

II. Materials And Methods

NBR rubber samples were mixed with different content of modified and unmodified nanosilica. The mixing of the rubber is carried out on a laboratory two-roll mill (152mm&330 mm) at a friction ratio of 1:1.4, according to ASTM D15-627. The different NBR compounds and their names can be found in Table 1.

Mechanical Properties

The tensile strength and elongation at break were measured by using a Zwick (Germany) Tensile Testing Machine (Model Z010) and a crosshead speed of 500 mm/min using five dumb-bell tensile specimens being shaped according to ASTM D-412. The hardness test was measured by a Zwick (Germany) Hardness Tester Machine (Model 3150) according to ASTM D-2240.

Measurement of Gamma Ray Intensities:

The attenuation coefficient[μ] of samples under investigation has been determined by the usual attenuation equation:

$$I = I_0 e^{-\mu x}$$

Where I is the gamma ray intensity after the shield material, I_0 is the gamma ray intensity before the shield material, μ is the attenuation coefficient factor and x is the shield material thickness [18].

Gamma ray intensities behind NBR samples with different percentages of nanosilica have been measured. Measurements have been carried out using a collimated beam of the point isotropic γ -ray sources ^{137}Cs , with energy 0.662 MeV and ^{60}Co with energy $E_1=1.173$.

Table 1

Ingredients (phr) [#]	N0	N25 ¹	N25m ²	N50 ³	N50m ⁴
NBR	100	100	100	100	100
Silica	--	25	25	50	50
Silane	--	--	3	--	3
DOP	10	10	10	10	10
Zno	5	5	5	5	5
Str. Acid	3	3	3	3	3
6PPD	2.5	2.5	2.5	2.5	2.5
Sulfur	0.5	0.5	0.5	0.5	0.5
MBTs	1	1	1	1	1

Part per hundred parts by weight of rubber.

1. N25: NBR rubber with 25 unmodified Nano-silica.
2. N25m: NBR rubber with 25 modified Nano-silica.
3. N50: NBR rubber with 50 unmodified Nano-silica.
4. N50m: NBR rubber with 50 modified Nano-silica

III. Results And Discussion

Mechanical Properties

Addition of nano silica shows an increase of the tensile strength (TS). As NS concentration increases, tensile strength decreases (fig.1). Such behavior can be explain that in case of small quantities, particles will be fill the spaces between rubber chains, thus gave a rigid structure with better tensile strength. While in high quantities of nano silica aggregate occurs in rubber matrix, this weakening the bond between chains and decrease the tensile strength [19- 21].

The elongation at break (EB) property decreases with the addition of nanosilica as (fig. 2), because the rubber is highly stretching so that when very fine particles fill the spaces, it will be restrict the movement of chains and then decrease elongation property. As an increase in the concentration of nano silica, the elongation property increases. This is due to the diffusion of very fine nano silica through the rubber chains and support the rubber chains so enhanced stretching which reflect on elongation [21].

This is clear that the values of TS and EB of the rubber samples improved significantly due to the modified NS. NBR samples with modified nanosilica have high values compared with samples with unmodified. This could be explained by both crosslink density, nano filler dispersion and the presence of the nano filler-matrix covalent bonds, the fillers acting like multifunctional crosslinks. Indicating that modification of silane on the NS surface had high effect [22].

The hardness results of NBR/ NS samples are showed in fig. 3. The hardness increased due to the increasing of nanofiller and crosslinking reactions in the matrix provided by silane treatment. NBR with N50m

has a lower hardness, this result may be due to good physical interaction and more homogenous between the rubber and nano filler and hence no much filler agglomeration takes place within the rubber matrix [21, 23].

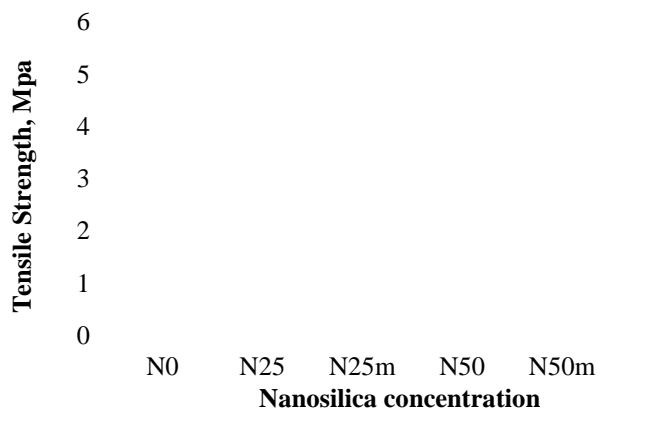


Fig.1: Effect of nanosilica on tensile strength of NBR samples

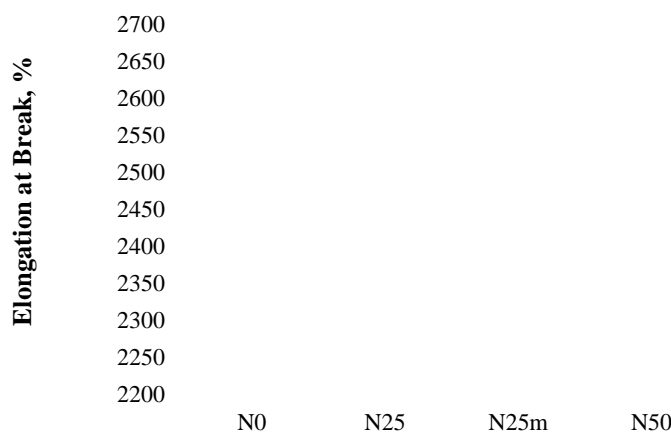


Fig.2: Effect of nanosilica on elongation at break of NBR samples

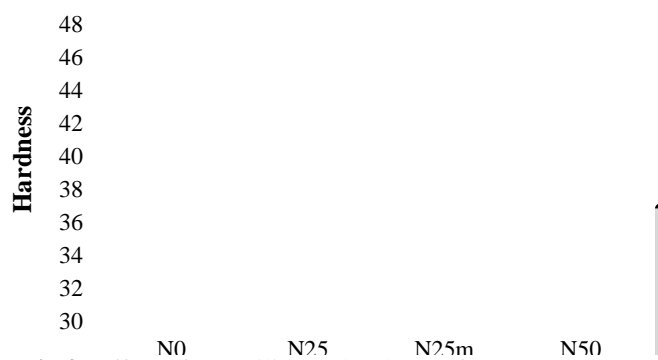


Fig.3: Effect of nanosilica on hardness of NBR samples

Shielding Properties

The shielding properties of the studied samples have been investigated in the field of gamma emitted by ¹³⁷Cs (energy 662keV) and ⁶⁰Co (energy 1173kev). The obtained results are illustrated in figures (4, 5) respectively. Generally, it is clear that the transmission of γ -ray through the investigated composite samples decrease as the sheet thickness increase. And the transmission of γ -ray decrease by adding nanosilica to the composite samples than that of the control sample, as well as the sample with modified NS has the lowest transmission of γ -ray. This means that NS additive increase the ability of composite to reduce the transmission of γ -ray and also the attenuation increases as the thickness increase. It is bright that NBR/NS samples which modified has the lowest transmission of γ -ray and the highest one is the NBR/NS samples which unmodified with silane.

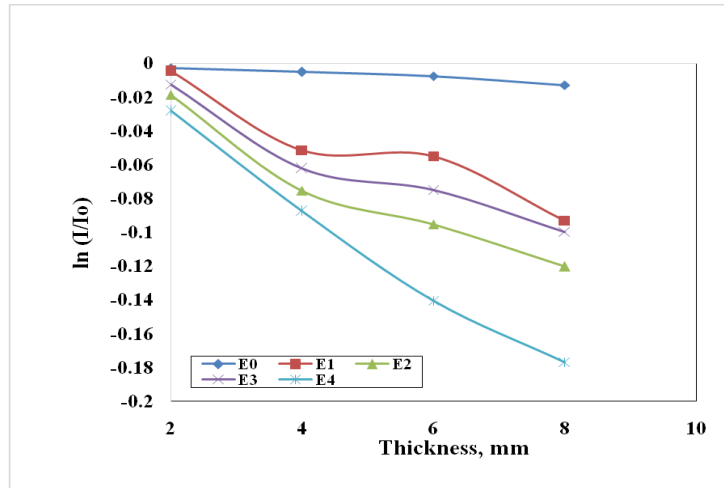


Fig. 4: The transmission of gamma ray through the investigated samples as function of their sheet thickness; E=662KeV.

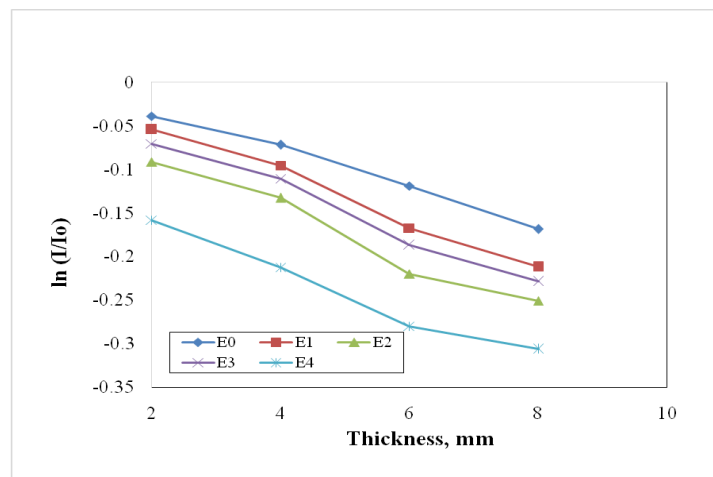


Fig. 5: The transmission of gamma ray through the investigated samples as function of their sheet thickness; E=1173KeV.

IV. Conclusion

NBR / NS composites are prepared with surface modified silica nanoparticles and their mechanical and gamma shielding properties are studied. It is concluded that the addition of NS particles to NBR samples improved the mechanical and gamma shielding properties. The increase of NS particles increases the total γ -ray attenuation coefficient for all energies. It showed that NBR/NS composites with surface modified nanosilica particles has higher tensile strength, elongation at break and gamma attenuation coefficient compared with that without surface modified. NBR with 50 phr modified NS has the best mechanical and gamma shielding properties for the investigated samples.

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