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An Innovative Approach to Electromagnetic Radiation Shielding by Graphene: An Experimental Study

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ABSTRACT

The need to use electromagnetic radiation in clinical practices indicates the defense from the electromagnetic radiation itself which have a destructive impact on the human tissue and brain. Therefore, the wearable aprons as electromagnetic shields are the protective gears required to enhance their blend and structure to attain effective shielding. The aprons that are made of textile materials are widely considering protecting from electromagnetic radiation. In this context, conventional textile-materials are not appropriate, but their adaptations, which are in the form of composites, are utilized.

The contemporary literature contributed by the recent past research works has several methods of making textile electromagnetic radiation shield.

Recent innovations of conductive polymer application in electromagnetic radiation shielding were considered.

The treating of textile materials by conductive polymer displayed higher electrical property in the form of electromagnetic radiation shield. Protective mechanisms such as aprons of electromagnetic radiation shielding are essential for enhancing their blend and structure to attain effective radiation shielding. The carbon nanotube is deliberated as a productive polymer result for the electromagnetic radiation shielding.

The review experiment aimed to discuss the possibility of using a graphene coat on the polymer composite of carbon nanotube and to improve the practical solution for shielding the protective aprons. The confines of a polymer composite of carbon nanotube attenuation stages are deliberated in this article.

Keywords: Carbon Nanotube, Electromagnetic Radiation, Graphene

INTRODUCTION

ICT is named "Information & communication technology" and several other types of engineering improvements, which are progressing rapidly and leading to various innovations. Besides the improvements in positive, yet there are definite intricacies which are on the raid. McNamee and Chauhan, 2009 presents that from the former decade, many solutions regarding wireless communication came into existence, which leads to the erection of mobile towers that result in greater levels of emission of radiation [1].

The researchers still debated why the radiation that is emerging from the towers of mobile and another spectrum of wireless communication affects humans and other lives [2]. Besides the remittance of mobile tower radiation, many different aspects led to the emission of radiation that affects the environment's safety and health menaces [2].

Mousa, 2011 presents that many research types are carried out to restrict electromagnetic radiation which is the most critical radiation form that affects health and occupational safety. Formerly several researchers suggested the solutions to lessen the emissions of radiation to restrict the emission of radiation and protect from the radiation [3].

Several contributions are produced regarding the suggested/improved clothing solutions which can safeguard the human being from radiation. (Saeid, 2013), and (Haoran et al., 2015) present that even though many contributions are focused mainly on the zones of high emission of radiation, and now wearable protection for the ordinary public became a vital interest in the research. Most of the former solutions are in the mixture of bismuth or lead Pb coated and a combination of tungsten-based polymers of textile, which are proposed [4,5].

The aprons for the protective gear are made by coating with lead to enhance the shielding levels from radiation. The material based on Pb is utilized in aprons design and is bulk, and hence the mass of the aprons will be high. Regular using such kind of heavy aprons may lead to troublesome users [6]. Another issue with the Pb is toxic when the aprons are utilized for a long, leading to many implications. 025mm, 0.35mm, and 0.50mm are the benchmark thickness adapted in the aprons based on lead. The thickness level utilized for the aprons may change based on the intensity of transmission associated directly with the voltage used in the X-ray. The contribution explored in this manuscript is an attempt to enhance the aprons' attenuation levels with a coat of graphene is explored [7].

Graphene Structure

The single graphene atomic layer is the graphene, a lavish mineral that is the carbon allotrope made of tightly joined carbon atoms structured into the hexagonal lattice. The thin thickness of atomic and sp2 hybridization makes graphene special. Here, these properties allow graphene to break several records related to heat conduction, strength, and electricity. Here, let us discuss what makes the graphene so distinctive, what were the intrinsic properties that separate it from other carbon forms, & other compounds of 2D crystalline [8].

Fundamental Characteristics

In 2004, before isolating the monolayer graphene, theoretically, two-dimensional compounds might not be present because of thermal instability while it is separated. Nevertheless, once isolated graphene, it is evident that it is possible, but it took some time for the scientists to identify it. After graphene sheets that are suspended were contributed by the "transmission electron microscopy," the scientists believed they recognized the reason because, in graphene, there is slight rippling, altering the material structure. Nevertheless, suggesting the later research that carbon-carbon bonding in the graphene is robust and small might safeguard thermal variations from threats [8].

Electronic Properties

"Zero-overlap semi-metal" is one of the essential graphene properties with greater electrical conductivity. The atoms of carbon have 6 electrons in total, 4 in the outer layer & 2 in the inner layer. Here, the four outer layer electrons in carbon atom are accessibly aimed at chemical bonding. Yet, in graphene, every atom will be linked with three other carbon atoms on a 2-dimensional plane where one of the electrons is available freely in 3rd dimension aimed at electronic-conduction. The mobile electrons were known as pi electrons & were positioned below and above graphene. Overlapping of pi-orbitals and assisting to improve carbon-carbon bonding in the graphene. Graphene electronic properties are said by anti-bonding & bonding of the π orbitals [8].

Over the past 50 years, integrated research has proved that holes & electrons have 0 effective mass at Dirac-point (DP) in the graphene. This mass happens because energy movement is linearly aimed at minimum powers proximate the Brillouin zone six individual corners. These holes & electrons are called graphons or Dirac fermions, and Brillouin zone 6 corners are called DP. Because of 0 states density at DPs, the electronic conductivity will be relatively low generally. Nevertheless, the level of Fermi will be altered by doping to create the material, which is better potentially at electricity conducting than, for instance, the copper at room temperature [8].

METHODS AND MATERIALS

Proposed Solution: In this article, the suggested solution can enhance the new solution, which can assist in strengthening the shielding gear and clothing solution, which can protect scattered radiation.

The piercing capability of hard x-rays is utilized intensely for capturing the image inside the elements or objects. Rasheed, 2019 presents that the soft X-rays are noticed quickly in the air, and the length of attenuation is ~2 nm (600 eV) in water; the X-rays are lower than 1mm.

In this article, the concentration will enhance a carbon nanotube-polymer solution with fabric solution, which is coated with graphene, which can last long at greater capacities of attenuation to repel the penetration of radiation.

The solution suggested has a fabric solution of carbon nanotube poly-composite where graphene is coated, unlike in the case of lead coating, which is having an impact on toxic and bulk mass. In contrast, in the case of the solutions based on graphene, the effect could be more on effective shielding and effectively managing the distribution above carbon nanotube’s surface.

Importance of Graphene Coating:

The wearable coats utilize the graphene as it is light in weight to prevent radiation. The graphene coat has certain essential factors that are positive are the graphene coat attenuation levels and penetration levels. Fig. 1 represents the soft tissue penetration and graphene for diverse energies of photons.

(Sprawls, 1987) presents that the penetration levels are depicted in the graph, which there might be possible conditions for utilizing the coat of graphene to lessen the effect of radiation [10].

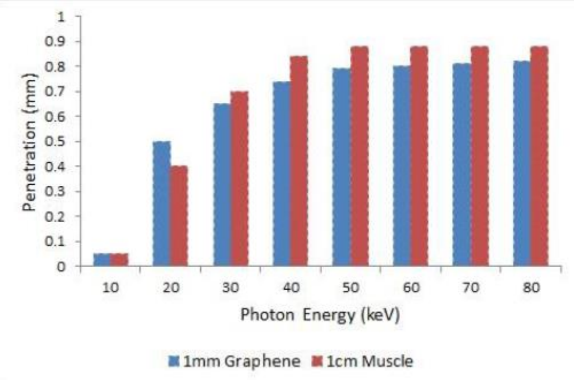

Fig. 1: Graphene penetration levels

Carbon nanotube Polymer: The one-time contributions proposed many solutions in textiles in terms of carbon nanotube-polymer composites. The surface of carbon nanotube composite is layered effectively, which is resourceful in materials for better optimal performance [10].

(Dul et al., 2007) presents that it is evident from tests conducted that when the composites of aligned combination and polymer/ carbon nanotube composites which are oriented randomly are tested, the effect of composites of the aligned configuration is more significant. It is, therefore, necessary to confirm that the composite carbon nanotube must be aligned. The tensile strength and scattered elasticity of polymer/ carbon nanotube must be emphatically lower than 100 Mpa and the 6Gpa. Nevertheless, it achieves more significant levels of 80 Gpa and 3600 Mpa in the case of aligned carbon nanotube composites [11].

Moreover, the elastic modulus & tensile strength are higher in Polymer/ carbon nanotube's aligned composites, which contain a more significant content of carbon nanotube; however, in the example of polymer/ carbon nanotube, which is oriented randomly, such features are not predicted [11].

Also, from the study, it is evident that the materials of carbon nanotubes are very productive in heat-conducting. (Pop et al., 2006) presents that the professional is in the opinion that thermal conductivity of SWNT has a more significant proposal of about $3500 w/mK$ at the room temperature, but Lukes and Zhong, 2007) presents that in the case of experimental studies the room temperature of the isolated MWNT is predicted $3000 W/mK$ [12,13].

It is evident from the previously stated factors that carbon nanotubes are more effectively identifying the problems of thermal stability and thermal conductivity at greater temperatures for polymers (Pradhan et al., 2007; Zhang et al., 2008; Yunsheng et al., 2007; Park and Taya 2006) presents those experiments are carried out on the classical molecular dynamics, by adding carbon nanotubes, the increased levels of T_c (Temperature of crystallization). From the outcomes of the experimental and theoretical examination, it will be evident that lessening the thermal resistance related to carbon nanotube’s performance is non-recommended and therefore specific novel methods are suggested [14-17].

Mass Attenuation (MA): Penetration levels of energy are based on the mass attenuation coefficient (MAC) of the magnitude of selected material (Pradhan et al., 2007). The coefficients of "mass attenuation" are determined by analyzing EM-radiation. Here, the attenuation of mass is signified (m^2/kg). For assessing attenuation, the other frequently used unit is cm^2/g that it is mainly utilized for measuring the coefficient of mass attenuation of X-ray (McNaught and Wilkinson, 1997) [18].

The Graphene density and efficiency of mass absorption: - X-rays are diminished as a screen via matter. Nevertheless, it decreased the radiation intensity based on every intersection of a photon compared to the atom of material. The reduction of quantum in intensity mostly relies on two main factors.

First is the penetration difficulty (x) or thickness, where it is essential to be pierced.

Second is the individuality of the material named as "absorption coefficient (AC)."

The intensity decreases as distance traveled $I = I_b \exp(-ACx)$ and I_b denotes the first x-ray beam intensity.

(Elmahrougi et al., 2013) presents the "Beer-Lambert Law," which is the process of applying the photon exponential delay over the region of the optical, electromagnetic spectrum [19].

The decreased length is considered as deepness of material where x-rays intensity is diminished nearly $37\%(1/e)$ over the surface.

The comparative analysis aimed at X-ray energy depth is depicted for heavier & lighter elements. And the graphene's decreased length is more significant than other factors such as lead and iron. Moreover, as mentioned above, the effect of lead regarding toxicity and weight of substance transfer over a certain period is the main challenge that may restrict the solution [19].

(Zhang et al., 2008) presents an essential effect on the levels of "mass attenuation," and a combination of graphene and carbon nanotube is adapted, then there could be an effective outcome [15].

The effect of radiation can be addressed by the inputs over carbon nanotube-polymer efficiency and Graphene effectiveness in terms of the elements' weight, and its decrease in co-efficiency will be a compelling combination. Among the main aspects such as graphene, lead, and iron, the graphene's efficiency of mass absorption is 2.22, (cm^2/g) and decreased length is 1.65. And when it is compared with the other elements like iron and lead (18.2 and 64.1 (cm^2/g) co-efficiency respectively) and the attenuation length (0.07 & 0.014mm), the most resourceful part for maintaining an attenuation factor is the "Graphene." [15]

The radiation individuality is that real photons might not have a similar region regardless of having equal energy. And it will be challenging to determine the range of a particular photon. The essential characteristic of penetrating a photon will be predicted when the number of photons penetrated through every thickness range of the material is calculated (Park and Taya, 2006). The association between the material's viscosity to that point and the diverse range of the photons achieving specific topic results exponentially [17].

HVL (Half Value Layer): HVL is an ingenious prediction, as it is a more commonly utilized quantity ore feature in means of describing both penetrating abilities of definite radiations and distribution of actual entities. HVL is defined as material viscosity that penetrates one part of radiation & measured in distance units mm/cm [10].

Increasing the piercing ability of radiation will enhance HVL and is relative; however, it is not the same in the average photon range. The variation among the 2 is essential due to distinctive X-ray attenuation characteristics & the scattering.

The relationship will be predicted utilizing-

HVL = 0.693 X Average Range = 0.693/µ.

HVL is contra wisely proportional to the decreased coefficient. The scattering of 0.5 developed for the exponent value of 0.693. By the altering feature of interactions, the attenuation coefficient value and the HVL is modified. In Fig. (2a) and (2b), the decreased coefficient of HVL and graphene is compared for the application in high radiation regions, where the material graphene is modified for sieving radiation [10].

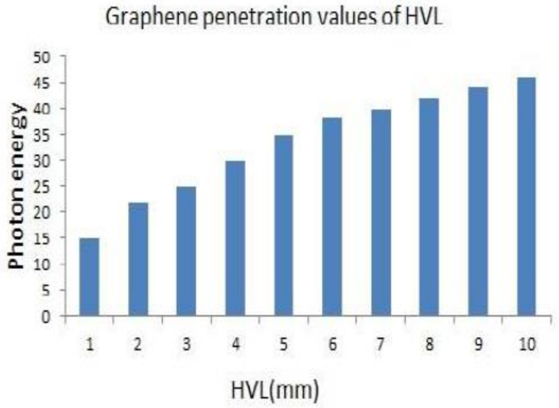

Fig. (2a): Relationship amid attenuation coefficient at graphene penetration values

From an examination of computations, it will be evident that radiation quantum that scatters over specified thickness material will be affected by individual photons energy and some essential aspects such as & thickness & atomic value. The importance of HVL is crucial in identifying values of HVL and predicting the piercing via another width is feasible [10].

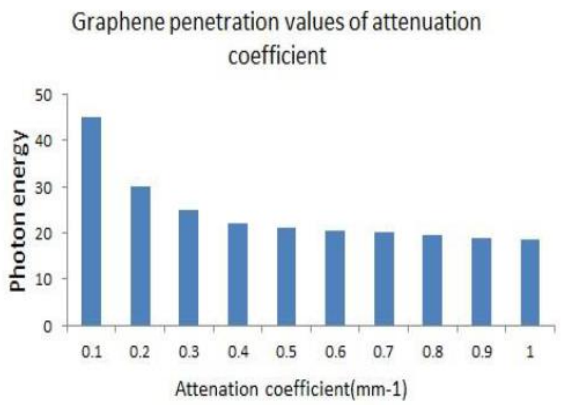

Fig. (2b): Relationship amid HVL at graphene penetration values

Nanostructure composites: MWNT with a length of 10-20 µm and diameter thickness of 0.01-0.05 µm are deliberated. EM categorization of the nanostructure composites is conducted with the reflection/transmission model by utilizing the range of frequency from 8 to 12.5 GHz.

The carbon nanotube configuration allows them towards the combination of electronic, which is essential for the electronic transference's unique behaviors. Theoretical predictions reflected that the carbon nanotubes incline to act as metals, and insulators based on the chirality and their extents. The composites containing MWNTS, which are essential to the polymer, are altered for shielding of EMI [20-26].

Weight Estimations: The procedure for estimating the weights, aimed at the wave, flourishes from side to side at an angle θ_i. Refractive index is denoted by n, and thickness of each layer is represented by d, count of layers n_a & n_N denotes the free space of "refractive index quotient."

Snell's law is modified to achieve the angle diffused for each layer. In case of vertical performance of wave penetration towards multilayer stack, then θ_i goes to 0. And the notation i denotes the integer number $1,2,3,...,i,i+1,...,N$, indicating a diverse count of layers.

(Chantler, 1995) presents that NIST data is necessary for C-ray rules selection aimed at evaluation. Weight ratio will be achieved utilizing:

As discussed, using the graphene as a coat on the apron, we exposed the Dose-meter at 100 cm distance and with 40.5 kV, 0.90 mAs. Also, the result was 6.3 msv/h. Then we exposed graphene with one layer of paper cup material (healthy) at the same kV and mAs used. The result was 7.4 msv/h. We doubled the layer using graphene on x-ray film and paper cup material, at the same kV and mAs. The result was 6.8 msv/h.

We noticed that the graphene is so robust but not absorbing the radiation. It is scattering it.

Therefore, we wanted to make a comparison with lead absorption:

Lead only:

- At the similar kV and mAs, the result was 4.3 msv/h

Lead and Graphene:

- -At similar kV and mAs, the result was 3.39 msv/h.

In conclusion, we were not sure of the readings because we cannot determine the thickness of the graphene sample used. Since we have low accuracy equipment in our laboratory, that's one of the experiment's limitations. The final idea that we have is that graphene is not absorbing the radiation. It's scattering it.

Later, we approached an expert physician who assisted us in testing graphene's performance as a coat on CNT. It is absorbed that the apron is meant for radiation up to 10 Kev [27].

Experimental Study

In the simulation (EPOC 828), Epoxy resin is utilized as samples joined with the "amine-based hardener" containing resin vs. 1:4wt%, and SW carbon nanotube of 1÷2nm diameter, 5÷30µm of length is used for the procedure of research. The small size graphene powders with different percentages of weight are also considered for the simulation study.

Generally, when x-ray travel through SW carbon nanotube towards the detector of X-ray, definite photons tend to cooperate with the SW carbon nanotube absorbed towards the beam, and specific scattering will also be there.

I_b I The incident intensities of x-ray & transmitted beams I_b are represented as measured SW carbon nanotube. Elmahroug et al. [20] presents that the procedure "Beer-Lambert law" $[I = I_b \exp(-\mu\rho x)]$ will be utilized to define SW carbon nanotube - MAC samples. In the simulation, the x-rays comprise the value "I" and are used when it travels via SW carbon nanotube, then the reduction of intensity takes place due to the diminished characteristics of SW carbon nanotube. Therefore, X-rays are identified by utilizing a detector and observations I_b for the fair values of p, x.

The ρ, x, and µ are "linear absorption coefficients" of x-ray absorbing material among one is represented by the values of density for the material, and the distance among the photon passes by a matter. In the simulation study, the sample density is modified to address the issue of material density. The term $\mu\frac{1}{\rho}$ will be noticed as MAC and will be broadly modified in the form of pre-requisite value and is represented in Table 1, which contains the x-ray MAC". Tungsten, an anode, is utilized in operating simulation at a current of 0.2 mA, 38 kV.

RESULTS

The "Beer-Lambert law $I = I_b \exp(-\mu\rho x)$" is utilized for predicting the value of the coefficient of mass attenuation with the SW carbon nanotube having diverse kinds of percentages of weight, and such types of deals are represented in Table 1. The analysis indicates that samples' attenuation levels lessen with the increasing incident energy levels, which results from the

Photoelectric effect commanding at definite low energies.

It is assisted by assessing the performance to the outcomes which are collected to the materials that are graphene oriented. The decrease of a sample containing massive addition of the graphene powder at a weight of 50% more and familiar to ones achieved at SW carbon nanotube. Inclusions of the importance of 1% that overcomes filling the nanotube up to the weight of 2%.

(Shen et al., 2015) presents that the percentage of attenuation is predicted for the graphene by utilizing the "NIST standard reference simulation website" at 10kev photon energy diverse thickness [28]. And such decreased values are depicted in Table 2.

The simulation studies are carried by utilizing the benchmark electromagnetic radiation of energy 10kev. Table 1 shows that the weight of the 2% SW carbon nanotube coefficient of mass attenuation results in 6% for 10kev, representing that 6% is the attenuation ratio. Therefore, in the procedure to address the gap and to augment reduced levels to the maximum quotient, the graphene coating at 0.7mm value will be generative based on inputs represented in Table 2.

Table 1: The X-ray MAC value of diverse epoxy composites based on carbon

x-ray Energy (Kev)	2%wt SW carbon nanotube $\mu(cm^2/g)$	0%wt SW carbon nanotube $\mu(cm^2/g)$	0.2%wt SW carbon nanotube $\mu(cm^2/g)$	1%wt SW carbon nanotube μ (cm^2/g)
7	10.4	9	9.8	9.8
8	7.8	6	6.2	7
9	7	4.4	5.2	6
10	6	3.8	4.2	5
11	5.2	2.8	4	4.4
12	4.2	2	3.6	4
13	3	1.8	2	2

Table 2: Attenuation and essential graphene thickness statistics

Sample No.	Graphene Target Length in mm for 10Kev	Attenuation [%]
1	0.01	6.8271
2	0.02	13.1882
3	0.03	19.115
4	0.04	24.6371
5	0.05	29.7822
6	0.06	34.5761
7	0.07	39.0427
8	0.08	43.2043
9	0.09	47.0819
10	0.1	50.6947
11	0.2	75.6898
12	0.3	88.0138
13	0.4	94.0902
14	0.5	97.0861
15	0.6	98.5633
16	0.7	99.2916

DISCUSSION

The essence of exploration related to the method is depicted here compared with the other contemporary practices in the following.

Atomic numbers of graphene are 13, iron is 26 respectively, and it is evident that the graphene density is smaller than the thickness of iron. (Bayat et al., 2014) presents that the concentration will be on EM shielding, which contains the compounds iron-(Fe3O4) that might enhance polymer composite weight. The coating of graphene with a lower density can reduce the overloaded weight at carbon nanotube composite, improving shielding capacity [29].

(Song et al., 2014) presents that researcher concentrated on the EM shielding at a frequency range '8.2-12.4 GHz' with [1.24meV, 1.7ev] capacity of a volt. (Tantawy et al., 2013) presents the EM shielding comparison with polyaniline Nano-powders. Nano-powders generated in solvent-constrained circumstances," which displays on microwaves comprising the energy in the range $1.24\mu eV - 1.24meV$ [30,31].

Nevertheless, this manuscript's suggested explanation reflects that EM's shielding at the level of life is 120eV to 50KeV defined X-rays. (Joseph and Sebastian, 2013) presents the "EM interference shielding nature of PVDF-carbonyl iron composites," where scholars have suggested the solutions for EM shielding depend on powder composites of iron it is lesser.

Simultaneously, it is compared with graphene coat results and delivers effective results despite having lower density levels than the composites of iron powder [32].

CONCLUSION

The radiation of the EM shielding is opposed effectively by the polymer carbon nanotube in the textile region. Nevertheless, definite aspects such as interfacial and dispersion affect the solutions of carbon nanotube execution in maintaining EM shielding. Deliberating the scope, confines, and the effect of the surface coating above carbon nanotube polymer to enhance the productivity for performing better, the layer of graphene is considered. Utilizing graphene as a coating material for the procedure because of its higher attenuation & fewer weight characteristics has helped address carbon nanotube attenuation features more productively. The simulation studies proved that the suggested coating solution of graphene above carbon nanotube polymer would be highly capable of enhancing the EMR shielding abilities of the C carbon nanotubes, which are coated with the graphene material. The limitation is that using graphene on carbon nanotube as a coat radiates up to 10Kev only.

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