Asian Journal of Scientific Research

ISSN 1992-1454

OPEN ACCESS Asian Journal of Scientific Research

ISSN 1992-1454
DOI: 10.3923/ajsr.2017.259.270

Research Article
Light Weight Metallic Coating over Carbon Nano Tubes Polymer Composite Shielding for Electromagnetic Radiation

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Abstract

Background and Objective: Phenomenal rise in the electromagnetic radiation levels is driving the need for exploring contemporary solutions towards shielding from electromagnetic radiation. Protective gears like electromagnetic shielding aprons are in need to refine their structure and blend to achieve effective shielding from radiation. The CNTs are considered as one of the effective polymer solution for electromagnetic shielding. However, the limitations of attenuation levels of CNT polymer composite considered in this manuscript. The objective of this study was to explore the scope of applying aluminium coat over CNT polymer composite and develop more effective shielding solution of protective aprons. **Materials and Methods:** The research method adapted is to gather inputs on the CNT polymer composite oriented apparel solutions, using the empirical analysis. Considering the scope for improving the attenuation levels of CNT, an experimental study of applying an aluminum coat over the CNT polymer composites was carried out. Attenuation property of the materials (CNT polymer) was evaluated using Beer Lambert Law. Results of the aluminum coat over CNT were discussed as results and outcome of the experimental study. **Results:** Results from the experimental studies reflect that the mass attenuation levels of CNT can be very resourceful for improved shielding capacities. It was also imperative that the mass attenuation levels of CNT polymer can be improved in apparel with the coat of aluminum, which can improve the shielding effect. **Conclusion:** It was concluded that CNT polymers are resourceful solutions for EM shielding and with the usage of aluminium coat over CNT polymer, the quality of shielding can be improved to higher levels.

Key words: Aluminium coat, EM radiation, CNT attenuation, lead coating, CNT polymer composite

Received: May 29, 2017 Accepted: August 07, 2017 Published: September 15, 2017

Citation: Vijaya Saradhi Dommeti and Dharma Raj Cheruku, 2017. Light weight metallic coating over carbon nano tubes polymer composite shielding for electromagnetic radiation. Asian J. Sci. Res., 10: 259-270.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Information and communication technology (ICT) and the other kind of engineering developments that are evolving in a rapid pace is leading to many advancements. Along with the positive developments resulting from such developments, even certain complexities are also on foray. For instance, the quantum of wireless communication solutions that has compounded since last decade of time, has led to more number of mobile towers getting erected every day resulting in high levels of radiation emission[1].

It is still a debated issue among the researchers as why and why not the radiation emerging from mobile towers and the other wireless communication spectrum could be an impact over the humans and the other lives[2]. Apart from the mobile tower remittance of radiation, many others such factors that led to radiation emission exists, which are affecting the environmental safety and health hazards.

Numerous researches carried out in curtailing the electromagnetic radiation, which is one of the significant forms of radiation that affect the occupational and health safety[3]. Earlier, many researchers have proposed solutions to reduce the radiation emissions both in the form of curtailing radiation emission and securing from the radiation.

In the recent past, many contributions made in terms of proposed/developed wearable solutions that can protect the Humans from radiation. Though, many of the first trend contributions were mainly focused on high radiation emission zones, currently wearable protection to the common public has become a significant research interest[4,5]. Majority of the earlier solutions were in the combination of lead coated, or bismuth and tungsten combination based textile polymers that were proposed.

Though Lead based wearable kits were adapted since many decades (specifically used by the resources working in high radiation emission zones), the weight of lead based solutions[6,7] has been a major concern.

McCaffrey *et al.*[8] in "Radiation attenuation by lead and non-lead materials used in radiation shielding garments." McCaffrey *et al.*[8] emphasized that a minimum value of 0.25 mm of lead based shielding is very essential for guarding a person in a region with sparse radiation. Whereas, a minimum value of 0.50 mm of lead equivalent shielding is ought to be adapted in protection of an individual in the direct radiation beam like the x-ray tubes, etc. For instance, lead coated aprons are one of the commonly used solutions in the real-time scenario for thwarting direct radiation in high radiation zones[9].

Alternate solutions like using the carbon nano tubes based polymer for improved polymer quality for shielding the solutions proposed in some of the studies[5,6,8,10]. However, some of the shortcomings in the process has to be addressed. The key advantage of CNT based solutions are, the low density in CNT-based polymer composites, whereas, the carbon fibre with reinforced composites are high. Due to high surface area of CNT structures and the dimensions with polymer chains will be resourceful in composites that are acquired with new properties. It can be highly resourceful in controlling radiation. Mainly, the electronic properties of CNT[11] were very resourceful in improving the efficiency of many applications. CNTs have the ability to induce effective X-ray attenuation, which improves the level of resistance to radiation penetration. Using synergistic interactions amidst silver decorate and CNT polymers, when the attenuation levels are analysed by the researchers[10] it is imperative that mass attenuation coefficient of CNTs are with higher significance values than the ones that observed with HOPG (Highly Oriented Pyrolytic Graphite) and the Fullerenes.

It is evident from the earlier contributions that though the CNT based polymer solutions could be very resourceful for developing protective gear clothing[12]. For instance, the textile fabric comprising thin film of CNTs resulted in the enhancing the X-ray attenuation levels of 70%[13]. If better kind of solutions explored than the earlier levels of CNT composites, the scope of protection from radiation substantially improved.

Considering the scope for improving the CNT based polymer solutions for improved protection from radiation, in this manuscript, the proposed solution is about adapting the aluminium coat over the CNT polymer, which could support in improved range of solutions[14]. Aluminium has outstanding properties whilst dealing with EM radiation but because of its less density when compared to lead (Pb), it has sufficient mass attenuation coefficient values means a small thickness of aluminium sheet can also stops the higher energy photon like X-rays or γ-rays. Taking in to account the feasibility of the outcome, in this manuscript the attempt is towards improvising the effectiveness of wearable gear with high resistance to radiation.

The level of exposure to radiation might vary depending on the various aspects[15]. While for much of the public, the impact is from scattered radiation, in the case of certain professional working in high radiation zone as a part of the occupational purposes, the exposure to radiation levels are much higher[16]. For instance, in the case of the resources working in X-ray zone, or in the much higher levels of radiation, the impact could be much higher[17-20].

Predominantly such protective gear aprons produced with lead coating to improve shielding levels from the radiation. Lead (Pb) based material that used in designing the aprons, are heavy and thus the weight of aprons could be heavy. Consistent usage of such heavy aprons might lead to inconvenience to the users[21]. The other challenge with the lead could turn to be toxic, once the aprons used for long tenures[8], which could lead to more implications. The standard thicknesses that are adapted in the lead based aprons are 0.50, 0.35 and 0.25 mm. The level of thickness used for aprons might vary based on transmission intensity, which could be directly proportional to the voltage used in an x-ray.

In some of the earlier contributions, the emphasis was on adapting the bi-layer of tungsten (W) and bismuth (Bi) and the nano-metal with polymer metric etc. Some compounds like the bismuth oxide Bi_2O_3 and gadolinium oxide (Gd_2O_3) and bi-layer of tungsten (W) and bismuth (Bi) tried as a composition[8,22]. Currently in real-time environment, some of the protective gears that offered to radiation protection based on tungsten and bismuth coated fabric. Nano-metal comprising polymer metric or the rubber discussed by Diao *et al.*[23] and Uthoff *et al.*[24].

In further, set of solutions that has emerged, researchers have focused on usage of nano-composite polymers. The emergence of nano-technology has led to significant development in terms of experimenting nano-technology based solutions in majority of the technical disciplines. Polymer science is one of the key areas in which nano-technology based poly composite solutions explored. Some of the key areas that are explored in the domain are fuel cell electrode polymer bound catalysts, polymer films, imprint lithography, electro spun nanofibers, nano-composites and polymer blends.

Nanoscale dimensions are integral to the interfacial occurrences in the blends and composites. Recent interests in Polymer matrix related nanocomposites has discussed more about exfoliated clay based nanocomposites and slowly transitioned towards application of CNT (carbon nanotubes), CNF (carbon nano fibres) and Graphene (Exfoliated Graphene) and other range of fiber changes or nanoscale inorganic filler.

In the nano dimension scale, the nanoparticle can be substitute to the primary nuclei and it competes with confined crystallization. In the case of a higher nanoparticle content, there is scope of increased viscosity, which could result in decreased crystallization kinetics. Nucleation of crystallization was reviewed by the onset temperature of crystallization (Tc) and half time of crystallization was found in various nanocomposites and it is imperative in polypropylene/multi-walled carbon nanotube[25].

Retardation of crystallization rate was envisaged in greater levels of nanoparticle addition, even in the systems in which the nucleation identified at very low levels of nanoparticle incorporation[26].

From the review of characteristics and applications of CNT/Polymer structural composites, it is evident that the functional composites of CNT are multi-functional. If they are used appropriately, as a component for textiles, it can yield good results. There are many industrial verticals in which its application has delivered desired outcome[27-29]. Despite of such effectiveness, there are few implications in implementation of CNT which are detailed below.

One of the key factor that decides the functions and mechanical properties of CNT/polymer composites are the integral properties of CNTs. In the current scenario, profoundly the CNTs developed are on basis of electric arc discharge, laser ablation and chemical vapour deposition.

Many factors that could influence the dispersion of CNTs in a polymer matrix is targeted while managing the CNT composite application. There is potential scope that the CNTs might aggregated because of Van der Waals force. Because of it, separation of CNTs from each other within a polymer matrix, or during a mixing stage.

Dispersion in the case of CNT applications are currently managed by using two main kinds of surface treatment, within a polymer matrix. Surface functionalization is one method in which interaction amidst CNTs and polymer matrix are effectively united right to the seeming of CNTs.

In "Mechanical properties of multi-walled carbon nanotubes reinforced polymer nanocomposites"[30], MWNTs are treated with oxidized inorganic acids and they are embedded in the composite. The resulting composite, as a result depicts that the outer shells of CNT damaged to certain extent and over the surface formation of carboxylic groups take place. Such a formation over the surface supports better dispersion of CNTs.

Generating suitable CNT matrix interfacial bonding which could service effective stress transfer is the other key factor for fabrication of CNT based polymer composites.

Among the feasible solutions that could be incorporated for load transfer to reinforcement, application of weak Van der Waals bonding, as a load transfer mechanism. Interfacial energies categorically account to $\sim$ 50-30 mJm^{-2} [31]. The second solution adapted is the application of micromechanical interlocking with is marginal in the CNT/Polymer composites as they usually have a smooth surface by default. Third solution that is considered is the process of chemical bonding amidst CNTs and Matrix and it is not assured in many instances.

Study carried out in MWNTs[30] emphasize that the chemical crosslinks amidst SWCNTs and polymer matrix shall raise the strength of SWCNT-polymer interface. When compared to the weak non-bonded interactions the strength of SWCNTs are higher after the chemical bonding process. Considering the aforesaid factors and the scope for improving the mass attenuation levels of CNT, the scope of using the aluminium coat over CNT polymer composite, to improve the EM shielding is explored in this study.

MATERIALS AND METHODS

Proposed solution: The proposed solution in this manuscript with the objective of developing contemporary solution is that can support in improving the protective gear, wearable solution (aprons etc.) that can shield the scattered radiation.

The penetrating ability of hard X-rays is vividly used for image capturing inside objects. In the case of soft C-rays, they are much easily absorbed in air and the attenuation length of it is 600 eV (~2 nm) X-rays in water is less than 1 micro-meter[33]. As depicted in the Fig. 1 above, the electromagnetic spectrum varies with different ranges and the adaptation of such ranges vary based on the need for different real-time applications.

In this manuscript, the focus is on developing a solution of CNT polymer with Aluminium coated fabric solution that can last longer with higher attenuation capacities to resist the radiation penetration.

The proposed solution shall have CNT poly-composite solution fabric that is coated with aluminium. Unlike some of the coats like lead, which might have toxic impacts and heavy weights or the bismuth/tungsten solutions, in the case of aluminium based solutions, the impact can be much higher in terms of effective shielding from radiation and in managing the dispersion effectively over the surface of CNT.

Significance of aluminium coating: Aluminium is one of the lightweight coat that can be considered for the apparel coats to thwart radiation from the system. Some of the significant factors that are positive to aluminium coat are the penetration levels and the attenuation levels of aluminium coat.

Figure 2 below depicts the penetration of soft tissue and the aluminium for varied photon energies.

The penetration levels in the graph depict that certainly there are potential conditions for using the aluminium coat to reduce the radiation impact[34].

CNT Polymer: In the earlier contributions, numerous solutions were proposed in terms of CNT polymer composites in textiles. It is imperative from the review of contemporary literature that the CNT composite can be very resourceful in the textiles, provided its surface is effectively layered for more optimum performance.

It is evident from the tests conducted earlier[35] that when randomly oriented CNT/Polymer composites and the aligned configuration of the composites are tested, certainly the impact of aligned configuration is much higher. Hence, there is integral need to ensure that the CNT/polymer composites have to align. Figure 3a denotes the tensile strength and Fig. 3b indicates the strength of elastic modules in the case of a scattered and aligned CNT composites. It is imperative that the strength of tensile and elasticity of scattered (randomly deployed) CNT/Polymer are categorically lesser than that of 100 MPa and 6 GPa. However, it attains higher levels of 3600 MPa and 80 GPa in the instance of an aligned CNT/Polymer composites.

In addition, the tensile strength and elastic modulus are high in the case of aligned CNT/Polymer composites that comprise higher CNT content but in the case of the randomly oriented CNT/polymer composites, such factors are not envisaged.

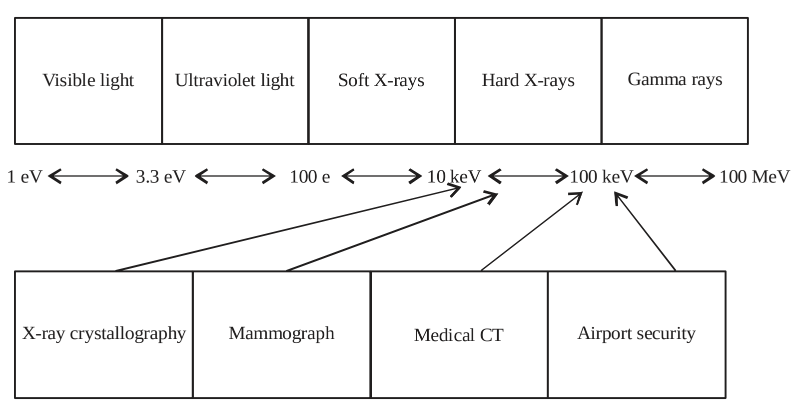

Fig. 1: Above figure illustrates electromagnetic spectrum and X-rays applications in different areas[32]

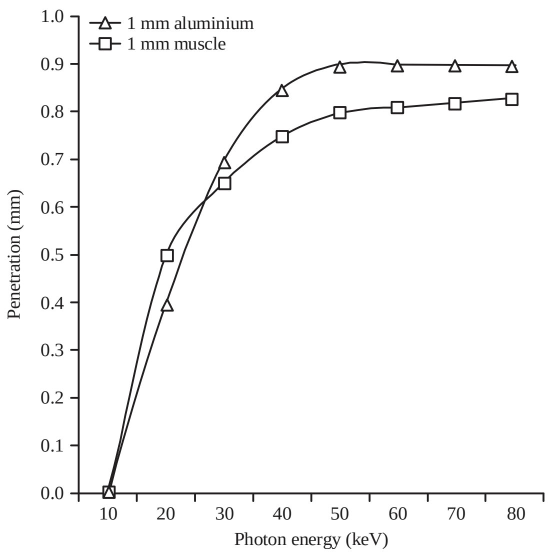

Fig. 2: Penetration levels of aluminium

Usually the CNT content in a matrix observed upon conducting CNT strengthening effect over the scattered CNT/Polymer composites investigation. Below such content levels, the effect of strengthening for a randomly oriented CNT/Polymer composite rises with increment in the CNT content.

It is imperative from the study that CNTs are very effective heat conducting material. Experts are of opinion that the thermal conductivity can reach higher proposition of 3500 W Mk at a room temperature for SWCNT[36], however, in the experimental studies it envisaged up to 3000 W/mK for isolated MWNT at the room temperature levels[37].

From the previously mentioned factors, it is imperative that the CNTs can be more effectively addressing the issues of thermal conductivity and thermal stability for the polymers at higher temperature[38-41]. According to some classical molecular dynamics simulations carried out in Park and Taya[41], by the addition of CNTs the T_g levels increment observed. In addition, the quantum of expansion resulting due to thermal expansion and related coefficients of diffusion in the composite above T_g was also attained. Based on the results of theoretical and experimental analysis, it is evident that the quantum of interfacial thermal resistance reduction in terms of performance of CNTs is not advocated and hence certain new techniques were proposed.

Mass attenuation: The penetration levels for a matter or a particle or the energy is decided by the mass attenuation coefficient of the volume of chosen material[38]. The mass attenuation coefficients are defined even for the electromagnetic radiation analysis. Usual measuring unit of mass-attenuation is sq.mtr per kilogram ($m^2\ kg^{-1}$). The other common unit that is used for evaluating attenuation is $cm^2\ g^{-1}$, which is predominantly used for measuring X-ray mass attenuation co-efficient[42].

Density of aluminium and its mass absorption efficiency: X-rays attenuated as the screen through the matter. However, the intensity of the radiation reduced based on every interaction of the photon against an atom of the material. The quantum of decrement in the intensity depends on two key factors.

One is the complexity of penetration (x) or the thickness to which it has to penetrate.

Secondarily, the distinctiveness of the material termed as “absorption coefficient” (A).

The intensity dwindles considerably upon the distance travelled.

$I = I_0 \exp(-Ax)$, wherein I_c is the intensity of initial X-ray beam.

Exponential decay of photon is considered is applied over the electromagnetic spectrum’s optical region. The process of such application is termed as[43] Beer-Lambert Law.

$$I = I_0 \exp(-\mu\rho x)$$

The attenuation length categorized as depth of material with which the intensity of X-rays reduced approximately to “37% (1/e)” of the value at the surface.
Which is:

$$I = \left(\frac{1}{e}\right) I_0$$

or $I/I_0 = 1/e$ [43].

In the above equation, e, is the Euler's number, which is base of natural logarithms, or e ≈ 2. 7183. Upon substituting them to above equation, the outcome is:

$$(I/I_0) = \exp(-\mu\rho x)$$

$$\ln (I/e) = (-\mu\rho x)$$

$$-I = (-\mu\rho x)$$

$$x = 1/(\mu\rho)$$

The aforesaid factor is termed as “mean free path”.

The comparative analysis of the depth of X-ray energy depicted for both lighter and heavier elements. It is imperative that the attenuation length of aluminium

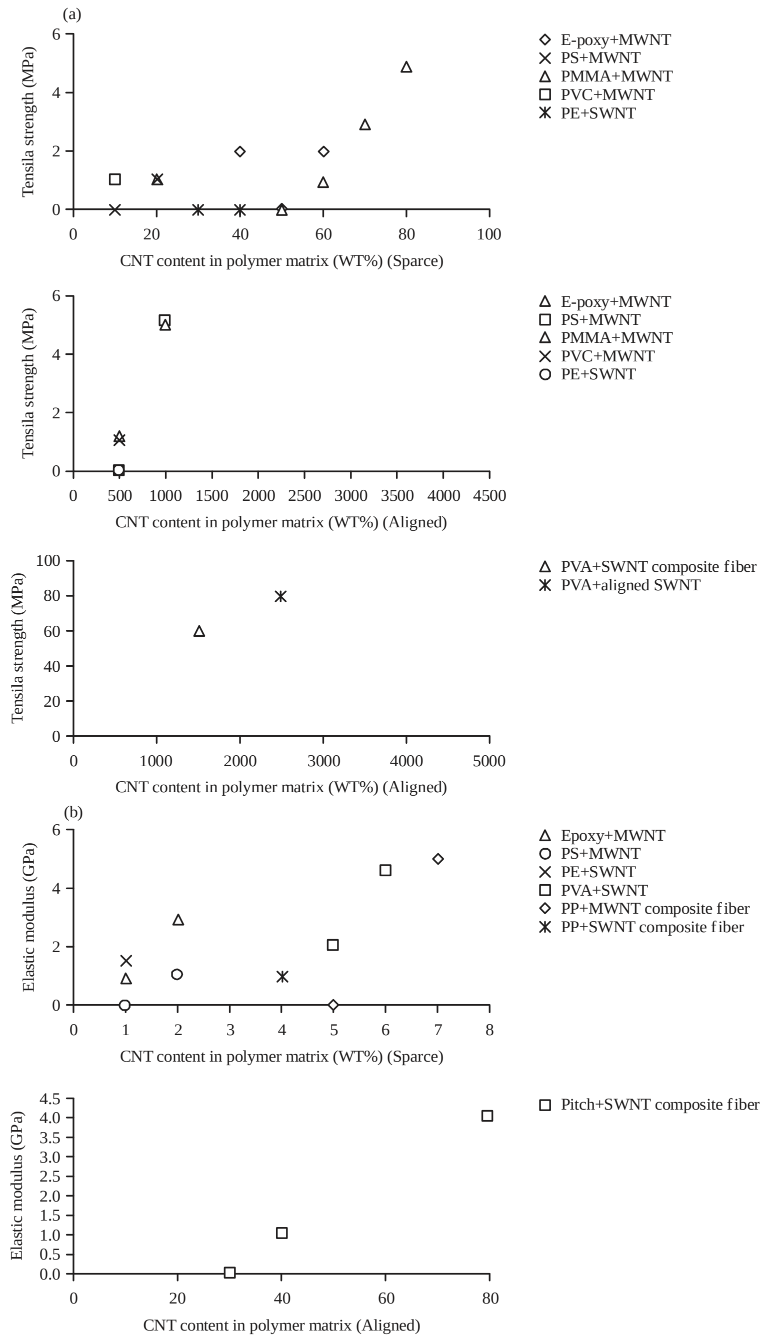

Fig. 3(a-b): (a)Tensile strength of Aligned CNT and Randomly oriented CNT and (b) Elastic modulus of Aligned CNT and randomly oriented CNT

is high that compared to the other elements like the Iron and Lead. In addition, as discussed in the impact of lead in terms of weight and the toxic substance remittance over a period is key challenge that might curtail the solution.

As discussed in the mass attenuation levels have significant impact and when the combination of CNT and the aluminium is adapted, effectively there could be better outcome[39].

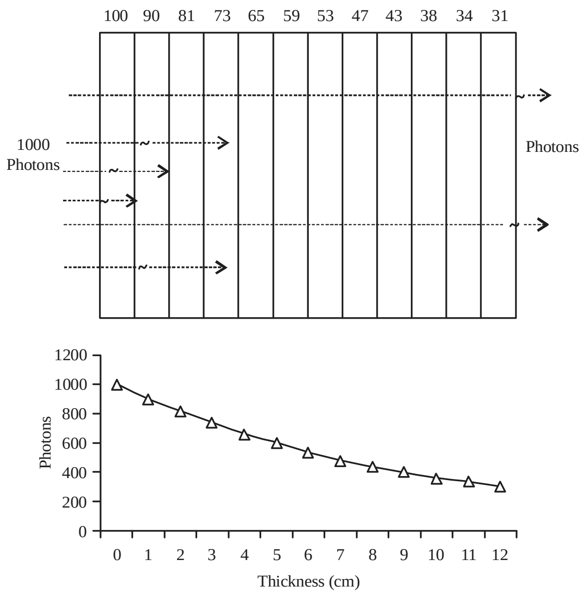

Fig. 4: Photons interacting in each one cm layer

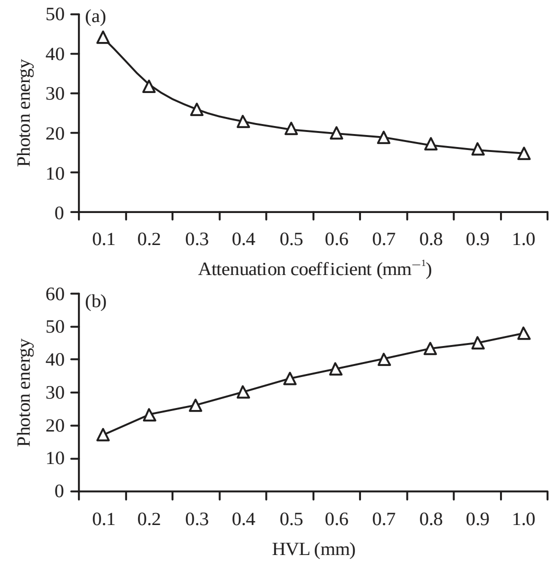

Fig. 5: Relationship between attenuation coefficient and HVL for aluminium penetration values

From the inputs over the efficiency of the CNT polymer and the effectiveness of aluminium in terms of weight of the element and its attenuation co-efficiency can be effective combination for addressing the impact of radiation. Among the key elements like lead iron and aluminium, that is mass absorption efficiency of aluminium is 2.22 cm^2 g^{-1} and the attenuation length is 1.65. When compared to the other two elements like lead and iron (respective co-efficiency is 64.1 and 18.2 cm^2 g^{-1} and their attenuation length (0.014 and 0.07 mm), aluminium can be more resourceful element for handling the attenuation factors.

Distinctiveness of radiation is that all the photons may not have identical region despite of having the same energy. It is very challenging to ascertain the range of a specific photon. In the case scenario of a group of mono-energetic photons penetrating into an object as depicted in Fig. 4, certain photons travel a relatively short distance prior to interaction, while some photons penetrate deep or pass through the object. The fundamental characteristic of a photon penetration can be envisaged if the number of photons penetrating thru each of the thickness range in a material is counted[41]. The relationship amidst the varied range of photons attaining a definite point and the viscosity of material towards that point results in exponential manner.

Half value layer: In estimation of half value layer (HVL) can be very resourceful estimation, as it is one of the most frequently used quantity ore factor in terms of detailing both piercing capacities of certain radiations and the dispersion over certain objects. HVL is the viscosity of a material that penetrates with one portion of radiation and is assessed in units of distance by mm or cm[34].

Raising the penetration capacity of a radiation can improve the HVL and it is relative but not similar in terms of average photon range. The difference amidst the two is imperative due to typical characteristic of X-ray attenuation and dispersion.

Figure 5 indicates that HVL is inversely relational to attenuation coefficient. The dispersion of 0.5 has emerged for 0.693 as the exponent value. With the changing factor of interactions, even the value of attenuation coefficient even the HVL is altered:

$$\text{HVL} = 0.693 \times \text{Average}$$
$$\text{Range} = 0.693\ \mu^{-1}$$

The attenuation coefficient of aluminium and HVL are compared in Fig. 5, for an application in a high radiation zones, where aluminium is adapted as material for filtering the radiation[34].

From the review of calculations, it is evident that the quantum of radiation, which disperse over a material of specific thickness is influenced by energy of individual photons and also some significant factors like thickness and atomic value of the material. HVL values are significant for finding HVL values and estimating the penetration through other thickness is feasible[34].

Material	HVL (mm)		
	30 keV	60 keV	120 keV
Tissue	20.0	35.0	45.0
Aluminium	2.3	9.3	16.6
Lead	0.02	0.13	0.15

Fig. 6: HVL values for certain materials

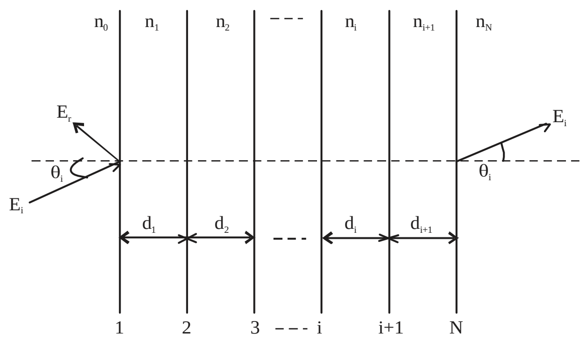

Fig. 7: Weight estimations for polymer composition

Figure 6 denotes HVL values for varied materials that vividly used in diagnostic imaging.

Nanostructure composites: In terms of observing the nanostructured composites processing, MWNT with 10-20 µm of length and thickness 0.01-0.05 µm of diameter are considered. The electromagnetic classification of nanostructured composites is conducted in lines with the transmission/reflection method using wave guide with frequency range boundary of 8-12.5 GHz.

Tube configuration of CNT enables them towards electronic combination that essential for unique electronic transference behaviours. Notional estimations reflect that CNTs tend to behave as insulators, metals depending on their extents and chirality. Composites comprising MWNTS (multi-walled carbon nanotubes) that are integral to polymer were adapted for EMI shielding or the microwave absorber[44-50].

Weight estimations: In the process of weight estimations, the targeted wave thrives from one side to the other with an angle θ_i. "n" is the refractive index and "d" shall be thickness of every layer, correspondingly the subscription N and number of layers, n_a and n_N shall be denoting the refractive index quotient of the free space.

From Fig. 7, Snell's law is adapted for attaining diffused angle for every layer. In an instance of wave penetration performed vertically towards a multilayer stack, θ_i turns equal to zero. "i" Shall be integer number, 1, 2, 3,..., I, i+1, ...,N, denoting varied number of layers.

NIST related data is the basis for C-ray regimes chosen for assessment[51]. The ratio of weights is attained using:

$$W_{ratio}\,(\%) = \frac{W_m}{W_{Pb}} = \frac{\sum_{1}^{N} \rho_m (xyz)_m}{\rho_{Pb} (xyz)_{Pb}}$$

If the materials are comprising matching dimensions and varying levels of thickness, ratio of weight is attained using the equation:

$$W_{ratio}\,(\%) = \frac{\sum_{1}^{N} \rho_m\, Z_m}{\rho_{Pb}\, Z_{Pb}}$$

In which, ρ and z are the viscosity (g cm^{-1}) and the viscosity (cm) of materials, correspondingly. Weight ratios are estimated using the above set of equation. In the instance of weight ratio being lesser than one, it emphasizes that the weight of the material considered is much lighter when compared to standard metric weight of 0.50 mm Pb.

Experimental study: In our Experiment Epoxy resin (EPOC 828) are used as samples combined with amine-based hardener comprising 1:4 wt% vs. resin and also the SWCNT (Single Wall) CNT with diameter of 1/2 nm, length 5/30 µm are used for the research process. Also, the micro-sized graphite powder having distinct weight percentages were also considered for the experimental study.

Usually when the X-rays pass through SWCNT to an X-ray detector, certain photons tend to interact with SWCNT and they might get absorbed to the beam and there could be certain scattering too as depicted in the Fig. 8.

I and I_0 are the intensities of incident for the x-ray and the transmitted beams. I_0 is depicted as the SWCNT sample measured. For the proposed experimental study, the process of Beer-Lambert law[43] [$I = I_0 \exp(-\mu\rho x)$] is used for determining mass attenuation coefficient of SWCNT samples. In this experiment, X-rays constituting "I" value are used and when it passes through the SWCNT, the intensity gets reduced because of the attenuation characteristic of SWCNT. Hence, the X-rays are detected using the detector and the readings are noted as I_0 for effective x, p values.

Wherein µ, ρ and x are, respectively, the linear absorption coefficient of material for X-ray absorption. The density values of the material are listed in Table 1 and distance amidst the photon travels by matter. The specimen density is adapted for the experimental study to address material density issue. Term µ/ρ is observed as the mass attenuation coefficient and is

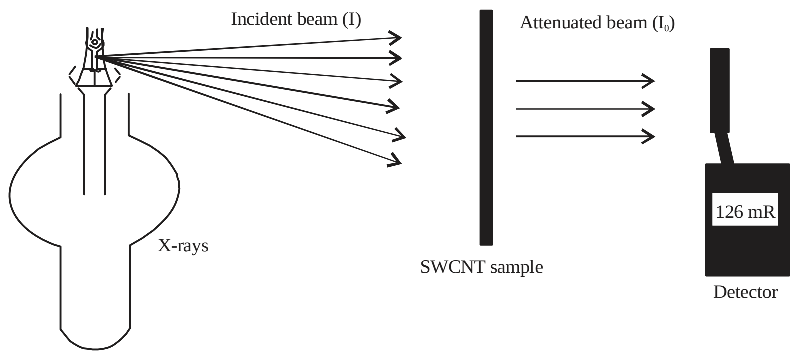

Fig. 8: Experimental set-up to measure the mass attenuation coefficient of SWCNT

Table 1: Average density of CNT composite materials tested based on standard error of the mean (SEM)

Reinforcements	Density (g cm^{-3})
0% wt SWCNTs	1.16±0.02
0.2% wt SWCNTs	1.15±0.03
1% wt SWCNTs	1.17±0.03
2% wt SWCNTs	1.12±0.02

widely adapted as an integral value as depicted in Table 2 comprising X-ray mass attenuation coefficients.

The tungsten anode is used in the experiment operating at 38 kV, 0.2 mA current. And the detector is Solid State Detector cooled by Peltier system, resolution of 150 eV at 5.9 keV.

RESULTS

Using the Beer-Lambert law $I = I_0 \exp(-\mu\rho x)$ the mass attenuation coefficient value is estimated with SWCNT having varied types of weight percentages and such values are plotted over and is depicted in Table 2. It is observed in the analysis that attenuation of the samples decreases with the rising levels of incident energy, resulting from photoelectric effect dominating certain 'low' energies. Attenuation rises with higher levels of SWCNT weight percentage of inclusion.

It supported by evaluating the performance to the results that are gathered to the graphite-oriented materials. Rather the attenuation of sample comprising 'heavy' addition of graphite micro-powder (50 wt%) is more in common to the ones that are obtained for value of 1% wt of SWCNT inclusions, which are overcome by the effect of nanotube filling of up to 2% wt.

Using the NIST Standard Reference Simulation Website[52], the attenuation (%) was estimated for aluminium at photon energy 10 KeV for varied thicknesses. All such attenuation values are depicted in Table 3 and the figurative representation is depicted in Fig. 9.

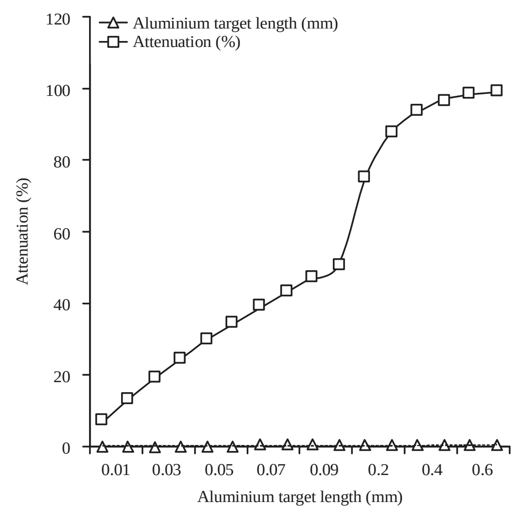

Fig. 9: Attenuation levels of aluminium at various thickness levels

Experimental studies are carried out using standard EM radiation energy of 10 KeV. It is imperative from the details depicted in Table 2 that 2% wt SWCNT mass attenuation coefficient results as 6% for the 10 KeV, signifying that the attenuation ratio is 6%. Hence, to address the gap in the process and to increase the attenuation levels to higher quotient, Al coating at value of 0.7 mm can be effective based on the inputs depicted in Table 3.

DISCUSSION

The gist of the discussion about the model depicted in this manuscript that compared to other contemporary models is following.

From the atomic numbers of Iron (Fe) as 26 and Al as 13, respectively, it is evident that the density of aluminium is lower than the iron. In "Electromagnetic interference shielding effectiveness of hybrid multifunctional Fe_3O_4/carbon nanofiber composite, polymer"[53], the authors have focused

Table 2: X-ray mass attenuation coefficient values of different carbon-based epoxy composites

X-ray energy (KeV)	2% wt SWCNT μ ($cm^2 g^{-1}$)	0% wt SWCNT μ ($cm^2 g^{-1}$)	0.2% wt SWCNT μ ($cm^2 g^{-1}$)	1% wt SWCNT μ ($cm^2 g^{-1}$)
7	10.4	9.0	9.8	9.8
8	7.8	6.0	6.2	7.0
9	7.0	4.4	5.2	6.0
10	6.0	3.8	4.2	5.0
11	5.2	2.8	4.0	4.4
12	4.2	2.0	3.6	4.0
13	3.0	1.8	2.0	2.0

Table 3: Attenuation and required al thickness statistics

Al target length in mm for 10 KeV	Attenuation (%)
0.01	6.8271
0.02	13.1882
0.03	19.1150
0.04	24.6371
0.05	29.7822
0.06	34.5761
0.07	39.0427
0.08	43.2043
0.09	47.0819
0.1	50.6947
0.2	75.6898
0.3	88.0138
0.4	94.0902
0.5	97.0861
0.6	98.5633
0.7	99.2916

on the EM shielding solutions that comprise the iron compounds as (Fe_3O_4) which could increase the weight of the polymer composite. Whereas, the aluminium coat with lesser density can reduce the weight load over the CNT composite and also can improve the shielding capacity.

In the research "Facile fabrication of ultrathin graphene papers for effective electromagnetic shielding"[54] the researchers has focused on electromagnetic shielding in the range of 8.2-12.4 GHz as the frequency, with volt capacity as [1.24 meV, 1.7 eV]. Research studies in "Comparison of electromagnetic shielding with polyaniline nano-powders produced in solvent-limited conditions"[55] reflect upon microwaves comprising energy between range of 1.24 μ eV-1.24 meV. However, the proposed solution in this paper reflect upon the EM shielding in the energy range of 120 eV-50 KeV called X-rays.

In "Electromagnetic interference shielding nature of PVDF-carbonyl iron composites"[56], researchers proposed the EM shielding solutions that depend on iron powder composites which is inferior when compared to the results of aluminium coat that delivers optimum results despite of lesser density levels than the Iron powder composites.

CONCLUSION

Electromagnetic radiation shielding is effectively countered by the CNT polymer textile. However, certain factors like the dispersion, interfacial factors are affecting the performance of the CNT solutions in managing the electromagnetic shielding. Considering the constraints, scope and impact of surface coating over the CNT polymer composite, to improve effectiveness for better performance, aluminium coating is considered. Using aluminium coating for the process due to its characteristic of higher attenuation and low weight has supported in addressing the CNT attenuation factors more effectively. Experimental studies reflect the fact that the proposed solution of aluminium coating over the CNT composite is more resourceful in improving the electromagnetic radiation shielding capacities of CNTs that are quoted with aluminium.

SIGNIFICANCE STATEMENTS

This study explores the emerging trends of fabric based electromagnetic shielding for protection from EM radiation. Profoundly, the focus is on understanding how the emerging trends like CNT based polymer composites are being adapted and the scope for improvement in using the CNT is reviewed. The outcome of this manuscript can provide possibilities of electromagnetic sheading based on light weight and thin coated CNT polymers, which exhibits higher attenuation properties in the electromagnetic radiation fields.

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