Biodegradable dielectricmaterial using PLA and luffa fiber modified by medical linear accelerator

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Research Article

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Biodegradable dielectricmaterial using PLA and *luffa* fiber modified by medical linear accelerator

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Running title

Biodegradable dielectrics

Abstract

Biodegradable electronic devices are presently in command in various sectors mainly in health care system.The present work comprehends the dielectric properties of biodegradable composites made from biodegradable polymer poly (lactic) acid (PLA) and natural fiber of *luffa cylindrica* (LC) fabricated using microcompounding and injection molding . LC fibers are an agricultural waste, rich in cellulose.LC fibers were exposed to 6 MeV electron beam of doses 0.5Gy, 1.0Gy, 2.0Gy, 4.0Gy and 10.0 Gy generated from medical linear accelerator(LINAC) in presence of air. Such low doses are normally used for treatment of cancer patients and not for modifying polymers where doses in the range of 20-200KGy are used. The effect of such low irradiation dose on fiber and study if any significant changes taking place is the innovative aspect of the present work. The effects of irradiation dose on dielectric behavior such as dielectric constant and ac conductivity were investigated at different temperatures 26^0C, 40ºC, 60ºC and

80ºC while keeping frequency constant . The increase in dielectric constant from 57 in virgin PLA at 26^0C,500Hz to a maximum of 84 in composite sample due to reinforcement of low dose irradiated LC fibers recording 49% increase is an important result of the investigation.

Keywords: PLA, LC fiber,electron beam, dielectric constant, ac conductivity

Introduction

Biodegradable material has recently plunged major impact in biomedical terrain such as drug delivery, therapeutics and tissue engineering. There is always a need of biodegradable dielectric material through which electrical signal can be transmitted in myocardial tissue and neurons.Biodegradable bioimplant devices for human body are currently in high yearning.The need of biodegradable electronic devises arise to eliminate the problem of disposal of synthetic electronic devices waste which cause serious environmental problem like soil pollution and contamination[1,2]. The current research uses the fruit of LC, a common tropical fruit which is basically a waste, as reinforcement in completely biodegradable PLA matrix producing green composites.PLA has captivated substantial research interests due to its biodegradable and biocompatible nature. The LC fibers are rich in cellulose(60%), cost effective, readily available with low CO_2 emission along with high electrical resistance, good thermal and acoustic insulating properties. Most importantly they are biodegradable and can be recycled [3-6].However the LC fibers are hydrophilic in nature due to presence of cellulose, hemi-cellulose and lignin, with a tendency to absorb moisture from the surrounding making them less reactive having poor compatibility with the polymer matrices during fabrication of composite materials.Thus fiber modification is necessary prior to its use as reinforcement[4-6]. Ionizing radiation for modification of natural fiber hold great consideration because of no use of

chemicals, low processing time leading to energy saving, clean waste free procedure leaving no bad impact on environment. Electron beams are used in radiation processing mostly, which bring significant structural changes in the fiber with very low irradiation dose [4,7,8]. Celluloses , which are the major component of plant fiber ,are long chain polymers consisting of identical gluco pyranose units which are linked to its neighbor by glucosidic linkage. When natural fibers rich in celluloses are exposed to electron beam and gamma rays, free radicals are formed on the surface of the fiber leading to enhanced bonding between fiber and matrix . Crosslinking and chain scisson are two major chemical changes observed when the cellulose rich natural fiber is irradiated with electron beam and gamma rays[4,9]. Further the increase in surface area due to defibrillation of cellulose fibers enhance the compatibility between fiber and matrix. The interaction of electrons with the solid can be soft interactions(excitation) or hard interactions or knockout interactions.When these radiations interact with solid molecules ,they transfer energy to the solid molecules leading to formation of reactive molecules in the excited states. This can be represented as

$$e + M \rightarrow M^{+} + 2e^{-} \qquad (1)$$

where M is the solid molecule and M^{+} is the ionized solid molecule as well as excited solid molecule. Finally the irradiated material is ionized during electron beam irradiation and large number of electrons are available on the surface, thereby generating many free radicals. Presence of free radicals and monomers enhance the chemical bonding between irradiated LC fiber and matrix when the fiber is used as reinforcement during fabrication of composites[8-10].

Normally polymers are modified with irradiation doses in the range from 20-200KGy and incase of some biopolymers which are highly sensitive, changes are observed from 1KGy irradiation dose. Cellulose, the major component in plant fiber is usually rather resistant to

irradiation.The most significant and innovative matter concerning this investigation is doses applied for modification of LC fiber at the level from 0.5Gy to 10.0Gy.The objectives behind this work is to detect whether any significant changes are occurring at this low level of doses. Such low doses are used for treatment of cancer patients and not normally for modifying polymers.Thus this is an innovative way of modifying surface of LC fiber using radiation obtained from medical linac. Electrons are accelerated to high energy of 6MeV The different components of a linac are given in **Figure 1**.

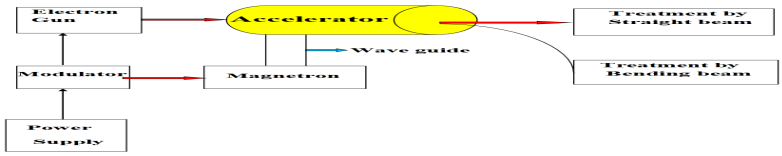

Figure 1:Schematic diagram of a medical linac

As shown in **Figure 1**,the linear accelerators are connected to a power supply ,supplying alternating currents to the modulator.The modulator converts the alternating current to direct current.The modulator is a pulse modulator that converts the dc voltage in terms of pulses of few microseconds duration. Linacs accelerate electrons to few mill volts of energy in pulsed manner and not in continuous manner. The output of the pulse modulator are fed to the electron gun as well as to the magnetron. The magnetron generates microwaves required to accelerate electrons to 6MeV coming from electron gun.These accelerated electron beams are further directed to a target having high Z to generate X-rays/gamma rays by bremsstrahlung interactions using microwave technology.

All agricultural materials such as natural fibers, foods conduct electric currents to some extent. Knowledge of dielectric properties of these materials will determine the distribution of electromagnetic field in the materials in presence of external alternating field. How rapidly a material can be heated by radio waves or microwaves, can be ascertained from the evaluation of dielectric properties. All crystalline materials consist of two sublattices, ordered lattice exhibiting normal oscillations obeying Lyddane-Sachs-Teller (LST) model and disordered lattice having random oscillations obeying Debye's relaxations. Thus the crystal when exposed to external electric field is polarized in different ways .and the total polarization is expressed as $p = p' + p_d$ .The p' is the polarization due to ordered motion having contribution from dipole polarization , atomic polarization and ionic polarization while p_d is the polarization due to disordered motion caused by jumping of particles between two positions also known as orientation polarization. ε_r is the dielectric constant of the material and is sum of two terms contributing from ordered oscillation(ε') and disordered oscillation(ε_d) i.e $\varepsilon_r = \varepsilon' + \varepsilon_d$

Here in both ordered and disordered sublattices, particles oscillate as harmonic oscillators but in ordered lattice .There occurs resonance for disordered sublattice and relaxation for ordered sub lattice.

The relaxation time of the dipoles can be related to the energy barrier between two available states as $\tau = \tau_0 e^{\frac{\Delta U}{KT}}$ ……(2).

ΔU is the energy barrier between the two states and T is the temperature.As temperature increases, the relaxation time decreases leading to increased relaxation frequency.

The dielectric constant of a material due to disordered state is a complex number having both real part and imaginary part. $\varepsilon_d = \varepsilon' - j\varepsilon''$.The real part ε' is the dielectric constant which is a measure of ability of the material to store energy in presence of external electric field.The

imaginary part $\varepsilon"$ is dielectric loss which indicates the ability of the material to absorb or dissipate energy obtained by conversion of electrical energy to heat energy.It shows the tendency of the material to be heated in presence of electromagnetic field of different frequencies. Both the real part and imaginary part tells about the polarizing ability of the material in presence of external electric field. The frequency dependence of real part and imaginary part of the dielectric constant can be obtained from Debye s model[11,12].

$$\varepsilon_d = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_\infty}{1 + j\omega\tau}, \qquad \text{.....(3)}$$

Separating the real part and imaginary part we get

$$\varepsilon' = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_\infty}{1 + (\omega\tau)^2} \qquad \text{.....(4)}$$

$$, \varepsilon" = \frac{(\varepsilon_s - \varepsilon_\infty)\omega\tau}{1 + (\omega\tau)^2} \qquad \text{.....(5)}$$

ε_∞ is the dielectric constant of the material at very high frequency of the applied electric field where the orientation of polar molecules are not possible due to much less time interval and ε_s is the static dielectric constant at zero frequency of the applied electric field. In addition to real and imaginary part of dielectric constant, the knowledge of ac conductivity of a material is essential , whose expression can be obtained using Maxwell electromagnetic wave equation.

The displacement current in the dielectric is expressed as $j = (\omega\epsilon_0\epsilon'')E = \sigma E$

Where

$\sigma = (\omega\epsilon_0\epsilon'')$ is known as ac conductivity of the material.

Dielectric behavior of a material relate the intrinsic interactions of the electromagnetic waves with the matter. The biodegradable nature of both PLA and natural fibers

of LC fascinates us to carry out the work and to study the complex dielectric properties of the prepared blended materials with variation in irradiation dose, temperature and frequency.

Materials and methods

Material

Polylactic acid (PLA) of grade 4042D (molecular weight Mw ~ 6, 00, 000) was acquired from Nature Works, USA. The LC fibers were obtained from local forest area.

Electron beam irradiation

Electron beam of energy 6 MeV generated from the medical LINAC (Millenium True Beam Linear Accelerator, Varian) installed in Health Care Global Panda Cancer Hospital, Cuttack, India. The LC fiber was mounted below cotton gauge of 3 inch thickness and was irradiated with a rate of 600MU/min to attain doses of 0.5Gy, 1.0Gy, 2.0Gy, 4.0Gy and 10.0Gy.

Composite processing and fabrication

The PLA pellets and the electron beam irradiated LC fibers were left for drying in vacuum at 80° C for 24 h before using. The PLA and LC fiber were mixed mechanically at 100 rpm with a micro compounding molding equipment at 170°C for 10 minutes. After extrusion through a preheated cylinder, the molten composite samples were transferred to the mini injection molder in order to obtain the desired specimen samples for studying various properties .

Variety of samples for characterization

Composite samples were prepared with PLA matrix and different doses of electron beam irradiated LC fibers. in E1, E2, E3, E4, E5 samples, the PLA and 5% wt fibers are mixed with electron beam irradiation dose of 0.5Gy, 1.0Gy, 2.0Gy, 4.0Gy and 10.0Gy respectively.

X-Ray diffraction

WXRD/SHIMADZU/JAPAN, goniometer facilitated with scintillation counter records the the X-ray diffractograms at 26˚C with bragg's angle ranging from $10^0$to 80^0 using Ni filtered Cu Kα radiation of wavelength of 0.1542 nm.

Dielectric properties measurements

Rectangular specimens of 10mm × 10mm × 2mm were prepared and coated with conductive silver paint for study of electrical properties. The test samples were fixed between two electrodes and kept inside the sample holder. Measurements were carried out at 26^0C,40^0C, 60^0C and 80^0C temperature keeping constant frequency from 500 Hz to 5MHz to examine various dielectric properties such as dielectric constant and ac conductivity.

Results and discussion

X-ray diffraction pattern of virgin PLA

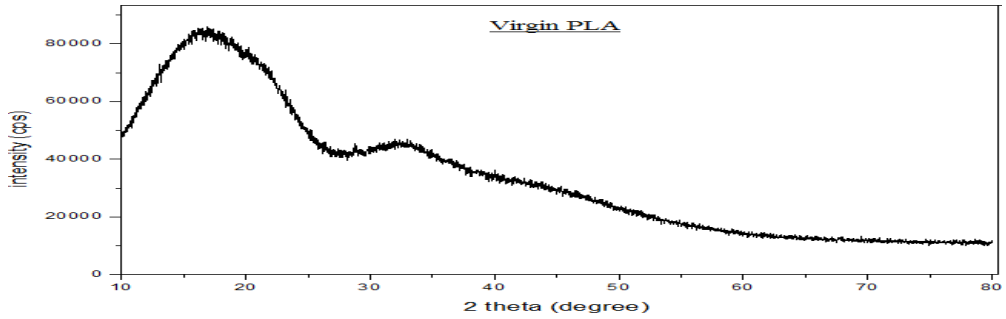

Figure 2: XRD pattern of virgin PLA

Figure 2 depicts the XRD pattern of virgin PLA. The figure exhibits diffused diffraction peaks at18^0 and 32^0 rather than sharp crystalline peaks.Two broad peaks in PLA is attributed to amorphous nature of PLA and presence of two crystalline structures .

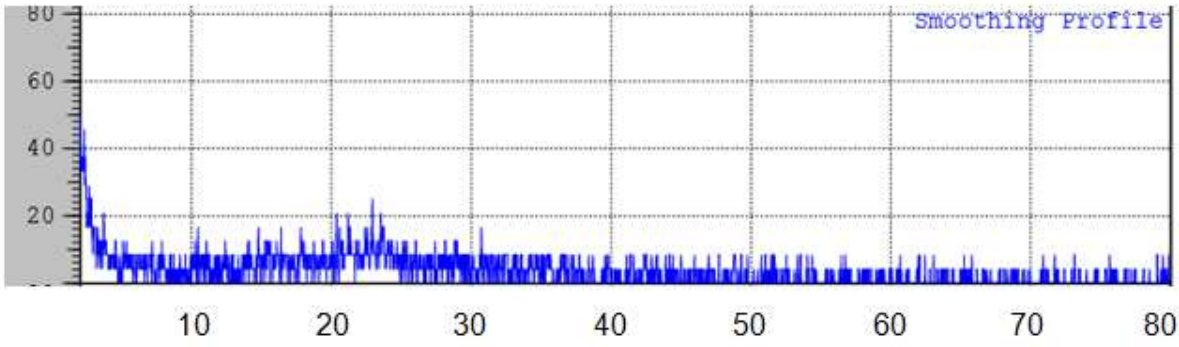

Figure 3: XRD spectra of composite sample E2 (PLA with 5% fiber having electron beam irradiation dose 1.0Gy)

Figure 3 gives the XRD pattern of LC fiber irradiated by 1.0Gy.The XRD spectra have no distinct peaks owing to destruction of crystallinity of LC fiber due to radiation at 1.0Gy beam. Highly amorphous nature of the fiber increases the number of polar monomers leading to increase fiber roughness and subsequent generation of numerous voids . The roughness of the irradiated LC fiber and numerous voids are expected to enhance the bonding between fiber and matrix during the composite synthesis.**Figure 4** shows the XRD spectra of composites using PLA as matrix and 5wt% electron beam irradiated (1Gy)LC fiber as reinforcement. The diffractogram of **figure 4** show the presence of broad peaks around 20.90^{0} and 39.23^{0} .

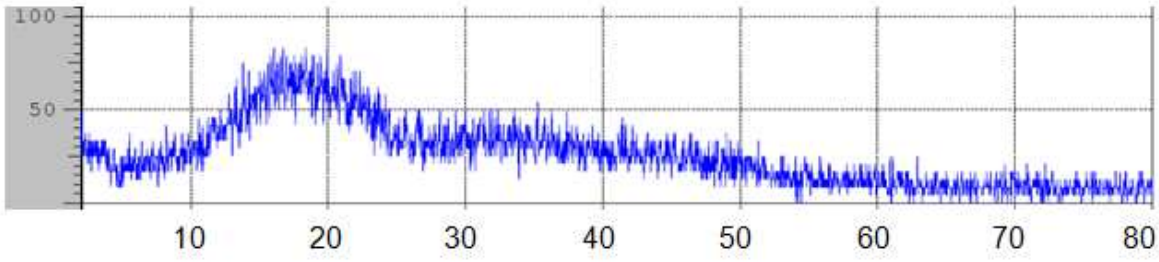

Figure 4:XRD pattern of 1 Gy electron beam irradiated LC fiber composite (sample E2)

The shifting of peaks from 18^0 and 32^0 in the XRD pattern of PLA shown in **figure 3** to 20.90^0 and 39.23^0 in composite sample E2 shown in **figure 4** is indicative of chemical bonding between irradiated LC fiber and PLA matrix.

Effect of temperature on dielectric constant and ac conductivity of electron beam irradiated LC fiber composites

Table 1 lists the values of dielectric constant of virgin PLA matrix, composite samples E1,E2,E3,E4 and E5 at temperatures of 26^0C, 40^0C, 60^0C ,80^0C at frequency 500Hz, 5KHz, 5MHz respectively.

Table 1:Dielectric constant at different temperature and different frequencies

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Sample	**At frequency 500Hz**				**At frequency 5KHz**				**At frequency 5MHz**			
	26^0 C	**40^0 C**	**60^0 C**	**80^0 C**	**26^0 C**	**40^0 C**	**60^0 C**	**80^0 C**	**26^0 C**	**40^0 C**	**60^0 C**	**80^0 C**
B0(virgin PLA)	57 ± 2.90	113 ± 3.66	120 .3 ± 3.65	108 .3 ± 3.00	38 ± 1.90	110 ± 1.43	116. 22 ± 1.33	104. 22 ± 1.02	12 ± 0.4	77 ± 1.01	82 ± 1.02	92 ± 0.92
E1(0.5GyLCfiber/ PLA)	71. 9 ± 2.9	19 ± 0.3	30 ± 0.3	65 ± 0.3	68. 5 ± 0.3	17.4 ± 0.2	26.2 ± 0.3	58.4 ± 0.3	66. ± 0.3	16. ± 0.1	18. ± 0.1	54.1 ± 0.2
E2(1.0GyLCfiber/ PLA)	84. 7 ±	63 ± 2.8	65 ± 2.7	63 ± 2.7	73. 78	55 ± 2.7	59 ± 2.8	57 ± 2.8	45 ± 1.9	16 ± 0.8	12 ± 0.8	18 ± 0.8

	2.8				±2.6							
E3(2.0GyLCfiber/ PLA)	73.1±3.0	49.1±2.6	55.2±2.6	76.5±2.8	42±2.6	50±2.6	58±2.5	70±2.8	56±2.5	15.7±0.8	14±0.9	19.5±1.1
E4(4.0GyLCfiber/ PLA)	64.9±2.4	64±2.4	68±2.5	71±2.4	61.±2.4	59.614±2.4	60.387±2.6	63.22±2.4	48±2.4	45.46±2.5	49.80±2.6	49.785±2.6
E5(10.0GyLCfiber/PLA)	70±2.5	27±1.2	28.±1.2	54.±1.8	61±1.8	23±1.9	21±1.7	53±1.9	17±0.9	14±0.4	18±0.4	20±0.8

Note: The values represent mean ±SD of 10 replicates

Table 1 betokens that dielectric constant for virgin PLA is 57 at 500Hz at temperature of 26^0C and it decreases to 38 at 5KHz frequency and to 12 at 5MHz frequency respectively keeping temperature constant at 26^0C . The similar dielectric dispersion is well exhibited by all other composite samples obeying Debyes model as given in expression 2 i.e

$$\varepsilon' = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_\infty}{1+(\omega\tau)^2}$$

At low frequency, the dielectric constant ε' is nearly same as the static dielectric constant ε_s .With increase in frequency of the applied electric field ω , ε'decreases and at high frequency ε'approaches ε_∞ .Polar -OH groups and ester (polar molecule) linkage present in PLA and LC fiber contribute for high orientation polarization at low frequency because there is sufficient time interval for which the dipoles or polar groups present in the composite samples realign themselves in resonance with the applied electric field. However when the frequency increases, the time interval decreases and the polar groups were not able to polarize in accordance with the external electric field leading to decrease of dielectric constant.

It is observed from **table 1** that the dielectric constant of virgin PLA (B0) is 57 at temperature of 26^0C at frequency 500 Hz. It first increases to 113 at 40^0C and 120.3 at 60^0C keeping frequency unchanged at 500Hz and then decreases to 108 at 80^0C. PLA contains polar hydroxyl group(-OH) in its backbone. When temperature rises, the thermal energy of the dipoles increases leading to increase in orientation polarization and increase in dielectric constant. The initial increase of dielectric constant with rise in temperature has also bequest from dc conductivity and space charge polarization at the grain boundaries.The dc conductivity varies with temperature as $\sigma_{dc} = \sigma_0 \exp(-\frac{\Delta U}{KT})$. Dc conductivity increases with increase in temperature leading to increase in dielectric constant.However with rise of temperature beyond a certain temperature,the amount of moisture present in the sample decreases leading to decrease in number of polar groups(-OH) and orientation polarization resulting in decrease of dielectric constant. [11,12] . The temperature at which dielectric constant starts decreasing is the transition temperature and it represents a relaxation.With rise of temperature beyond the transition temperature the chemical bonds vibrate more vigorously causing decraese of dipole moment and orientation polarisation of the functional groups obeying Debyes relaxation given

by the expression $\tau = \tau_0 e^{\frac{\Delta U}{KT}}$. Where τ is the relaxation time and T is the temperature. When temperature goes beyond transition region, relaxation time decreases with increase of temperature. The dipoles couldn't orient effectively with decrease in relaxation time in accordance with external electric field leading to decrease of dielectric constant.

However for composite samples E1,E2,E3,E4 & E5, the dielectric constant is enhanced as compared to that of virgin PLA at room temperature 26^0C & at frequency 500Hz. For the fixed wt of irradiated LC fiber(5wt%) in the PLA matrix, the dielectric constant increases from 57 in virgin PLA matrix to 71.98 in composite sample E1 (0.5 Gy irradiatedLC fiber/PLA) , 84.79 in E2 (1.0 Gy irradiatedLC fiber/PLA),. 73.16 in E3 (2.0 Gy LCirradiated fiber/PLA) , 64.92 in E4 (4.0 Gy irradiated LCfiber/PLA) and 70 in E5 (10.0 Gy irradiated LCfiber/PLA). The maximum increase of dielectric constant is 49% for composite sample E2, where the LC fiber is irradiated with 1.0 Gy electron beam irradiation dose. The increase in dielectric constant of composite samples as compared to that of virgin PLA at 26^0C, 500Hz is contributed by chain scission of celluloses and hemicelluloses in LC fiber induced by electron beam irradiation. The chain scission breaks the long chain polymers of cellulose to fragments. Portability of functional groups or polar groups increases the polarization leading to enhanced dielectric constant. However when the irradiation dose increases beyond 1.0 Gy, the dielectric constant decreases from 84.79 in E2 (1.0 Gy irradiated fiber) to 73.16 in E3 (2.0 Gy irradiated fiber) , 64.92 in E4 (4.0 Gy irradiated fiber) and 70 in E5 (10.0 Gy irradiated fiber). The decrease in dielectric constant beyond irradiation dose 1.0 Gy may be due to cross linking induced by the electron beam irradiation. The irradiation process on fiber induces both chain scission and cross linking. The increase of dielectric constant could be explained by chain scission process while decrease of dielectric constant could be explained by cross linking. Due to cross linking, the

different smaller fragments are linked together leading to decrease in mobility of polar molecules. Thus decrease in mobility decreases the dielectric constant[11-14].

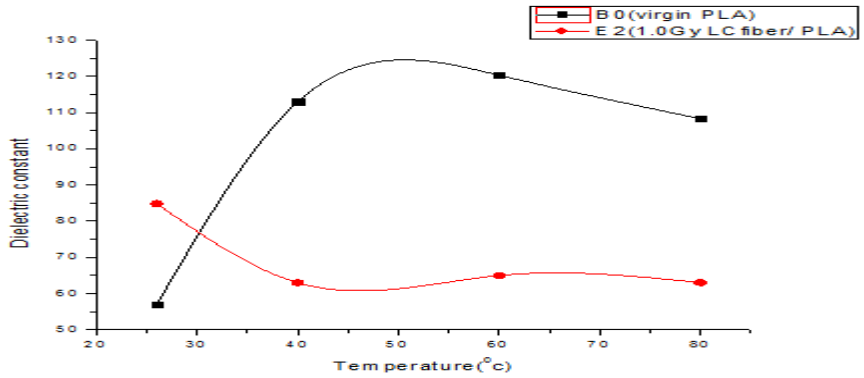

Figure.5:Variation of dielectric constant with temperature of virgin PLA and composite sample E2at frequency 500 Hz

Figure 5 gives the variation of dielectric constant of virgin PLA and composite sample E2 with temperature.The dielectric constant of matrix PLA initially rises with temperature followed by decreasing after a certain transition temperature. For composite sample E2, the dielectric constant at 26^0C is 84.79.But with rise in tempearature to 40^0C , it decreases to 63.When LC fibers are reinforced into the matrix,the number of –OH groups are increased .With increase in tempearature, the moisture present in the sample vapourizes leading to decrease in number of polar groups and hence orientation polarization .Beyound 40^0C, the dielectric constant of E2 rises to 65 at 60^0C owing to increase in greater mobility of polar molecules.Similar trends are observed for all other composite samples with variation in temperatures.As perceived from table 1, the dielectric constant varies from a minimum of 12 for composite sample E2 at 5MHz frequency, 60^0C to a maximum of 116.2 for virgin PLA at 5KHz frequency , 60^0C.Thus the virgin PLA and the composite samples can be tunable to wide range of variation in dielectric constant opening up many possibilities of future applications.

Table 2 betokens the values of ac conductivity of electron beam irradiated LC fiber/PLA composites with varying temperature and at different frequencies.

Table:2 Values of ac conductivity PLA and composite samples with varying temperature and at different frequencies.

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Sample	**AC conductivity (*10^{-9}ohm^{-1}m^{-1}) At frequency 500Hz**				**AC conductivity (*10^{-9}ohm^{-1}m^{-1}) At frequency 5KHz**				**AC conductivity (*10^{-9}ohm^{-1}m^{-1}) At frequency 5MHz**			
	26^0 C	40^0 C	60^0 C	80^0 C	26^0 C	40^0 C	60^0 C	80^0 C	26^0 C	40^0 C	60^0 C	80^0 C
B0(virgin PLA)	5.68 ± 0.4	0.3 66 ± 0.04	0.8 22 ± 0.04	0.1 27 ± 0.02	98.1 ± 2.8	8.45 ± 0.9	1.15 ± 0.2	0.2 91 ± 0.08	333 00 ± 904	460 0 ± 120	284 0 ± 102	306 00 ± 902
E1(0.5GyLCfiber /PLA)	1.53 ± 0.2	0.9 83 ± 0.03	1.40 ± 0.2	1.75 ± 0.3	7.75 ± 0.4	30.9 ± 0.8	2.64 ± 0.1	6.67 ± 0.2	403 0 ± 98	645 0 ± 120	123 00 ± 130	356 00 ± 370
E2(1.0GyLCfiber /PLA)	3.96 ± 0.06	96.6 ± 1.4	202 ± 2.2	101 ± 1.4	35.3 ± 0.6	328 ± 1.8	359 ± 1.8	360 ± 2.0	114 00 ± 120	370 00 ± 980	903 0 ± 120	532 00 ± 1020

E3(2.0GyLCfiber /PLA)	6.35 ± 0.8	3.85 ± 0.8	6.21 ± 1.2	6.57 ± 1.2	115 ± 10	0.612 ± 0.04	39.6 ± 0.8	8.87 ± 0.2	26100 ± 540	16400 ± 900	16100 ± 240	16100 ± 240
E4(4.0GyLCfiber /PLA)	2.65 ± 0.2	2.57 ± 0.2	4.10 ± 0.2	3.35 ± 0.2	17.6 ± 0.3	14.3 ± 0.2	36.3 ± 0.2	11.9 ± 0.2	6940 ± 120	31600 ± 900	36300 ± 900	15000 ± 560

Note: The values represent mean ± SD of 10 replicates

Table 2 depicts that the ac conductivity of the virgin PLA is 5.68nSi at 500Hz and 26^0C. It changes with incorporation of electron beam irradiated LC fiber into the matrix.Maximum ac conductivity is observed for composite sample E3(2.0Gyirradiated LC fiber/PLA) at 6.35nSi. This increase of conductivity may be attributed due to chain scission in the polymeric chain of fiber at that irradiation dose. But for other composite samples E1,E2,E4,E5, breakage of (C-C) and (C-H) bonds occour creating barriers against the mobility of charge carriers resulting a decrease in the conductivity of composite samples as compared to virgin PLA.Further the **table 2** portrays that ac conductivity of virgin PLA and composite sample s increases with increase in frequency.With the increase in frequency of the applied electric field, the dipole molecules oscillate more frequently leading to enhanced ac conductivity.With rise in tempearure at low frequency, dielectric constant of virgin PLA decreases from 5.68nSi at 26^0C to 0.127nSi at 80^0C owing to increased random motion at higher temperatures causing decreased mobility.However for composite samples, the variation of ac conductivity with temperature follows an irregular manner owing to multitude factors like presence of fiber, interfacial bonding between fiber and

matrix, chain scisson, cross linking and variation in frequency of the applied electric field.The maximum ac conductivity is 53200 nSi for composite sample E2 at 80^0C and frequency 5MHz and the minimum ac conductivity is found to be 0.127nSi for virgin PLA at 500Hz and 80^0C.Again the observance of such wide range of ac conductivity explores many oppertunities in use of these composite materials.

Conclusions

The present exploration delineated the fabrication of an ecofriendly,green,biodegradable dielectric material utilising an agro waste LC fiber and biodegradable PLA. Values of dielectric constant and ac conductivity of virgin PLA matrix and the composites made using irradiated LC fibers/PLA matrix were experimentally evaluated. Dielectric constant of virgin PLA was reported 57 and it increased from 57 to a maximum of 84.79 with reinforcement of electron beam irradiated LC fiber in the matrix reporting increase in dielectric constant by 49% at frequency 500Hz and temperature 26^0C.This is an important result showing that changes are detected in the dielectric constant at this level of doses from 0.5Gy to 10Gy and at energy 6MeV, normally used to treat cancer patients. Further the dielectric constant of the composite samples can be tuned to vary from 12 for composite sample E2 at 5MHz frequency at 60^0C to a maximum of 116.2 for virgin PLA at 5KHz frequency at 60^0C.Similarly the ac conductivity varies from a maximum of 53200 nSi for composite sample E2 at 80^0C and frequency 5MHz to a minimum ac conductivity is of 0.127nSi for virgin PLA at 500Hz and 80^0C. This wide range of tunability of dielectric constant and ac conductivity with variation in irradiation dose , frequency and temperature opens up many possible applications in the future. Connectors for electrically responsive neurons and cardiac cells in human body can be

synthesized using biodegradable dielectric materials considering the results of dielectrophoresis of interior human cells .

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Figures

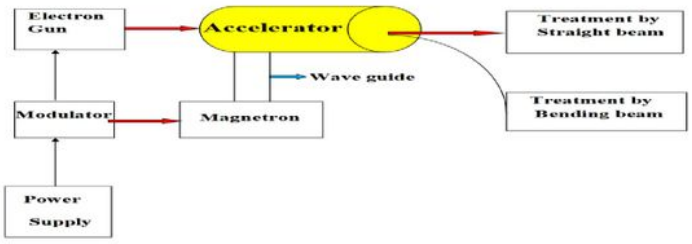

Figure 1

Schematic diagram of a medical linac

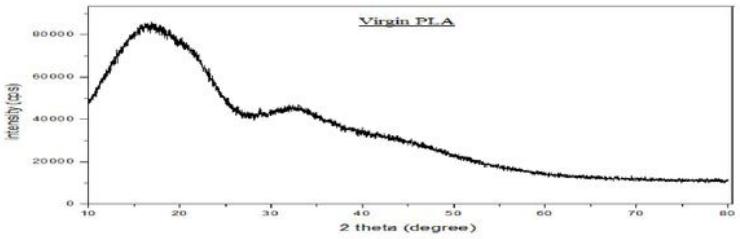

Figure 2:XRD pattern of virgin PLA

Figure 2

XRD patern of virgin PLA

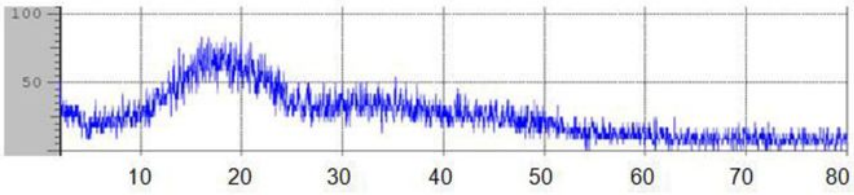

Figure 4:XRD pattern of electron beam irradiated LC fiber

Figure 3

XRD pattern of 1 Gy electron beam irradiated LC fiber composite (sample E2)

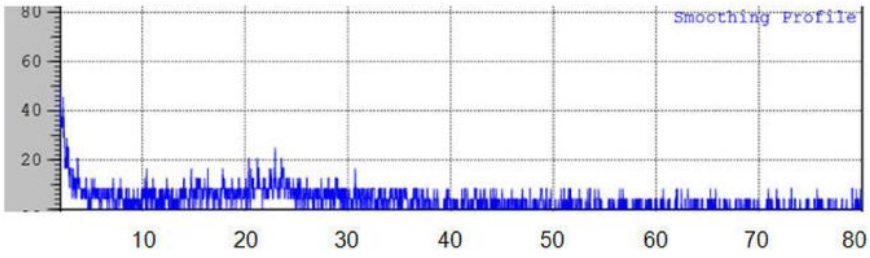

Figure 3:XRD pattern of XRD spectra of composite sample E2 (PLA with 5% fiber having electron beam irradiation dose 1.0Gy)

Figure 4

XRD pattern of electron beam irradiated LC fiber

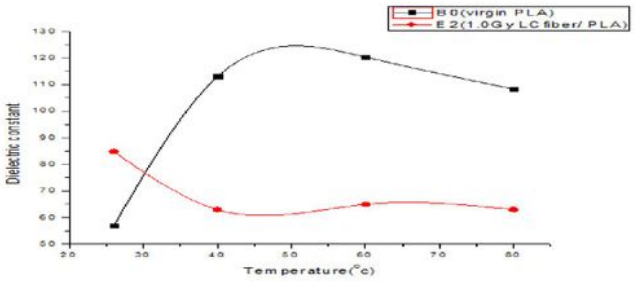

Figure 5: Variation of dielectric constant with temperature of virgin PLA and composite sample E2 at frequency 500 Hz

Figure 5

Variation of dielectric constant with temperature of virgin PLA and composite sample E2at frequency 500 Hz

Supplementary Files

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- graphicalabstract1.jpg