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RESEARCH ARTICLE

Characterisations of the electron beam impact on natural coir fibers

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Abstract

The surface morphology of coir fibers irradiated by electron beam has been investigated by scanning electron microscopic analysis. The tensile strength and thermal properties of the treated and untreated coir fibres are further investigated by using Instron tensile tests and thermo gravimetric analysis. From SEM studies it become obvious that the waxy, pectin and primary layers of coir fibers, which have heterogeneous structures, are removed from the fiber surface by electron beam irradiation. But high dose of irradiation is found to be detrimental to the tensile and thermal properties of coir fibers. It is therefore suggested that electron beam irradiation at 10kGy dose can be used to improve the surface properties of coir fibres and preserves the fibre thermal and mechanical properties.

INTRODUCTION

During the last few decades, recyclability of the materials and government regulations about carbondioxide emissions has produced an increase in the use of natural fiber composites both in the automobile and construction industries. Many studies of sustainability and life cycle assessments have demonstrated the environmental advantages of these materials (Nele et. al,2010, Flavio et. al 2008, Paul et. al ,2003) The global trends indicate the market place is leaning towards natural fiber use because of the various societal concerns. Despite the advantages of the cellulosic fibers, the polymer composite reinforced with natural fibers have a problem in the poor adhesion between the cellulose fiber and the polymer matrix. The adhesion between the reinforcing fibers and the polymer matrix in composites play an important role in the final mechanical properties of the material because the stress transfer between the matrix and fibers determines the reinforcement efficiency (Bledski et. al. 1999). Many chemical and physical methods have been utilized to overcome these problems. The chemical processes of mercerization (Weyenberg et. al. 2006), silane treatment (Bledski et. al. 1996), maliec acid and acetylation (Zafeiropoulos et. al. 2002) were developed to clean the fiber surface , modify the surface chemically, restrain moisture absorption and make the surface hydrophobic and remove the hydrophilic group of natural fiber. Also physical treatments such as plasma treatment (Marcandalli B et. al, 2007), corona treatment, and electron beam irradiation(Han et. al, 2008) have been conducted to create a hydrophobic group, cause cross linking, and increase the interfacial surface area. The present research aims to provide the necessary information about the major morphological, thermal and mechanical characteristics of electron beam irradiated Indian natural lignocellulosic fiber “THE COIR”.

2. Experimental

2.1 Material

Samples of coir fibers are collected from Centre for Coir Research Institute, Allepey , Kerala. Uniform fibers are separated out. They are combed and surface impurities are removed by gently rubbing, followed by prolonged washing in distilled water and drying. Electron beam irradiation of coir fibers are done at Microtron Center, Mangalore University (by lanthanum hexa fluorite source). The dose delivered to different samples is measured by keeping alanine dosimeter with sample during irradiation. The samples are subjected to various integral doses, which were accumulated in steps, where the irradiation doses are conducted at 10 and 20 kGy.

2.2 Scanning electron microscopy

A scanning electron microscope (Joel, JSM model)is used to observe the surface morphology and cross-sectional structures of raw and electron beam irradiated coir fibers. The acceleration voltage is 10kV. The samples are pre-coated with platinum using a sputter coater.

2.3 Single fibre tensile test

Tesile properties are measured with an Instron tensile testing machine (model 2710) according to ASTM D 3822-7, using a gauge length of 25mm and a strain rate of 5mm/min. Specimens are prepared using a paper cutter with dimension of 25mm * 25mm. the tensile strength is obtained for the average value of 10 test specimens. The tests are performed on conditioned specimens in the standard atmosphere of temperature 25 ^{0}C +/- 2^{o}C and 65% relative humidity.

2.4 Thermogravimetric analysis

Thermogravimetric analysis(Perkin Elmer, Diamond TG/DTA) is conducted to study the differences in thermal stability of coir fibers before and after electron beam irradiation at different doses. Nitrogen gas is used to purge the system and a heating rate of 20^{0}C is used.

3. Results and discussion

3.1 Surface Morphology by SEM

Like all other natural fibers, the cell wall of coir fiber has complex structure on surface. The fibre cell wall consists of the outer layer, which is the primary wall and the cuticle; the secondary wall consists of three layers S1, S2, and S3, which connect the secondary wall to the lumen (Fig.1). The S1 is next to the primary layer and is known to be resistant to swelling media such as water and acetic acid just like the primary wall. The fibrillar structure layout in this layer is nearly perpendicular to the fiber axis and stabilizes the fibre to lateral forces. The S2 layer, which constitutes the bulk of the secondary wall, swells easily breaking into fibrils, which follow a helical path and the fibrils are inclined at an angle to the fibres axis. It gives the greatest contribution to the mechanical strength of the fibre. (Nevell et. al. 1985). Electron beam irradiation gives effects on the surface properties of coir fibers significantly. Fig.2 shows SEM micrographs of the surface coir fibers irradiated with different intensities of EB. It is evident that the surface morphology of untreated coir fiber is different from that of irradiated fibers particularly in terms of their level of smoothness and roughness. It is shown that the surface of the virgin coir fiber is covered with wax, pectin, and P layer, which makes the surface smooth. The porous structures of irradiated coir fibers are revealed in the SEM images, and this is due to the leaching of waxes and pectin substances by electron beam irradiation. Fig. 2(b) shows the SEM image of 10 kGy irradiated fiber. It can be observed that almost all impurities have been removed from the fiber surface. At the high doses of 20 kGy the surface of ligno-cellulosic coir fiber looks uneven and flattened again and the inner part of the structure disappeared due to the degradation of S2.

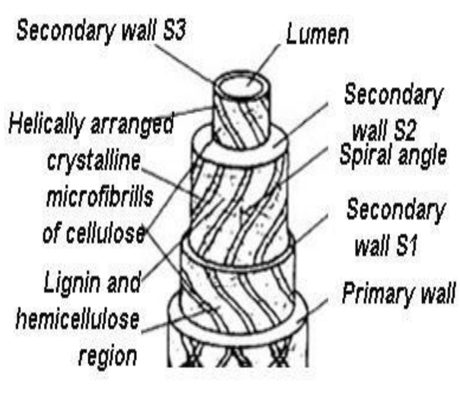
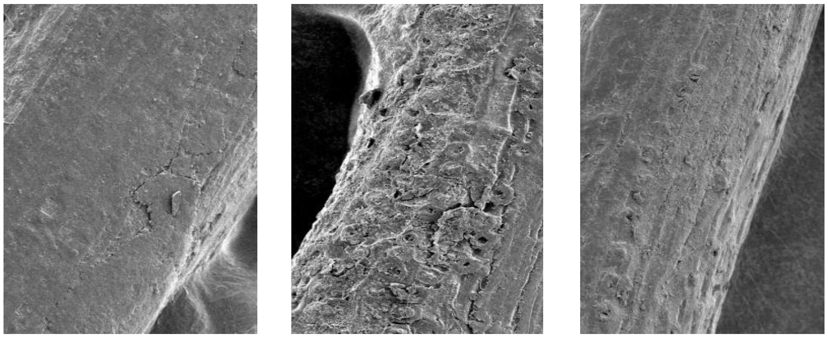
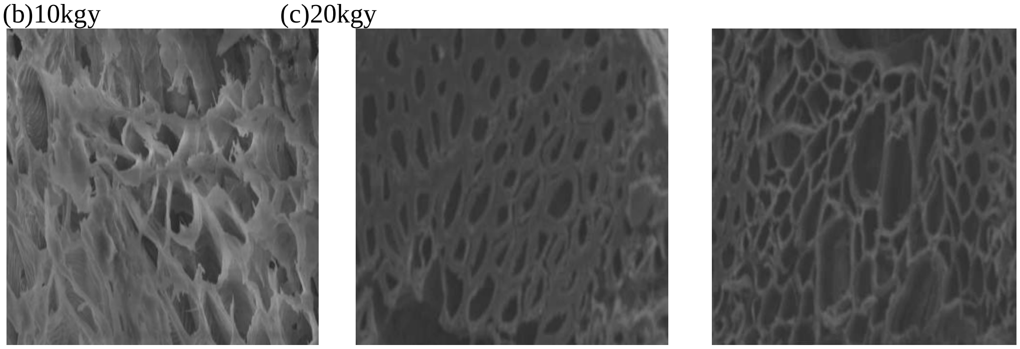


Fig 1. Structure of natural fiber



(a)0kgy (b)10kgy (c)20kgy

Fig 2. SEM images of the coir fibers irradiated by electron beam at different doses (a) 0kgy (b)10kgy (c)20kgy



(a) (b) (c)

Fig3. SEM images of the cross section of coir fibers irradiated by electron beam at different doses (a)0kgy (b)10kgy (c)20kgy

Fig.3 shows the SEM images of the cross section of coir fibers irradiated by electron beam at different doses. The untreated fiber has relatively larger pore diameter with the range of 10^4 nm to 10nm, compared to the EB irradiated fibers. Smaller pores are found to be introduced at 10 kgy irradiation. These phenomena can be explained that first, EB irradiation of 10kGy separates pectin, wax, and P layer from coir fiber, second, the level-off degree of polymerization in coir fiber results in a significant decrease in pore diameter in connection with remarkable enhancement of the micro pore on the surface. With increasing doses of EB such as 20kgy, the small pores decrease in coir fiber, because pores are generated, existing pores are enlarged, and neighboring pores are annexed. The decrease in small pores is also due to the removal of damaged S layer of coir fiber. This results in a decrease of tensile strength.

b. Mechanical Properties

The tensile strengths of coir fibers irradiated by electron beams with different doses are shown in Fig 4. The highest tensile strength is observed in the coir fibers irradiated with EB dose of 10 kGy, and it decreased as EB doses increased. With a high electron beam irradiation of 20 kGy, tensile strength decreased significantly. These results are in agreement with the results from the previous studies, which showed reductions in the α-cellulosic content, and crystallanity with electron beam irradiation, which are explained as the result of the dehydrogenation and destruction of the anhydroglucose unit (Driscoll et. al, 2009). However, it is interesting to note that the tensile strengths of the fibers maintained at the irradiation dose of 10 kGy, even though structural changes were observed after irradiation at this dose of electron beam (Han et. al. 2006)

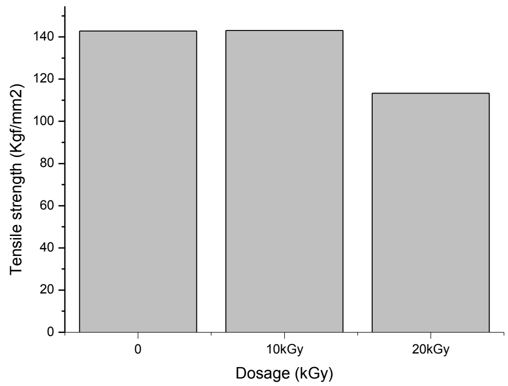
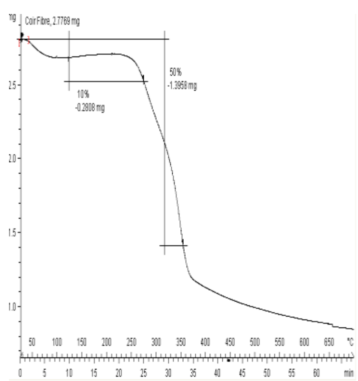


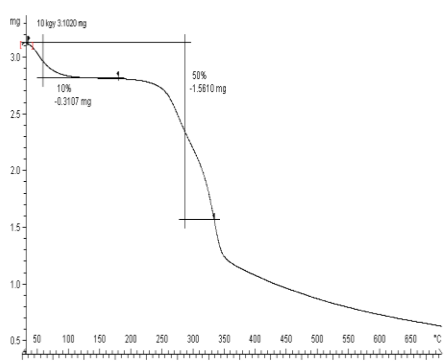
Fig 4. The tensile strength of coir fibers treated with different electron beam doses.

3.3. Thermo gravimetric Analysis

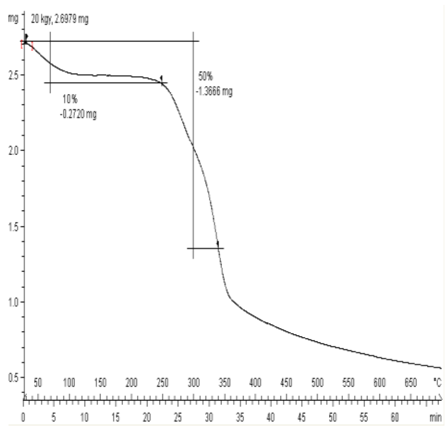
Thermo gravimetric analysis is used to monitor the compositional and structural effects electron beam irradiation on the thermal decomposition of the natural lingo cellulosic fibers. This is because the different compositions and molecular structure of cellulose behave differently when undergoing decomposition (Ouajai et. al, 2005). . The thermal stability of coir fibers irradiated with different electron beam doses in the range of 0-20kGy is investigated



a) TGA curve of untreated coir fiber



b) TGA curve of 10kGy irradiated coir fiber



b) TGA curve of 20kGy irradiated coir fiber

The results of thermo gravimetric analysis for untreated and electron beam irradiated coir fibers are shown in the figure. It can be seen that the decomposition profiles of the fibers are characterised by three peaks. The first one is attributed to the evaporation of water and occurs between room temperature and 150^0 C. The second step, which corresponds to the hemicelluloses degradation, starts at about 190^0 C; the third step occurs between 290 and 360^0 C, corresponding to thermal degradation of cellulose. Lignin presents a broad peak throughout the range, degrading between 280 and 500^0 C (Ezekiel et.al. 2010)

Table1 summarizes the maximum thermal decomposition temperatures of coir fibers irradiated with different electron beam intensities. As shown in Fig. 8, the two peaks of thermal decomposition are slightly shifted to lower temperatures with increasing of electron beam dose. It is also confirmed that the temperature of T2 (the decomposition temperature at 10% weight loss) and T3 (the decomposition temperature at 50% weight loss) decrease with increasing dose of electron beam, as shown in Table 1. The thermal decomposition temperature obviously shifted to a lower temperature, especially for the samples irradiated with electron beam doses 20 kGy. This is also consistent of the results of the surface morphology and tensile strength tests in which degradation was observed to have occurred in the S2 layer of coir fibers irradiated by electron beam doses of 15kGy and 20kGy.

Weight loss(%)	**T_1 (5%)**	**T_2(10%)**	**T_3(50%)**
Untreated	55.88	75.11	315.12
10kGy	54.33	71.88	310.32
20kGy	53.62	70.99	300.88

4. Conclusion

The effect of electron beam irradiation the surface morphological, mechanical and thermal properties of coir fibers are investigated. The surface morphology of the coir fibres are changed by electron beam irradiation. At low dosage of 10 kGy, the waxy, pectin and P layer on the surface of the coir fibre are found to be removed. The roughened surface resulting from electron beam irradiation of 10kGy may play a vital role for the adhesion between coir fibers and the polymer matrix of the composite. But increasing dose of irradiation to 20kGy causes the degradation of S2 layer. But the tensile strength is maintained up to the dose of 10kGy. The reduction of tensile strength and thermal decomposition temperature are observed clearly after the degradation of S2 layer during the exposure to the high dose of electron beam.

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