PAPER • **OPEN ACCESS**

Mechanical and electrical properties of heterogenous four-components combining bagasse, polyethylene, natural rubber and titanium dioxide

To cite this article: L C Sin *et al* 2019 *J. Phys.: Conf. Ser.* **1170** 012001

Mechanical and electrical properties of heterogenous four-components combining bagasse, polyethylene, natural rubber and titanium dioxide

L C Sin[1], W L Leaw[1], Aulia[2] and H Nur[1,3,*]

[1] Center for Sustainable Nanomaterials, Ibnu Sina Institute for Scientific and Industrial Research, Universiti Teknologi Malaysia, Johor Bahru, 81310, Malaysia
[2] Department of Electrical Engineering, Andalas University, Padang, West Sumatera, Indonesia
[3] Central Laboratory of Minerals and Advanced Materials, Faculty of Mathematics and Natural Sciences, State University of Malang, Indonesia

*Corresponding author: hadi@kimia.fs.utm.my

Abstract. Sisal fibre is a promising material to be used as a filler to enhance the polymer matrix composites due to its low cost, low density, high specific strength and modulus, no health risk, easy availability in some countries and renewability. In this study, sisal composites were manufactured from NaOH (1.0%) treated sisal fibres, natural rubber (NR), low-density polyethylene (LDPE) and titanium dioxide (TiO_2). The influence of fibre loading on the tensile strength as well as the electrical properties has been evaluated. The electrical performance was tested through the partial discharge (PD) characterization utilizing CIGRE Method II test. Our results showed that the addition of sisal fibre not only enhanced the mechanical properties of sisal composite but also lowered the PD activity of the composites. It is demonstrated that the composites containing 16.0 wt% sisal fibre, 46.0 wt% LDPE, 31.0 wt% NR and 7.0 wt% TiO_2 can be used as an electrically insulating high strength material.

1. Introduction

Over the past decade, there has been growing interest for the use of lignocellulosic fibre as reinforcing element within the matrix. Bio-composites are defined as composites materials that bind with natural fibre such as bagasse, kenaf and coconut husk with titanium dioxide, polymer and natural rubber. The utilization of natural fibre has many advantages, including the biodegradability, low cost, low density, eco-friendly and good mechanical properties. An investigation has been carried out using sugarcane fibre in order to improve the fibre-matrix interfacial bonding. The fibre matrix interfacial bond strength is expected to be very weak in the composites of cellulosic fibre due to the incompatibility of hydrophilic properties of cellulosic fibre with the polyethylene (PE) which is hydrophobic. Therefore, physical or chemical modification to the surface of lignocelluloses has been studied to alter the crystalline structure of the cellulose to obtain better adhesion between fibre and matrix. The properties of composites were found to be dependent on the fibre length, fibre distribution and fibre content. This experiment investigated the mechanical and electrical properties of sugarcane fibre reinforced composite of low-density polyethylene (LDPE), Standard Malaysian Rubber (SMR10) and titanium dioxide (TiO_2). With the proper combination, these materials can offer compact products which reduce maintenance and operating cost. The composites were optimized through the electrical and tensile performance. Some analysis was done in previous studied [1,2], but only limited papers were discussed about PD characteristic of LDPE/SMR10/fibre/TiO_2 blend.

2. Experimental

2.1. Sample preparation

The sample compositions are listed in Table 1. The fibre was added into LDPE/SMR10/TiO_2 at different compositions. Titanium dioxide was added to the elastomeric composite as a white colour agent and brightener. The samples were blended using a two-rollers mill for 15 minutes in the temperature of 140°C. The samples were moulded through compression-moulding at 120°C followed by cold compressions until room temperature.

Table 1. Compound formulation and coding of LDPE/SMR10/TiO_2/fibre blends.

	LDPE (wt%)	SMR10 (wt%)	TiO_2 (% of total weight)	Fibre (% of total weight)
A1	36	55	9	0
A2	35	52	9	4
A3	33	50	8	8
A4	32	48	8	12
A5	31	46	7	16
B1	40	60	0	0
B2	0	91	9	0
B3	0	100	0	0

2.2. Characterization

2.2.1. Partial discharge testing. To investigate the electrical performance, LDPE/SMR10/TiO_2/fibre samples were cut into a spherical form and analyzed using CIGRE Method II. The applied voltage was set at 7 kv for 1 hour of aging. The sampling rate is 125 kS/s. The capturing, saving and analyzing of PD data were monitored via LabView 8.5 software.

2.2.2. Tensile test. Tensile strength, elongation at break, Young's Modulus and stiffness were measured on a dumbbell-shaped sample. This test was carried out according to the ASTM D638 (Standart Test Methods for Tensile Properties). The tensile properties were measured at room temperature using Instron Universal Tester. The Lloyd mechanical testing machine (model 5567) with a crosshead speed 50 mm/min was used for the tensile strength test. Five specimens were tested, and the average values were reported.

2.2.3. FTIR. Perkin Elmer Spectrum2000 FTIR was used to obtain qualitative information about the functional group and chemical characteristics of the composites. For sample preparation, each sample was scratched into very tiny particles and mixed with dry potassium bromide powder (KBr). The mixture was then hard-pressed into the form of a thin disc. The thin disc was scanned for 16 times to reduce the noise to signal ratio. The appeared IR spectrum stretching frequencies that represent certain bonding of the fibre composites were determined in order to confirm the formation of fibre composites.

3. Results and discussions

Bagasse fibre was treated with 1.0 % NaOH (Figure 1) to modify the surface properties. This is to improve the interfacial adhesion between the hydrophobic matrix and the hydrophilic fibre. After compounded together with the SMR10, LDPE and TiO_2, all the samples were checked for the tensile properties. Mechanical performance is one of the major considerations for designing the insulation material [3]. The general mechanical performances of the composites determined by this test are tensile strength, elongation at break, Young's Modulus and stiffness. The results of the tensile test are summarized in Table 2. According to Table 2, the higher the Young's modulus values, the lower the values of elongation at break. One can notice, tensile strength did not increase linearly with the fibres fraction. Instead, the tensile strength almost constant from 0 wt % to 16 wt % fibre composition. From the data, we can deduce that the titanium dioxide (TiO_2) did not contribute to the reinforcement of the composites. Low stiff and Young's modulus materials help to avoid the stress shielding effect but also a high stiff and Young's modulus able to avoid spring back so that the implants offer a better handling ability during operations.

Figure 1. Bagasse fibre image: (a) Bagasse fibres drying process under sunlight, (b) Bagasse fibre soaking process in 1% NaOH solution.

Table 2. Tensile properties of LDPE/SMR10/TiO_2/fibre blends.

	Tensile strength (N/m^2)	Stiffness (N/m)	Elongation at break (mm)	Young's Modulus (Mpa)
LDPE/SMR10/TiO_2/Fibre-4%	2.5765	148564	71.326	1443.6
LDPE/SMR10/TiO_2/Fibre-8%	3.3704	157130	38.920	1510.5
LDPE/SMR10/TiO_2/Fibre-12%	2.8718	187168	20.353	1551.0
LDPE/SMR10/TiO_2/Fibre-16%	3.3163	277328	9.2404	2332.8
LDPE/SMR10/TiO_2	3.6655	387570	64.076	3776.6
LDPE/TiO_2	0.71123	460910	35.041	5505.6
SMR10	0.49952	355998	41.653	2474.5

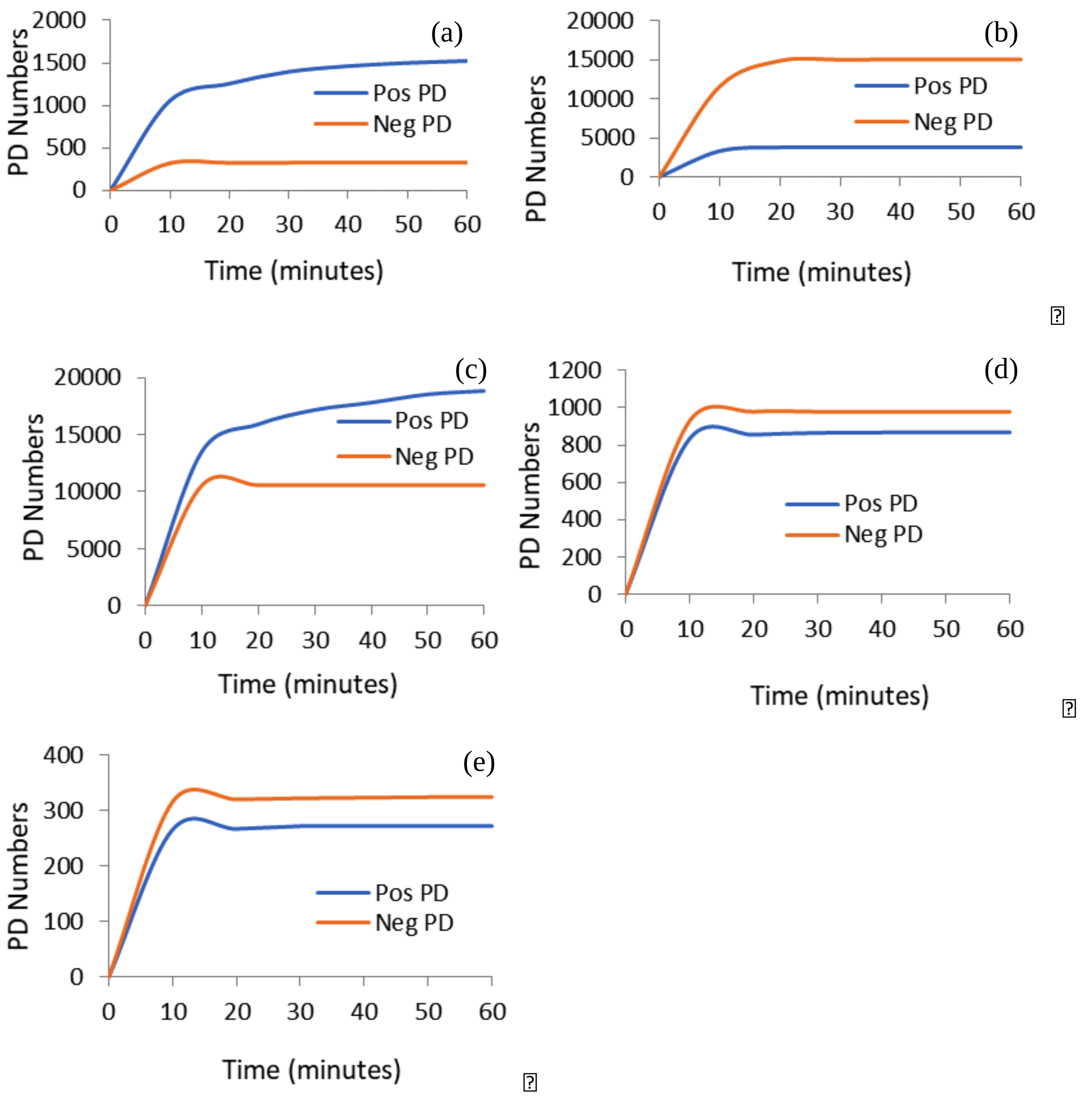

Figure 2. Time dependence of PD of positive (PD+) and negative (PD-) discharge numbers for: (a) SMR10/LDPE/TiO_2/Fibre-0%, (b)SMR10/LDPE/TiO_2/Fibre-4%, (c) SMR10/LDPE/TiO_2/Fibre-8%, (d) SMR10/LDPE/TiO_2/Fibre-12% and (e) SMR10/LDPE/TiO_2/Fibre-16%.

Figure 2 shows the PD numbers of SMR10/LDPE/TiO_2 blended with different weight percentages of fibre. The results are based on the CIGRE Method II [4]. The electrical properties for each composite are determined from the total PD numbers. As can be seen in Figure 3, the total PD numbers increase with the increasing of fibre content, but the PD numbers drop very significantly when 12.0 wt% and 16.0 wt% of fibre were loaded into the composite. It is clearly found that the composites with 16.0 wt% of fibre resulted in the general improvement of the PD characteristics. The presence of fibre tends to fill the void within composite. Therefore, it increases the insulation region and decrease the PD activity.

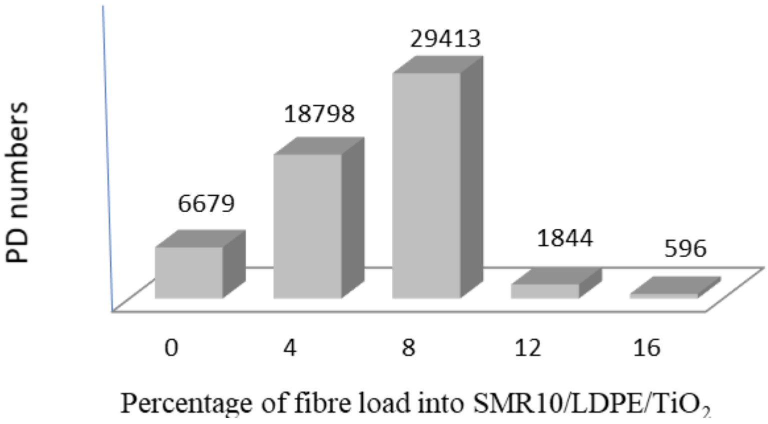

Figure 3. The comparison of total PD Numbers for all LDPE/ SMR10/ TiO_2/fibre blends formulation

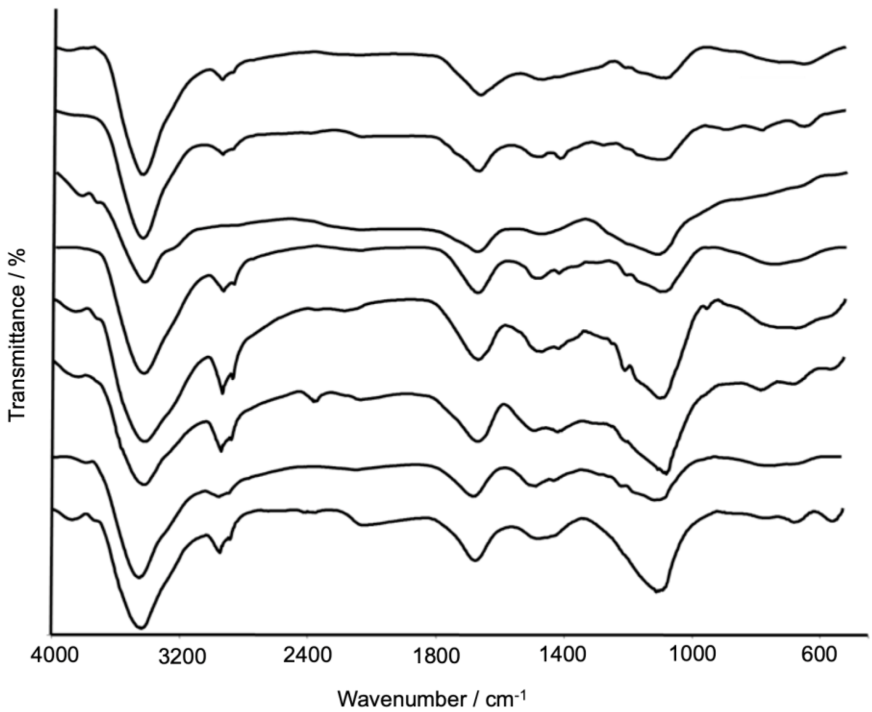

Figure 4. The FTIR spectra of (a) SMR10, (b) SMR10/LDPE, (c) SMR10 /TiO2, (d) SMR10/LDPE/TiO_2/Fibre-16%, (e) SMR10/LDPE/TiO2/Fibre-12%, (f) SMR10/LDPE /TiO2/Fibre-8%; (g) SMR10/LDPE/TiO_2/Fibre-4% and (h) SMR10/LDPE/TiO2/Fibre-0%.

Figure 4 shows the FTIR spectrum of all composites. The absorption at wavenumber from 3400 cm^{-1} to 3450 cm^{-1} was detected and belongs to the functional group of –OH. This may be due to the presence of cellulose in sugarcane fiber. Each glucosidic ring in cellulose contains two hydroxyl groups and one methyl hydroxyl group. Thus, the –OH group absorption should be prominent in the IR spectrum. In addition, there was also absorption for composite A, B, C and H, even no sugarcane fiber was added for these composites. This is properly due to the absorb water moisture from the air. Other than –OH group, methyl group was also absorbed in the spectrum. At 2900 – 2950 cm^{-1}, C–H stretching functional group was found with low intense. This may due to the structure of polyisoprene, whereas for the spectra C, C-H stretching was not detected, this properly due to the effect of titanium dioxide. In addition, there was absorption at 1620 –1650 cm^{-1}, this indicates the present of C=C bond in the composites. The exits of C=C bond is due to the rubber. The structure of polypropene consist of double bond, therefore existed of C=C bond in every composite. At 1020-1060 cm^{-1}, we can notice the present of C–O bond in all spectra. This is assigned to the effect of hydrogen bonding on the skeletal vibrations, which involve stretching of the CO bond [2].

Titanium dioxide is usually added to elastomeric goods as a white color agent and as a brightener. The FTIR spectra of titanium dioxide must have a broad peak between 800 – 470 cm^{-1}. From the spectra, it shows that the samples treated or untreated with TiO_2 does not have any effect on reflectance in the IR region. This means that titanium dioxide does not help to absorb IR rays. It may due to the substitutes of titanium dioxide for composites, removing the effect of porous composite structures. The filling or embedded TiO_2 inside the matrix, this avoid the absorb IR rays of TiO_2.

4. Conclusion
In conclusion, the agricultural waste such as bagasse can be used as component of polymer matrix composite. The insulating performance of LDPE/SMR10/TiO_2 /fibre blends under electrical stress and mechanical strain were investigated by analyzing PD characteristics and tensile properties. Generally, the composite filled with 16 wt% of bagasse fibre tend to suppress PD activities and has the potential to be used as an electrical insulator. It is showed that the fibre able to control the PD activities of the composite materials. Besides this, 16 wt% of sugarcane fibre has the strongest tensile strength and make it harder to break down under strain. By considering the PD characteristics and tensile properties, 16 wt% of bagasse fibre loaded into SMR10/LDPE/TiO_2 is good and may considered to be applied as electrical insulating material in the future.

References
[1] Piah M A M, Darus A and Hassan A 2003 Leakage current and surface discharge phenomena: effect on tracking and morphological properties of LLDPE-natural rubber compounds. Properties and Applications of Dielectric Materials *Proceedings of the 7th International Conference on Properties and Applications of Dielectric Materials* (New York: IEEE)
[2] Chughtai A R, Smith D M, Kumosa L S and Kumosa M 2004 *IEEE Trans. Dielectr. Electr. Insul.* **11** (4) 585
[3] Mackevich J and Shah M 1997 *IEEE Electr. Insul. Mag.* 1997 **13** (3) 5
[4] Del Casale M D L, Schifani R, Testa L, Montanari G, Motori A, Patuelli F, Guastavino F and Deorsola F A 2007 *IEEE Int. Conf. Solid Dielectr.* DOI**:** 10.1109/ICSD.2007.4290822