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Tensile and Physical Properties of Linear Low Density Polyethylene-natural Rubber Composite: Comparison between Size and Filler Types

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ABSTRACT

Linear Low Density Polyethylene-Natural Rubber (LLDPE-NR) composites in the ratio of 70:20 were made with different loadings of nanosilica and micro-scale Palm Oil Fuel Ash (POFA). Linear Low Density Polyethylene grafted with maleic anhydride (LLDPE-g-MAH) of 10 wt% was added as a compatibiliser. The composites were produced by using two-roll mill machine. The tensile properties of the composites were determined by carrying out tensile test. From the test, it was found that the tensile strength of LLDPE-NR decreased with increasing weight percentages of POFA in the composition. Tensile strength of LLDPE-NR increased with increasing nanosilica content of the composition. The water absorption test was done on all samples, and it was found that water absorption of LLDPE-NR nanocomposites decreased with increasing nanosilica content. However, water absorption of LLDPE-NR microcomposites increased with increasing POFA content.

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1. INTRODUCTION

Electrical insulation plays an important role to protect high-voltage (HV) system from operation failure [1]. Several causes, such as electrical treeing and voids, can affect the functionality of insulators [2]. Thus, it is important for electrical insulating materials to have good tensile properties in addition to high dielectric strength and low dielectric constant [1].

Linear Low-Density Polyethylene (LLDPE) is widely used as electrical insulating materials in power cables [3]. The electrical insulating properties of LLDPE can be increased by the addition of nano-sized fillers or nanofillers [4, 5]. Nanofillers have larger surface area compared to micro-sized fillers with the same phr/volume. Most commonly used nanofillers are montmorillonite (MMT) [6] which can improve electrical insulating and tensile properties, carbon nanotube (CNT) and grapheme [7]. The tensile strength of LLDPE nanocomposites increased with the content of nano-sized silica (or nanosilica) increased from 0 phr to 8 phr [8]. Increasing the content of MMT from 0 phr to 10 phr can also improve the tensile strength of LLDPE nanocomposites from 9.9±0.32 MPa to 13.8±0.52 MPa [9]. The addition of CNT from 0 phr to 1 phr increased the tensile strength of LLDPE from around 10 MPa to more than 35 MPa [10].

Natural rubber (NR) is native to Malaysia since the 1870s [11]. It is made from a renewable source to make heavy-duty tires, gloves, etc. [12]. NR-based electrical insulation was the only polymeric material used as a wire and cable up to the 1930s, when the first suitable synthetics became available [13]. The dielectric strength of NR ranges from 100 kV/mm to 215 kV/mm [14]. Rubber, with a low modulus of elasticity, can sustain a deformation of as much as 1000 percent and will return to its original dimensions after such deformation [15].

Silica is one of the reinforcing fillers used in natural rubber [16]. The mechanical properties of composites can be increased by adding nanosilica. The tensile strength of polyvinyl chloride (PVC) increases from

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4.18 MPa to 6.83 MPa as higher loading of nanosilica from 0wt% to 5.0wt% is added to the composite. At 5.0wt% filler loading of nanosilica, the tensile strength of PVC reaches its maximum value of 6.83 MPa, which is 63.37% higher than base PVC [17].

Natural fibers have been used as reinforcement for polymer composites due to their availability and desired properties [18] including good electrical resistance [19], and also due to their environmental-friendly properties [20, 21]. Ash, such as rice husk ash, coal waste ash, and palm oil ash, has been used to increase the mechanical properties of cement [22-24]. Palm oil fuel ash (POFA) can increase the tensile properties of a material. In a study done by Ooi et al. [25], the tensile strength and elongation at break of NR compound improved by 16% and 7.4% respectively, up to an optimum level of 1 phr.

In this study, LLDPE and NR had been combined to be the composite base (LLDPE-NR). Currently, there are almost no study done on LLDPE-NR composite which uses POFA and nanosilica as fillers. Previous research on LLDPE-NR that used nanosilica as filler only studied the electrical properties [5] and not its mechanical properties. Thus, the purpose of this paper is to study the effect of POFA and nanosilica fillers on the tensile and physical properties of LLDPE-NR composite.

2. MATERIALS AND METHODOLOGY

2. 1. Materials Linear Low Density Polyethylene (LLDPE) and LLDPE-g-MAH were used in this study. The other material used was Natural Rubber SMR 20 (NR), obtained from Sabah Rubber Industry Board (LIGS). Fillers used were POFA, which were obtained from Faculty of Engineering, University Malaysia Sabah and sieved to achieve the finest size as below 300 µm, and 200 nm silicon dioxide (nanosilica) from Sigma-Aldrich.

2. 2. Sample Preparation The samples were prepared using two-roll mill. The NR was masticated in the two-roll mill, and then other materials were combined according to the formulation in Table 1 using the two-roll mill. After that, the products obtained from the two-roll mill were moulded in a hot compression moulding machine into slabs of 1mm thickness.

2. 3. Tensile Test The tensile test was done on the samples cut into the shape of dumbbell with thickness, width, and length of 1mm, 19mm and 115mm, respectively, according to ASTM D638. The tensile tests were carried on a Universal Testing Machine, GOTECH AI-7000M, equipped with load capacity of 10kN at pulling jaw speed of 50mm/min. These tests rendered the values of tensile strength, elongation at break and tensile modulus of the samples.

TABLE 1. Blending formulation of LLDPE-NR composites with respective fillers

Sample	LLDPE	NR	LLDPE-g-MAH	POFA*	Nanosilica*
LN	70	20	10	-null-	-null-
LNP2	70	20	10	2	-null-
LNP4	70	20	10	4	-null-
LNP6	70	20	10	6	-null-
LND2	70	20	10	-null-	2
LND4	70	20	10	-null-	4
LND6	70	20	10	-null-	6

*parts per hundred (phr) of LLDPE-NR weight

2. 5. Water Absorption Test Method The standard used for water absorption test was ASTM D570. The initial weight of the samples was taken as W1. Then, the samples were immersed in distilled water in separate containers for 24 hours at room temperature. After that, the samples were taken out and any water on the surfaces was wiped off. The samples were weighted, and labelled as W2. The formula for calculating water absorption (%) of the samples was:

$$\text{Water absorption } (\%) = \frac{W2 - W1}{W1} \times 100\% \quad (1)$$

3. RESULTS AND DISCUSSIONS

3. 1. Mechanical Properties Table 2 shows the tensile strength of all samples. The tensile strength of LLDPE-NR composite (14.3 MPa) decreased with the addition of 2 phr of nanosilica to 11.7 MPa. This may be due to the poor interaction of nanosilica filler with the LLDPE-NR composite for small volume fractions [26]. However, the tensile strength increased as more nanosilica was added up to 6 phr. A similar trend can be seen in the study by Rong et al. [27], where the incorporation of nanosilica decreased the tensile strength of polypropylene (PP) in the lower loading region up to 2.0 vol% particle fraction, but then the tensile strength increased when the particle fraction reached 4.7 vol%. Lay et al. [28] also found that low filler loading of nanosilica at 1 phr decreased the tensile strength of NR composite, but higher filler loading up to 3 phr lead to higher tensile strength. In a study done by Kontou & Niaounakis [8], the tensile strength of LLDPE increased up to 4 wt% of nanosilica. They stated that the nanoparticles had a mobility to act as temporary crosslinks between the polymer chains, providing localised regions of enhanced strength that would resist the growth of cracks or cavities in the LLDPE.

TABLE 2. Results of tensile tests for all samples

Sample	Tensile Strength (MPa)	Elongation at Break (%)	Tensile Modulus (MPa)
LN	14.3	274.8	302.9
LNP2	11.9	249.1	264.2
LNP4	11.2	227.6	281.0
LNP6	10.0	221.0	388.6
LND2	11.7	238.4	278.7
LND4	12.4	251.2	351.4
LND6	14.4	295.9	432.4

The tensile strength of LLDPE-NR composite decreased as POFA loading was added up to 6 phr. In a study by Ooi et al. [25], POFA had a reinforcing effect on NR for a very low loading from 0.5 phr to 1 phr, then the tensile strength dropped at higher filler loadings. Ooi et al. [25] stated that the POFA particles could be fully wetted by the NR matrix, especially at a low POFA loading. The rubber chain would penetrate into the pores of POFA and become part of the filler (bound rubber). At higher filler loadings, however, POFA particles had the tendency to position themselves in agglomeration [25, 29], especially in humid conditions [29], which greatly affected the tensile strength and elongation at break. Due to agglomeration, Ooi et al. [25] stated that the filler could not be fully wetted by the NR. In this test, the ratio of NR to LLDPE was only 20:70. Thus, it was believed that the tensile strength of LLDPE-NR composites with POFA decreased with increased loading because of the agglomeration of POFA at higher filler loadings. In a study done by Ghanbari et al. [30], nanocomposites had larger yield stress compared to microcomposites, meaning that nano-sized fillers had greater influence on the interactions between particles.

It was shown that LLDPE-NR composite with filler loading of nanosilica at 6 phr, LND6, had the highest tensile strength (14.4 MPa), followed by LLDPE-NR composite with no filler, LN (14.3 MPa). Sample LNP6 with POFA loading of 6 phr had the lowest tensile strength of 10.0 MPa.

The elongation at break (%) for all samples is shown in Table 2. The elongation at break of LLDPE-NR composite decreased from 274.8 % to 238.4 % at nanosilica loading of 2 phr. However, the addition of nanosilica up to 6 phr increased the elongation at break of LLDPE-NR composite to 295.9 %. In a study done by Rajkumar et al. [31], elongation at break (%) of Acrylonitrile Butadiene Rubber (NBR) increased with nanosilica loading. Rajkumar et al. reasoned that the elongation at break increased with loading because of the layer of silicate structure restricted the tearing of polymer molecules under stretching during tensile test [31]. In other words; the elasticity of the LLDPE-NR composite increased with loading.

As the POFA filler loading increased from 2 phr to 6 phr in the LLDPE-NR composites, the elongation at break (%) decreased to 227.6. Ibrahim et al. [29] reported similar findings, where the elongation at break (%) of unsaturated polyester (UP) decreased with higher loading of POFA. Ibrahim et al. related their results with the reduction of volume of matrix as more POFA was added to the UP, where the elastic properties were only obtained from the UP matrix [29]. In other words, the elasticity of LLDPE-NR composite with POFA was only obtained from the LLDPE-NR matrix. The higher loading of POFA reduced the volume of matrix of LLDPE-NR composite, which led to the decreasing trend of elongation at break (%).

Table 2 shows the tensile modulus (MPa) of all samples. The addition of POFA at 2 phr decreased the tensile modulus of LLDPE-NR composite. The tensile modulus increased from 264.2 MPa to 388.6 MPa with increased loading. In a study done by Ismail et al. [32], the tensile modulus of PP/recycled NR composites increased as the POFA loading increased up to 10 phr. They reasoned that the addition of POFA caused a reduction in chain mobility, while increasing the rigidity of composites at the same time [32]. Behzad et al. [33] reported that the tensile modulus of high density polyethylene (HDPE) increased with wood flour content. Sahari et al. [34] also reported that the higher the content of bio-filler, the higher the tensile modulus of plasticised sugar palm starch. Thus, the addition of POFA in LLDPE-NR composite increased the rigidity, or tensile modulus, of the composites with increased filler loading.

The addition of nanosilica at 2 phr decreased the tensile modulus of LLDPE-NR composite. However, the tensile modulus increased from 278.6 MPa to 432.4 MPa as more nanosilica filler was added into the composite. In another study by Makmud et al. [35], a similar trend was observed where the tensile modulus of LLDPE-NR composite decreased with nano-scale MMT at 2 phr, then increased with MMT at 4 phr. According to Fu et al. [36], the addition of rigid particles to a polymer matrix would improve its modulus since the rigidity of inorganic fillers are much higher than that of organic polymers. This was also supported by Lay et al. [28] which stated that the modulus would increase due to the embedding of nanosilica particles in polymer matrix. Thus, the addition of inorganic fillers (nanosilica) in the LLDPE-NR composited increased the rigidity, or tensile modulus, of composite with increased loading.

3. 2. Surface Analysis The SEM images of LN (Figure 1) and LNP6 (Figure 2) are shown below. In Figure 1, it is apparent that the NR has blended well in the LLDPE matrix, thus explaining the high tensile strength, high tensile modulus and high elongation at break compared to LLDPE-NR composites with fillers.

Meanwhile, in Figure 2, the areas marked in white circles show the agglomeration of POFA within the composites. There are also voids within the samples. The agglomerated POFA caused the voids to happen when the POFA was pulled out during the tensile test. Similar findings have been by Ooi et al. [25], where at higher filler loadings, agglomeration of POFA had caused the detachment of filler. This strengthened the claim that agglomeration of POFA due to higher filler loading caused lower tensile strength of LLDPE-NR composite.

3. 3. Physical Properties Table 3 shows the water absorption value (%) of all samples after being soaked in distilled water for 24 hours. The water absorption value of LLDPE-NR composites increased with POFA loading as it is evident in Table 3. Sample LNP6 with POFA loading of 6 phr had the highest water absorption value.

Meanwhile, water absorption value (%) decreased significantly with nanosilica fillers. According to Zhao et al. [37], the percentage of water absorption in epoxy resin decreased with increasing nano-alumina particle content.

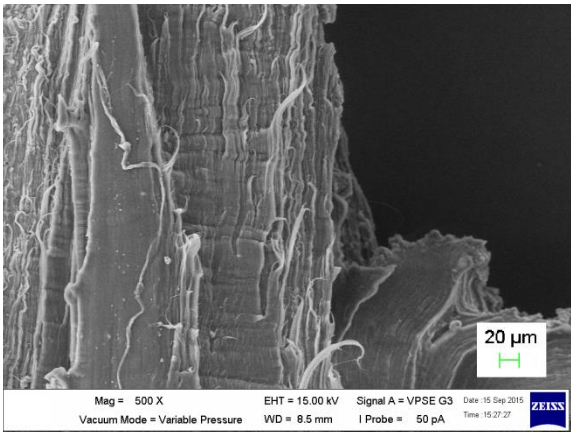

Figure 1. SEM image of neat LLDPE-NR, LN

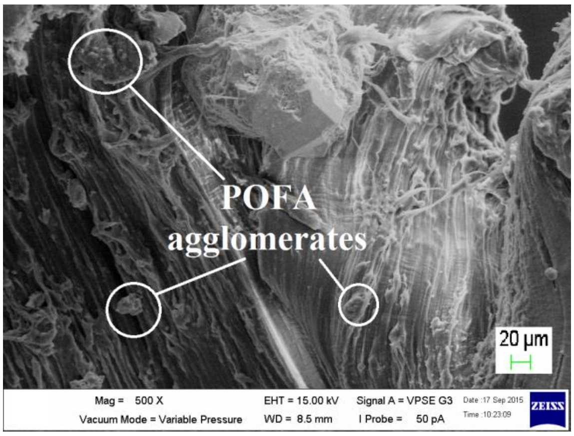

Figure 2. SEM image of LLDPE-NR with POFA at 6phr, LNP6

TABLE 3. Water absorption value for all samples

Sample	Water absorption (%)
LN	0.68
LNP2	1.10
LNP4	1.15
LNP6	1.20
LND2	0.35
LND4	0.44
LND6	0.38

They attributed this to the presence of nanoparticles which could increase the path length for moisture absorption. In this study, when increasing the loading of nanosilica in the LLDPE-NR composite, the nanosilica increased the path length for moisture absorption of the composite, which resulted in decreasing water absorption value (%) of LLDPE-NR composite. Although water absorption increased with nanosilica loading, but it was still lower than unfilled LLDPE-NR composite. Due to their small size, the surface interaction between nanosilica particles became magnified, hence agglomeration came into effect [38]. Lau reported similar findings, where increasing the content of nanosilica would increase the water absorption value of polyethylene attributed to the agglomeration which would inevitably penetrate into the nanosilica structure [39].

According to Nikolajevic [40], the increase of the amount of water absorbed by the insulation would increase the degradations of electrical characteristics of insulation. In other words, the lesser the amount of water absorbed by the insulation, the lesser the degradations of electrical characteristics of insulation, making it a better electrical insulation material. From this test, LND2 has the lowest water absorption value.

4. CONCLUSION

Nanosilica filler improved the tensile properties of LLDPE-NR composite up to 6 phr. The best loading of nanosilica was 6 phr, where it increased the tensile strength, elongation and tensile modulus of LLDPE-NR composite by 0.5%, 7.7% and 42.7%, respectively. Meanwhile, the tensile properties of LLDPE-NR decreased with increasing POFA content. SEM image showed the agglomerated POFA on LLDPE-NR surface, which affected the tensile strength of LLDPE-NR. However, tensile modulus of LLDPE-NR was improved by 1.3 % with POFA content of 6 phr. Physical properties of LLDPE-NR improved as the water absorption value decreased significantly when added with nanosilica compared to neat LLDPE-NR. Meanwhile, the water absorption value increased with POFA loading.

5. ACKNOWLEDGEMENT

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6. REFERENCES

1. Naidu, M.S. and Kamaraju, V., "High voltage engineering", Tata McGraw-Hill Education, (2013).
2. Teyssedre, G. and Laurent, C., "Advances in high-field insulating polymeric materials over the past 50 years", ***IEEE Electrical Insulation Magazine***, Vol. 29, No. 5, (2013), 26-36.
3. Chen, G., Zhang, C. and Stevens, G., "Space charge in lldpe loaded with nanoparticles", in 2007 Annual Report-Conference on Electrical Insulation and Dielectric Phenomena, IEEE., (2007), 275-278.
4. Makmud, M.Z.H.B., Sayuti, A., Arief, Y.Z. and Wahit, M.U., "Insulating performance of lldpe/natural rubber blends by studying partial discharge characteristics and tensile properties", in Electrical Engineering and Informatics (ICEEI), IEEE., (2011), 1-4.
5. Arief, Y.Z., Izzati, W.A., Adzis, Z., Muhamad, N.A., Ghazali, M.N.M., Sharip, M.R.M. and Makmud, M.Z.H., "Effects of nanosilica and nanotitania on partial discharge characteristics of natural rubber-lldpe blends as high voltage insulation material", in Electrical Insulating Materials (ISEIM), IEEE., (2014), 299-302.
6. Tanaka, T., Montanari, G. and Mulhaupt, R., "Polymer nanocomposites as dielectrics and electrical insulation-perspectives for processing technologies, material characterization and future applications", ***IEEE Transactions on Dielectrics and Electrical Insulation***, Vol. 11, No. 5, (2004), 763-784.
7. Matos, C.F., Galembeck, F. and Zarbin, A.J., "Multifunctional materials based on iron/iron oxide-filled carbon nanotubes/natural rubber composites", ***Carbon***, Vol. 50, No. 12, (2012), 4685-4695.
8. Kontou, E. and Niaounakis, M., "Thermo-mechanical properties of lldpe/sio 2 nanocomposites", ***Polymer***, Vol. 47, No. 4, (2006), 1267-1280.
9. Durmus, A., Kaşgöz, A. and Macosko, C.W., "Mechanical properties of linear low-density polyethylene (lldpe)/clay nanocomposites: Estimation of aspect ratio and İnterfacial strength by composite models", ***Journal of Macromolecular Science®, Part B: Physics***, Vol. 47, No. 3, (2008), 608-619.
10. Jin-hua, T., Guo-qin, L., Huang, C. and Lin-jian, S., "Mechanical properties and thermal behaviour of lldpe/mwnts nanocomposites", ***Materials Research***, Vol. 15, No. 6, (2012), 1050-1056.
11. Ho, C.C., "The production of natural rubber from hevea brasiliensis latex : Colloidal properties , preservation , purification and processing", ***Natural Rubber Materials***, (2014), 73-106.
12. Rojruthai, P., "Natural rubber: Biosynthesis, structure, properties and application", ***Natural Rubber Materials: Volume 1: Blends and IPNs***, Vol. 7, (2013), 28-35.
13. Zuidema, C., Kegerise, W., Fleming, R., Welker, M. and Boggs, S., "A short history of rubber cables", ***IEEE Electrical Insulation Magazine***, Vol. 4, No. 27, (2011), 45-50.
14. Lide, D.R., "Crc handbook of chemistry and physics, CRC press, Vol. 85, (2004).
15. Schaefer, R.J., "Mechanical properties of rubber", ***Harris' Shock and Vibration Handbook, Sixth edition, A. Piersol, T. Paez (Eds), McGraw-Hill Companies Inc***, (2010), 33.31-33.18.
16. Chandran, V., Raj, T.M., Lakshmanan, T. and Kumar, M.S., "Influence of different fillers on natural rubber composites to assess mechanical performance", ***Nternational Journal of Engineering***, Vol. 49, No. 6, (2011), 322-332.
17. Sugumaran, C.P., "Diagnosis on mechanical and electrical properties of cable insulation pvc with nanofiller", in Condition Assessment Techniques in Electrical Systems (CATCON), IEEE., (2013), 223-226.
18. Fiore, V., Scalici, T. and Valenza, A., "Characterization of a new natural fiber from arundo donax l. As potential reinforcement of polymer composites", ***Carbohydrate Polymers***, Vol. 106, (2014), 77-83.
19. Shinoj, S., Visvanathan, R., Panigrahi, S. and Kochubabu, M., "Oil palm fiber (opf) and its composites: A review", ***Industrial Crops and Products***, Vol. 33, No. 1, (2011), 7-22.
20. Sahari, J. and Sapuan, S., "Natural fibre reinforced biodegradable polymer composites", ***Reviews on Advanced Materials Scienc***e Vol. 30, No. 2, (2011), 166-174.
21. Sahari, J., Sapuan, S., Ismarrubie, Z. and Rahman, M., "Physical and chemical properties of different morphological parts of sugar palm fibres", ***Fibres and Textiles in Eastern Europe***, Vol. 91, No. 2, (2012), 21-24.
22. Shafabakhsh, G. and Ahmadi, S., "Evaluation of coal waste ash and rice husk ash on properties of pervious concrete pavement", ***International Journal of Engineering-Transactions B: Applications***, Vol. 29, No. 2, (2016), 192-200.
23. Mousavi, S., "Performance of non-fired green brick containing rice husk as sustainable building material", (2016).
24. Salih, M.A., Ali, A.A.A. and Farzadnia, N., "Characterization of mechanical and microstructural properties of palm oil fuel ash geopolymer cement paste", ***Construction and Building Materials***, Vol. 65, (2014), 592-603.
25. Ooi, Z.X., Ismail, H. and Bakar, A.A., "Synergistic effect of oil palm ash filled natural rubber compound at low filler loading", ***Polymer Testing***, Vol. 32, No. 1, (2013), 38-44.
26. Jordan, J., Jacob, K.I., Tannenbaum, R., Sharaf, M.A. and Jasiuk, I., "Experimental trends in polymer nanocomposites—a review", ***Materials Science and Engineering: A***, Vol. 393, No. 1, (2005), 1-11.
27. Rong, M.Z., Zhang, M.Q., Zheng, Y.X., Zeng, H.M., Walter, R. and Friedrich, K., "Structure–property relationships of irradiation grafted nano-inorganic particle filled polypropylene composites", ***Polymer***, Vol. 42, No. 1, (2001), 167-183.
28. Lay, M., Azura, A.R., Othman, N., Tezuka, Y. and Pen, C., "Effect of nanosilica fillers on the cure characteristics and mechanical properties of natural rubber composites", in Advanced Materials Research, Trans Tech Publ. Vol. 626, (2013), 818-822.
29. SM, S. and AA, F., "Mechanical and thermal properties of composites from unsaturated polyester filled with oil palm ash", ***Journal of Mechanical Engineering and Sciences (JMES)***, Vol. 2, No. June 2, (2012), 181-186.
30. Ghanbari, A., Alizadeh, M., Rad, R.Y. and Ghasemi, E., "Effects of micro and nano sized sic powder on the rheological properties of al based feedstocks for low pressure injection molding", ***International Journal of Engineering-Transactions A: Basics***, Vol. 28, No. 10, (2015), 1493.
31. Rajkumar, K., Ranjan, P., Thavamani, P., Jeyanthi, P. and Pazhanisamy, P., "Dispersion studies of nanosilica in nbr based polymer nanocomposite", (2013).
32. Ismail, H., Khoon, T.B., Hayeemasae, N. and Husseinsyah, S., "Effect of oil palm ash on the properties of

polypropylene/recycled natural rubber gloves/oil palm ash composites", ***BioResources***, Vol. 10, No. 1, (2015), 1495-1505.

33. Behzad, M., Tajvidi, M., Ehrahimi, G. and Falk, R.H., "Dynamic mechanical analysis of compatibilizer effect on the mechanical properties of wood flour-high density polyethylene composites", ***International Journal of Engineering Transaction B: Application***, Vol. 17, (2004), 95-104.
34. Sahari, J., Sapuan, S., Zainudin, E. and Maleque, M.A., "Mechanical and thermal properties of environmentally friendly composites derived from sugar palm tree", ***Materials & Design***, Vol. 49, (2013), 285-289.
35. Makmud, M.Z.H.B., Arief, Y.Z. and Wahit, M.U., "Partial discharge characteristics with morphological analysis and tensile properties of linear low-density polyethylene-natural rubber blends", ***International Journal on Electrical Engineering and Informatics***, Vol. 3, No. 4, (2011), 431-440.
36. Fu, S.-Y., Feng, X.-Q., Lauke, B. and Mai, Y.-W., "Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate–polymer composites", ***Composites Part B: Engineering***, Vol. 39, No. 6, (2008), 933-961.
37. Zhao, H. and Li, R.K., "Effect of water absorption on the mechanical and dielectric properties of nano-alumina filled epoxy nanocomposites", ***Composites Part A: Applied Science and Manufacturing***, Vol. 39, No. 4, (2008), 602-611.
38. Nelson, J.K. and Fothergill, J.C., "Internal charge behaviour of nanocomposites", ***Nanotechnology***, Vol. 15, No. 5, (2004), 586-592.
39. Lau, K.Y., "Structure and electrical properties of silica-based polyethylene nanocomposites", University of Southampton, (2013),
40. Nikolajevic, S., "The behavior of water in xlpe and epr cables and its influence on the electric characteristics of insulation", ***IEEE transactions on Power Delivery***, Vol. 14, No. 1, (1999), 39-45.

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Natural Rubber

چکیده

مواد مرکب (نانوکامپوزیت) پلی اتیلن خطی کم چگالی-لاستیک طبیعی (LLDPE-NR) با نسبت ۲۰:۷۰ و بارهای مختلف نانو سیلیکا و خاکستر روغن نخل (POFA) در مقیاس میکرو ساخته شده است. پلی اتیلن خطی کم چگالی پیوند داده شده با ۱۰ درصد وزنی انیدرید مالئیک (LLDPE-G-MAH) به عنوان یک سازگرکننده به کامپوزیت اضافه شده است. کامپوزیت با استفاده از آسیاب دو غلتکی تولید شد. خواص کششی کامپوزیت تعیین، و مشخص شد که استحکام کششی LLDPE-NR با افزایش درصد POFA در ترکیب کاهش یافته است. استحکام کششی LLDPE-NR با افزایش مقدار نانوسیلیکا در ترکیب افزایش یافته است. آزمون جذب آب برای تمام آزمونه‌ها انجام شد و مشخص شد که جذب آب از نانوکامپوزیتهای LLDPE-NR با افزایش مقدار نانوسیلیکا کاهش می‌یابد. با این حال، جذب آب ریزکامپوزیت‌های LLDPE-NR با افزایش مقدار POFA افزایش یافته است.

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