IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

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To cite this article: Aulia *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **602** 012010

IOP Conf. Series: Materials Science and Engineering **602** (2019) 012010 doi:10.1088/1757-899X/602/1/012010

The tensile properties of alumina and silica bionanocomposite material for high voltage insulation

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Abstract. In the present study, two sets of bionanopolymeric alumina and bionanopolymeric silica content samples were prepared. To each sample, the nano alumina particles with a weight percentage of 1.5%, 3%, 4.5% and 6% were added. To investigate the effect of nanoalumina and nanosilica filler to the mechanical properties of these nanocomposites materials, the tensile test had been carried out. The results show that the tensile strength of two groups of sampless decrease constantly with the increasing of weight percentage of nanofillers.

1. Introduction

Electrical insulation material that is widely used today is polymer-based insulation because it has some advantages compared to other materials [1] such as having water repellent properties, thermal properties, and good dielectric properties which are characterized by high penetrating stress levels. Also, polymer materials are also lightweight and simple in the manufacturing process [2, 3]. One of the inorganic polymer materials that have good electrical insulating properties is low-density polyethylene (LDPE) with a density of 0.91-0.925 gr / cm3 which can have short or long branches. LDPE has several advantages including strong mechanical properties, a bit translucent, high strength at low temperatures, resistant to chemical changes, can be made in the form of transparent thin films and has good electrical properties. To produce a polymer composite characterized by biopolymer, LDPE can be mixed with natural rubber (NR).

Natural rubber is a hydrocarbon compound containing a carbon atom (C) and hydrogen (H). Natural rubber has a general characteristic, namely a slightly dark brownish color, with a specific gravity of 0.91-0.93, the highest use temperature of 90^{o}C, softened at a temperature of 130^{o}C and decomposed at around 200^{o}C. SIR is an abbreviation of Standard Indonesia Rubber which is a technical specification of Indonesian production, one of which is determined by testing characteristics such as dirt, ash content, and PRI. SIR is divided into three categories, namely SIR 10, SIR 20, and SIR 50. To obtain a composite insulation material, nanolaminates can be added to LDPE-NR which is the most commonly used

IOP Conf. Series: Materials Science and Engineering **602** (2019) 012010 doi:10.1088/1757-899X/602/1/012010

nonsilicate ceramic material related to its high electrical resistance and resistance to thermal shock and corrosion. Alumina includes good heat and electricity insulators[4].

Mechanical, thermal, and dielectric properties of polymer materials can be improved by adding certain nano-sized particles called nanocomposite materials [5]. Nanocomposites can increase the resistance of insulating materials to partial discharge, improve thermal properties, and save costs [6-8]. In its use as an insulating material, environmental conditions such as gases that fill cavities, pressure, humidity, and temperature have a significant influence on nanocomposite-based insulation [9]. Also, several congenital disabilities can affect the performance of the polymer material is in the form void defects, impurities (impurities), and protrusions (protrusion) on the surface of a semiconductor or a conductor and insulating polymer in the production process. These defects can result in high electric field strength (electrical stress) on the part of the defect and cause accelerated aging in polymer insulation polymer [13, 14].

The development of nanocomposite insulation materials requires a comprehensive study including the mechanical characteristic so that the phenomena possessed by the material can be fully understood [15]. In this research, the tensile test of newly bio nanocomposite samples was investigated.

Testing of the mechanical properties of bionanocomposite insulation materials is also needed to determine the nature of the material, whether it is suitable or not to be used as a high-voltage insulation material, by predetermined requirements. One of the mechanical properties that need to be tested is the strength of the tensile test. The tensile test is a method used to test the strength of a material or material by giving it an appropriate load of force [16]. Tensile testing is used to measure the resistance of a material to the static force of money given slowly. This test is intended to determine the mechanical properties of bionanocomposite insulation materials to be used at high voltages so that they can be seen for their advantages and disadvantages.

Based on previous researchers, Irawati [17] tested the tensile strength of insulators with rice husk ash fillers and silicon rubber, found that the tensile strength of the test material before aging was better than after aging and the increasing filler composition of tensile strength tends to decrease. Aji Suryo Alam et al. [18] have examined the effect of variation and filler composition on the performance of epoxy silane resin insulator samples, resulting in tensile testing, the tensile stress decreases due to the increasing sand filler material and the decreasing MPDA hardening material. Increasing sand filler material and decreasing MPDA hardening material, the yield stress tends to decrease.

2. Experimental

Main materials that used are LDPE and natural rubber with fixed ingredients 80:20 from the total weight of the sample. This ingredient applies to all bionanocomposite samples. Total weight of sample for once processing is 60 grams, so LDPE weight is 48 grams and natural rubber weight is 12 grams.

Table 1. Ingredients of LDPE-NR and alumina insulation sample

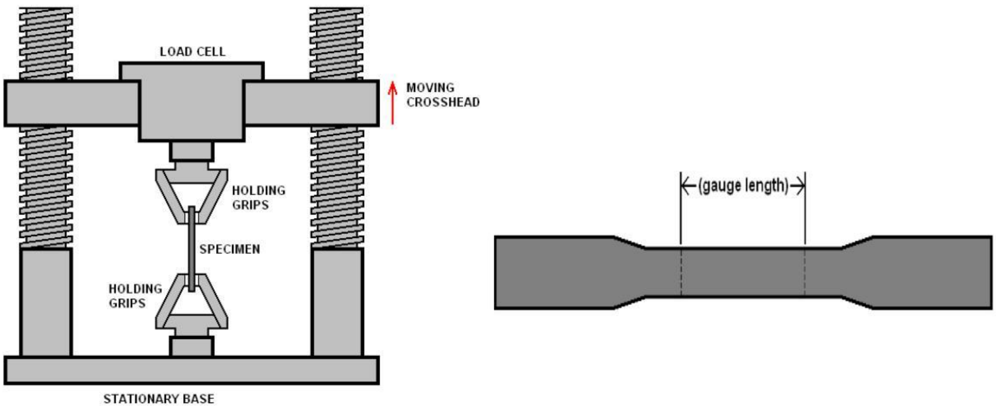
Sample Name	LDPE (%)	NR (%)	Alumina (wt)
A1	80	20	1,5
A2	80	20	3
A3	80	20	4,5
A4	80	20	6

Table 2. The composition of LDPE-NR and silica insulation sample

Sample Name	LDPE (%)	NR (%)	Silica (wt)
S1	80	20	1,5
S2	80	20	3
S3	80	20	4,5
S4	80	20	6

Weight percent means the weight of A1-S1 on grams, so it's 1,5% of sample total weight on once processing, so it's 1,5% × 60 grams = 0,9 grams. It means the weight of alumina and silica on A1-S1 is 0,9 grams. This treatment applies to every weight percent from each alumina and silica. The process of bionanocomposite is as follows. Firstly, the main material LDPE and natural rubber (NR) is prepared with the ratio of 80:20 wight percentage (w%). Then, set up the temperature on the rheomix machine for 150°C with a rotation speed of rotor 60 rpm for 12 minutes. The LDPE, NR, alumina, and silica is poured into the rotating machine simultaneously. The next step is to keep the masterbatch in the oven for 24 hours with temperature of 70° to for drying process.

After that, insulation sample is molded using a hotpress machine namely Collin 300p in 4 phase. Do the steps like this by the amount of variation of alumina and silica that used. For the tensile test purpose, the sample is molded and cut as shown in Figure 1 (b). Figure 1 (a) shows the schematic of tensile test equipment using Geotech Al-7000-S test system.



(a) (b)

Figure 1. (a) Scheme of the tensile test, (b) position of object test

3. Result and Discussion

In this research, LDPE-NR bionanocomposite insulation sample was prepared, and the tensile test was done. The result of this research is expected to have nanocomposite insulation that will give an optimum result that meets the technical specification target according to specification target which has been specified. The tensile test is a test to know the size of the load that needed to stretch the rubber compound until it breaks, stated with N for every mm^2 cross-sectional area of test object before it stretched.

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Figure 2 shows the impact of w% of alumina to the tensile characteristic — the tensile strength every sample has to reach the technical specification target 10 Mpa or larger than 10 N/mm^2. The highest score of the Tensile test is on Alumina 1. Alumina 1 is a variation that has the lowest addition of alumina.

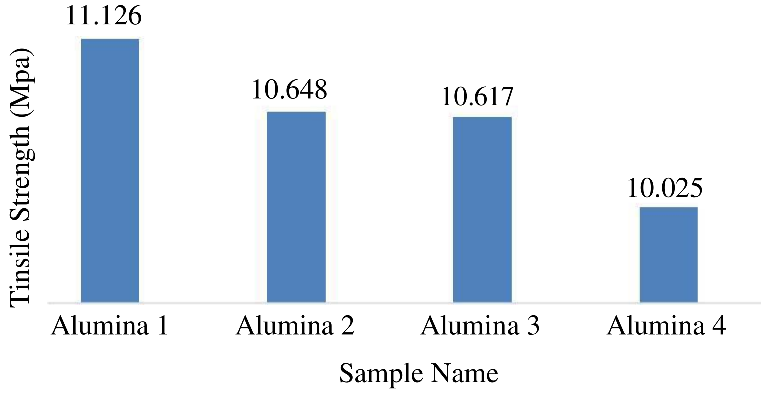

Figure 2. Tensile test result nanoalumina LDPE-NR biopolymer

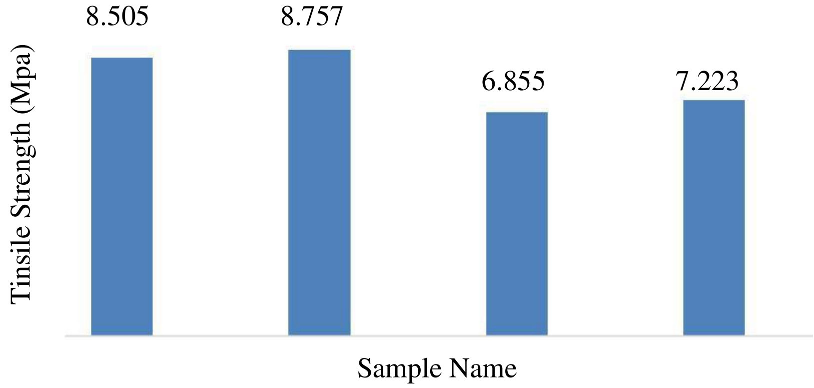

Figure 3. Tensile test result nanosilika LDPE-NR biopolymer

Figure 3 that every sample has not to reach the technical specification target 10 Mpa or larger than 10 N/mm^2. It happened because the addition of silica filler made the samples stiff so the result of tensile test become low.

Figure 4 shows a comparison of the results of tensile tests between variations of alumina and silica. It is seen that alumina has a high tensile strength value compared to silica. In alumina 1 with the addition of a filler composition of 1.5% wt has a tensile test value of 11.126 while the addition of filler of 6% wt has a tensile test value of 10.025. This means that there is a decrease in the tensile test value of 8.98% in the alumina composition. Silica with the addition of filler 1.5% wt has a tensile test value of 8.505, and the addition of filler 6% wt has a tensile test value of 7.223. This means that there is a decrease in the tensile test value of 15% in the composition of silica. The addition of silica is more influential than alumina.

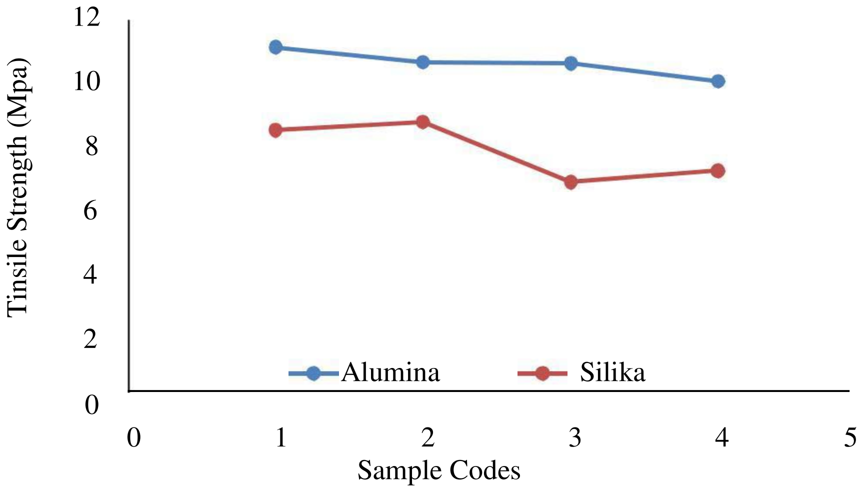

Figure 4. The tensile test of two groups of alumina dan silica bionanocomposites in different percentage of wight (w%)

4. Conclusion

The tensile test of four biopolymer nanocomposite samples was successfully done and reported. The addition of silica filler made the insulation samples become stiff and have a low score of the tensile test. The addition of alumina filler made the insulation samples become elastic and have a high score of the tensile test. The tensile test of alumina variation samples is higher than silica variation samples.

Acknowledgment

The authors thank Andalas University for funding this research through the Skim Cluster of Professorship Acceleration with contract number 52/UN.16.17/PP. PGB/LPPM2018. The authors also thank Polymer Engineering Center, the Agency For The Assessment And Application Of Technology (BPPT) of Indonesia Government for supporting the preparation of biopolymer nanocomposite samples in 2018.

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