Organic filler from golden apple snails shells to improve the silicone rubber insulator properties

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Abstract. This paper investigates the effect of an addition of filler compound using golden apple snail shell as an organic filler to the silicone rubber insulator. The filler obtained from golden apple snail shell is found mostly contained calcium carbonate. The organic calcium carbonate (CaCO₃) with particle size of 45, 75, 100 and 300 micron were prepared. Sample of silicone rubber that were filled with fillers were tested under ASTM D638-02a type standard for mechanical test. Also, electrical test such as I-V characteristics (ASTM D257-07) and dry arc test according to ASTM D495-14 have been performed. The results revealed that using larger particle size of organic filler obtained from the golden apple snail shell resulted to higher value of dielectric constant as well as higher dielectric strength. Also, the filler helps slow down the tracking activity at an insulator surface due to its crystals of calcium carbonate. However, when using excessive amount of filler, the sample will have a drawbacks in mechanical properties. By using agriculture waste as a filler compound, one can reduced the usage of commercial CaCO₃ as an inorganic materials and to lower the investment cost to a final silicone rubber product.

1. Introduction
Silicone rubber insulator are widely used in the industry of electronic, electrical power as well as in high voltage insulating materials. Researcher have found that inorganic filler such as calcium carbonate (CaCO₃), silica (Si) can improve its materials properties by adding appropriate amount to the silicone rubber. However, using these filler compound added cost to the initial investment. The choice of organic filler attracts more by using golden apple snail shells as an alternative filler so that it can replace the filler compound from commercial. This is another way to reduce cost of silicone rubber product. Also, the main objective of this research is to improve the silicone rubber insulator using organic filler from golden apple snail shells. The paper also investigates the effect of an addition of filler compound using particle size of 45, 75, 100 and 300 micron. South East Asia, the most agricultural plantation is rice. Golden apple snail shell can be found elsewhere in the rice field plantation. It consumes almost all kinds of soft plants such as rice seedlings, algae, morning glory, mimosa and duckweed. Moreover, golden apple snail would prefer to eat rice seedlings at the age of about 10 days. This causes farmer to look for a way on how to prevent and how to eliminate the golden apple snail from eating up rice plantation. One easiest method is to destroy the shells when those eggs were found, using natural enemies to reduce the usage of insecticide. At present, the fastest growth of golden apple snail shell becomes a problem and the shell itself becomes a solid waste from agricultural sector. However, the shell is mainly
composed of calcium carbonate (CaCO₃) of over 95% [1]. The composition attracts as a filler compound that can be used in many applications.

2. Experimental

2.1 Material and Organic filler preparation

Using the silicone rubber insulator room temperature vulcanization (RTV) that is in liquid form as a base material. Test sample is in solid form, the catalysed were used with the ratio of 100:3 by weight. Then, adds the filler into liquid base material. Using the degassing machine for 15 min to remove all bubbles. Next, inject the liquids without bubbles into a mold to a specimen dimension according to ASTM standard. And then, wait for the curing of liquid coagulation at the room temperature around 2 to 3 hours. Fillers used in the experiments are divided into 2 type; inorganic filler and organic filler. The inorganic filler is of commercial grade CaCO₃ and organic filler is obtained from golden apple snail shells. The preparation of the CaCO₃ from golden apple snail shells were needed. Typical golden apple snail shell is shown in the figure 1. First, wash the shell in clean water to remove dirt and after that heat them up to remove moisture contents at 100 °C in the oven for 24 hrs. After remove moisture contents, they were crushed and after that using the sieve to filter the powder for 45, 75,100 and 300 micron particle size. The powder of CaCO₃ were then wash using clean water and heats up to remove water at 100°C for 48 hrs. Finally, keep the filler in to the container.

![Figure 1. Golden apple snail shell](image)

2.2 Mechanical Test

The Mechanical test is for tensile strength and hardness according to ASTM D638-02a Type VI standard [2]. The tensile test machine set the crosshead speed at 50 mm/min. Before test begins, measurement of the original dimension and the original gauge lengths has to be read out first. After start the machine, the process involves pulling the specimen until a shear has occurred. Record the elongation, tensile strength, hardness and deflection of maximum load. The specimens shall have a dumbbell shape. The thickness is 4 mm; the width is 6 mm and 33 mm in length. The elongation of the modified silicone rubber when using 5% of 75 µm organic filler have been found to be much better than using the 100 µm of organic filler and inorganic filler. When the filler percentage is increased and using larger size of particle, the elongation of silicone rubber are declining steadily as same as tensile strength as shown in figure 2(a) and 2(b). However, for the case of the hardness issue, when the particle size of organic filler are increased, the hardness property of the silicone rubber may achieved but on the other hand the test sample may become much more brittle.
2.3 Contact angle Test & Scanning Electron Microscope(SEM) & X-ray Techniques
Measurement of the angle of contact when a drop of liquid is applied a coated surface according to ASTM D7334 standard [3] as shown in fig.3. Measure contact angle at the room temperature using water. Area surface specimen test shall not visible and not to be touched with the fingers or contaminate in any other way. The machine set a horizontal stage and deposits a drop size of test liquid no larger than 5 μL. The contact angle measured on this drop will be an advancing contact angle [4]. We have found that the silicone rubber with organic and inorganic filler have greater and larger contact angle than the controlled (without filler). Contact angle is increasing when the filler ratio is increased. However, the silicone rubber using organic filler have larger value of contact angle way much better than inorganic filler as shown in figure 3. Also, the inspection of the surface by scanning electronic microscopy (SEM) showed the details of silicone rubber using organic filler, inorganic filler and controlled sample. The surface of silicone rubber without filler has smooth surface and does not have any crease pattern of thin film like those that were found in an inorganic filler with the same filler ratio. But, the surface of silicone rubber using organic filler, were found to have crease pattern thin film cover on surface’s specimen and it is increasing when increase the filler as show in figure 4.

![Graphs showing elongation, tensile strength, and hardness of silicone rubber with different fillers.](image)

**Figure 2.** Comparison of (a) elongation (b) Tensile strength and c.) Hardness of silicone rubber with organic and inorganic filler
2.4 Current and Voltage Characteristic

Current-voltage characteristic test is a measurement of AC insulation resistance according to ASTM D257-07 [5] standard. This test using frequency at 50 Hz, AC voltage from transformer and adjustable voltage from 0 to 10,000 V with an increment of 100 V for measuring the current through the specimen. The specimen has cylindrical shape. Its radius is 50 mm and 2 mm of thickness [6].

Figure 5. AC insulation resistance test circuit and measuring the current through the specimen.

![Current-voltage characteristic graph]
c.) Silicone rubber using 100 µm organic filler can oppose the flow of current
d.) Silicone rubber using 300 µm organic filler can oppose the flow of current
e.) Silicone rubber using inorganic filler can oppose the flow of current

Figure 6. Comparison between the I-V characteristic of silicone rubber using organic filler particle size of 45, 75, 100 and 300 µm and inorganic filler using the same ratio

Figure 6 shows the relationship of the I-V characteristic of silicone rubber using organic filler and inorganic filler with the ratio of 0% to 50% by weight. When the apply voltage is increased from 0 to 10,000 Volts, the silicone rubber without filler can better oppose the current than the silicone rubber using 45 µm and 100 µm organic filler. On the other hand, the silicone rubber using the 5% of 300 µm organic filler can oppose the current much better than without filler. The inorganic filler used in silicone rubber material have shown similar behavior in terms of opposing the flow of electrical current.

Thus, the organic filler with the particle size of over 100 µm filled in silicone rubber can oppose the current better than without filler because the filler distributed through cross section as well as cover the surface of silicone rubber.

2.5 Dry-Arc Resistance Test
Dry-Arc resistance test is the test for material resistance against the high-voltage, low current applying close to the surface of silicone rubber insulator according to ASTM D495-14 standard [7]. This test using AC voltage from transformer and adjusted current from 10 mA to 40 mA.

The organic filler and inorganic filler can improved electrical property of the silicone rubber insulator. Silicone rubber using organic filler with particle size of 300 µm are better than using inorganic filler and without filler as shown in figure 7. It can increase the time duration of burning on the surface of the silicone rubber as long time possible and creates a slower path on the surface of the tracking activity. The prolonging of burning time is because of the organic filler mainly composed of calcium carbonate (CaCO₃). Since the CaCO₃ has malting point at 825 °C while the silicone rubber is at 300 °C, the surface of sample was covered with calcium carbonate so that the burning process cannot continue.
2.6 Dielectric Constant, Dissipation Factor and Dielectric Strength

This dielectric constant and dissipation factor of silicone rubber tested according to ASTM D150 [8] standard from Laboratory of National Metal and Materials Technology Center (MTEC). From table 1. The dielectric constant and dissipation factor value of silicone rubber using organic filler, inorganic filler and controlled. The dielectric constant of silicone rubber using organic filler is 3.26 which is better than silicone rubber that is using inorganic filler and controlled because calcium carbonate of organic filler has improved its polarization. The value of dielectric constant consistence with dissipation factor. Then, the silicone rubber using organic filler is considered to be a promising good insulation.

The dielectric strength test is to test an insulator ability to withstand the maximum electrical apply voltage at 50 kV, 100 mA according to ASTM D149-09 standard [9]. This result, silicone rubber using organic filler showed higher value of dielectric strength. Due to the larger particle size of organic filler that has a strong bond between atoms.

Table 1. Show the dielectric constant, dissipation factor and dielectric strength

| Type of silicone rubber                  | Dielectric constant ($\varepsilon_r$) ±S.D | Dissipation Factor (D) ±S.D | Dielectric strength (kV/mm) |
|-----------------------------------------|---------------------------------------------|----------------------------|-----------------------------|
| Silicone Rubber (without filler)        | $3.18 \pm 0.06$                             | $0.0214 \pm 0.0008$        | 18.24                       |
| Silicone Rubber+ Organic filler         | $3.26 \pm 0.01$                             | $0.0089 \pm 0.0006$        | 19.39                       |
| Silicone Rubber+ Inorganic filler       | $2.56\pm 0.03$                              | $0.0191 \pm 0.0007$        | 18.90                       |

3. Conclusion

The Organic filler from golden apple snail shell have been investigated. It can improve the electrical properties of silicone rubber insulator and little improvement on mechanical aspect. Using larger particle size of organic fillers resulted to higher value of dielectric constant as well as higher dielectric strength. Also, the filler helps slow down the tracking activity at an insulator surface due to the crystal structure of calcium carbonate. In order to develop a good insulator, the distribution of filler must be distributed throughout the surface and cross section of silicone rubber insulation thoroughly. However, when using excessive amount of filler, the sample will become more brittle and resulted to a reduction in mechanical properties.

Acknowledgement

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References

[1] Nittiama R, “Nano Calcium Carbonate from Golden Apple Snail and Oyster Shells as reinforcing Filler for Poly (Vinyl Chloride),” Master Thesis, Chulalongkorn University, Thailand.

[2] ASTM international, ASTM D638-02a 2003, Standard Test Method for Tensile Properties of Plastics This test method is under the jurisdiction of ASTM Committee D20 on Plastics and the direct responsibility of Subcommittee D20, p 46-58.

[3] ASTM international, ASTM D7334-08 2013, Standard Practice for Surface Wettability of Coatings, Substrates and Pigments by Advancing Contact Angle Measurement.

[4] Davi M. Soares, Serge Mendonça, Estacio T.W. Neto, Manuel L.B. Martinez, “Electrical field on non-ceramic insulators and its relation to contact angles for constant volume droplets,” Journal of Electrostatics, vol. 84, pp 97-105, Oct 2016.

[5] R. Raja Prabu, S. Usa, K. Udayakumar, M. Abdullah Khan and S.S.M. Abdul Majeed, “Electrical Insulation Characteristics of Silicone and EPDM Polymeric Blends – Part I,” IEEE Transactions on Dielectrics and Electrical Insulation, vol. 14, pp 1207-1214, Oct 2007.

[6] ASTM international, ASTM D257-07 2012, Standard Test Methods for DC Resistance or Conductance of Insulating Materials.

[7] ASTM international, ASTM D495-09-14 2014, Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation.

[8] ASTM D150. Standard Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation, ASTM International. [n.p.]: West Conshohocken, PA; 2011.

[9] ASTM D149-09. Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies, ASTM International. [n.p.]: West Conshohocken, PA; 2013.