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Recycling of Epoxy Moulding Compounds to Develop an Alternative Ceiling Board

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Abstract: Recycling is the process of repurposing waste into new products and materials where the semiconductor industry uses epoxy molding compounds extensively as a primary material for electronic packaging, the possible financial benefits of using recycled plastic especially polyethylene and agriculture waste of coir fiber and the majority of the residue is frequently burned or thrown at landfills, which could result in resource waste and environmental harm. This study is to determine the potential of EMC, coir fiber and PE as an alternative ceiling board and analyze the quality of the alternative ceiling board by using water absorption, sound absorption and tensile strength test as these focus on recycling waste material. The alternative ceiling board is produced by using the sandwich method as all three layers are hot pressed together. The data were analyzed after the sample quality analysis was performed. The PE sample which contains 80% PE and 20% EMC had less water absorption of 2% compared to coir fiber sample which contains 80% PE and 20% EMC with water absorption of 60%. Both samples contain 80% PE and 20% EMC where more water absorption means more capillaries inside the material and will decrease the strength of the materials. The coir fiber sample shows the best sound absorption for frequency between 500 to 1200 Hz. Tensile strength analysis shows that both PE and coir fiber samples had stress over 3 MPa. The best tensile strength is from coir fiber sample and PE sample which contain 80% PE and 20% EMC which contain less EMC than another sample. By adding more EMC, it will improve the performance of the alternative ceiling board.

Keywords: Ceiling Board, Epoxy Molding Compounds (EMC), Coconut Coir Fiber, polyethylene (PE)

1. Introduction

Sustainability refers to using a resource in a way that prevents irreversible depletion or damage. There are numerous methods for figuring out sustainability and implementation levels. The three Rs which are reduce, reuse, and recycle that can be used as sustainability methods. Recycling is the process

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of repurposing waste into new products and materials [1]. The aim is to use resources as efficiently as possible while creating the least amount of waste.

Epoxy moulding compounds (EMC), known also as epoxy resins are used extensively in the semiconductor, electronics and automotive industries to replace more expensive ceramics, metals and other plastics. EMC is a mixture of epoxy resin, a filler (silica, SiO2), a hardener, and additional components that contribute to their thermal and mechanical properties [2]. EMCs are used in industrial moulding applications and commonly come in the form of compressed solid powder pellets which are then heated into a liquid and moulded to encapsulate or "package" a semiconductor or electronic device.

Coir fibre is also known as coconut fibre is a natural fibre extracted from the outer husk of coconut. Coir is the fibrous material found between the hard, internal shell and the outer coat of a coconut [3]. The brown coir (made from ripe coconut) are in upholstery padding, sacking and horticulture. Coir fibre has been developed into ceiling and wall panels because it had a strong fibre with such a high tensile strength due to its high lignin concentration in comparison to other plant fibres.

The thermoplastic polymer known as polyethylene (PE) is created from petroleum. One of the most flexible plastic materials known, PE plastic is utilized in a variety of products, including milk jugs, shampoo bottles, cutting boards, piping, and plastic bottles. PE plastic is well-known for its excellent tensile strength and high strength-to-density ratio [4]. It also has a high melting point and impact resistance.

This research focuses on manufacturing the development of an alternative ceiling board from waste materials of epoxy moulding compound (EMC), coir fibre and polyethylene (PE) with high durability and strength requirements, as well as good sound and water absorption as according to American Society for Testing and Material (ASTM). Sound absorption test, tensile test and water absorption test are performed in each ceiling board sample.

2. Materials and Methods

2.1 Materials

STMicroelectronics Sdn. Bhd., a semiconductor company in Muar, Johor, Malaysia, provided waste epoxy moulding compounds (EMC) samples. The samples are black in colour as the epoxy molding material used in the circuit coating process. The by-product of the epoxy moulding compounds is subsequently crushed into particles between 0.3 and 0.5 cm in size. Next, coconut coir fibers were purchased from a local supplier. Meanwhile, plastic waste polyethylene (PE) is collected from ANKOP, Angkasa Kowaris Plastic Sdn Bhd. The PE waste was shredded into particles of 10 to 30 mm.

2.2 Methods

In this study, epoxy moulding compounds were ground and sieved and the powder form of moulding compound was used. Meanwhile, for the fibers, it is soaked in tap water to clean them from impurities inhibiting the bonding between the fiber and the binder. After soaking, the fibres were sun dried thoroughly cut in a 0.5 to 1 cm length. A square steel mold with dimensions 25 cm × 25 cm × 0.5 cm was used to fabricate the composite ceiling board.

Composite ceiling board samples with different ratios of PE and EMC and layered with two different materials which were coir fibre and PE were fabricated using a hot-pressed method based on a sandwich panel of the structural composites as illustrated in Figure 1.

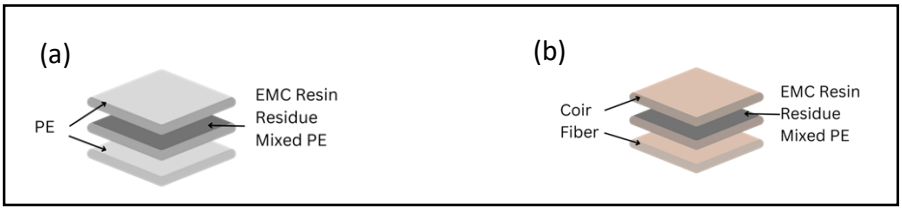

Figure 1: (a) Sandwich panel layered with PE and (b) Sandwich panel layered with coconut coir fibre

The composite ceiling board samples were cast into the steel mold in plate-like shapes and hot pressed at 200°C for 10 minutes and a pressure of 10 tonnes was applied by using the GO-TECH hot press machine. Then the developed alternative ceiling board is examined for water absorption, sound absorption and tensile strength based on the American Society for Testing and Materials (ASTM) procedures and International Organization for Standardization (ISO).

2.3 Optimization of Composite Ceiling Board Composition

The composite ceiling board was based on a sandwich panel, three layers of the panel were cast and compressed together to fabricate the composite ceiling board sample. The component ratio of PE +EMC for both samples are 50%: 50%, 60%: 40%, 70%: 30%, 80%: 20% as shown in Table 1.

Table 1: Composite of coir fibre ceiling board

First and Third Layer	Second Layer	
	EMC Resin Residue	PE
100% PE	50%	50%
	40%	60%
	30%	70%
	20%	80%
100% Coir Fiber	50%	50%
	40%	60%
	30%	70%
	20%	80%

2.1.1 Water Absorption

ASTM D570, the standard test method for the physical testing of ceiling boards, is referred for water adsorption testing procedures. The water absorption of the composite material samples was measured after 2 hours, 12 hours, and 24 hours of immersion in distilled water at room temperature (24°C). The percentage of water absorption was calculated using Eq. 1 below:

$$\text{Water Absorption (\%)} = \left(\frac{Wet\ weight - Dry\ weight}{Dry\ weight}\right) \text{x } 100\ \% \qquad \text{Eq (1)}$$

2.1.2 Sound Absorption

ISO 10534, the standard to determine sound absorption coefficient of ceiling board, the test was done using standing wave ratio in the impedance tube of 100 mm tube size using frequencies between 500 Hz to 1200 Hz. At the end of the tube, the sample will be held against a back plate, which has a very high value of acoustic impedance and thus, assumed to perfectly reflect the incident sound wave. The reflected wave will then be picked up by the movable microphones and the reduction of intensity will be registered as the reflected intensity.

2.1.3 Tensile Strength

ASTM D3039, the standard to determine the quality of different materials based on the ceiling properties of tensile strength. The sample is cut with a size of 3cm x 10cm x 1cm and the testing is to measure the force required to break a polymer composite specimen and the extent to which the specimen stretches or elongates to that breaking point. Specimens are placed in the grips of a Universal Test Machine at a specified grip separation and pulled until failure.

3. Results and Discussion

3.1 Water Absorption Test

Base on Figure 2, it shows that coir fiber sample with ratio of 80% PE and 20% EMC had the very least water absorption which was 37% after 2 hours, 53% after 12 hours and 60% after 24 hours while the highest is coir fiber sample with ratio of 50% PE and 50% EMC where 53% after 2 hours, 60% after 12 hours and 65% after 24 hours. The second highest is coir fiber sample with ratio of 60% PE and 40% EMC and then coir fiber sample with ratio of 70% PE and 30% EMC.

Based on the Figure 3, PE sample with ratio of 80% PE and 20% EMC has the very least water absorption which is 0% after 2 hours, 1% after 12 hours and 2% after 24 hours while the highest is PE sample with ratio of 50% PE and 50% EMC which 2% after 2 hours, 3% after 12 hours and 4% after 24 hours where it shares data after 24 hours with PE sample with ratio of 80% PE and 30% EMC and has the second highest of water absorption while PE sample with ratio of has 70% of PE and 30% of EMC has the water absorption which is 1% after 2 hours, 2% after 12 hours and 3% after 24 hours and had the second lowest of water absorption. As the properties of PE and EMC are resistant with water [2], [5], it can be stated that more water absorption means more capillaries inside the material where it is more porous which will lead to higher absorption of water and will decrease its strength [6].

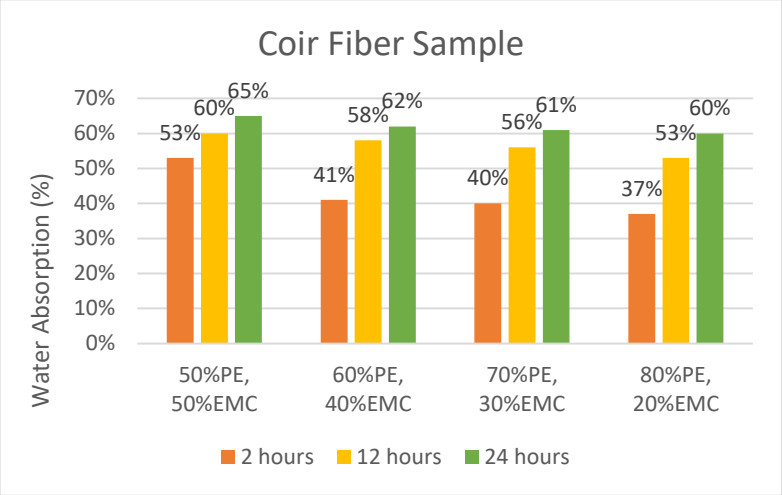

Figure 2: Water absorption of coir fiber sample

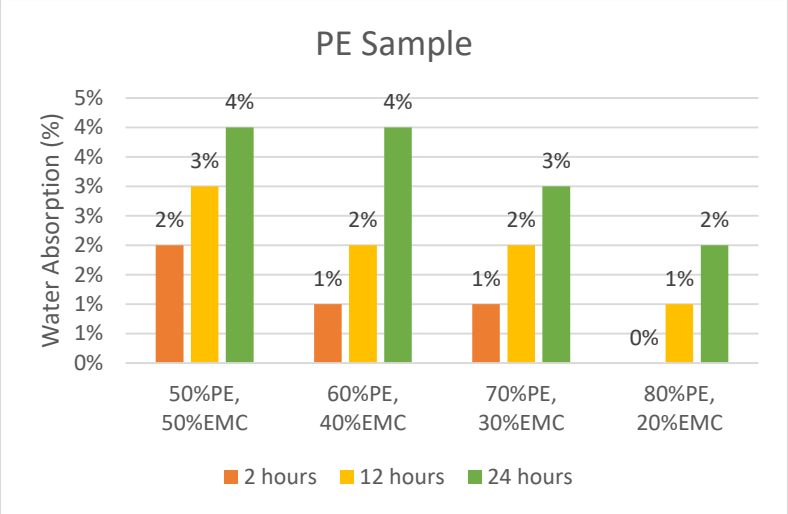

Figure 3: Water absorption of PE sample

3.2 Sound Absorption Test

Based on Figure 4.4 which is a coir fiber sample, shows that coir fiber is excellent at absorbing sound between 500 Hz to 1200 Hz. Coir fibre is already famous for its properties as a good absorber of sound [7]. This sample is layered with a different ratio of PE and EMC so that it will show slightly different from other coir fiber samples. The graph shows coir fiber samples with ratio of 50% PE and 50% EMC had a stable sound absorption from 800 Hz to 950 Hz and increasing gradually after 950 Hz. Thus, an absorption coefficient was improved by adding the EMC as the sample contains 50% PE and 50% EMC with the highest EMC ratio.

Based on Figure 4.5 the PE sample with ratio of 80% PE and 20% EMC shows a very good absorber on 900 Hz, PE sample with ratio of 70% PE and 30% EMC shows a very good absorber on 1000 Hz and PE sample with ratio of 60% PE and 40% EMC shows a very good absorber on 1200 Hz with a coefficient of 0.02, respectively. All the sample has a stable 0.01 coefficient from 500 Hz until 1200 Hz. According to research [8], the sound absorption coefficient was steady because, according to an analysis of the pure PE material's sound absorption characteristics is 0.05. From 3200 to 4800 Hz the largest sound absorption coefficient was observed ranging from 0.15. Hence, an absorption coefficient was improved by adding the EMC mixed with PE.

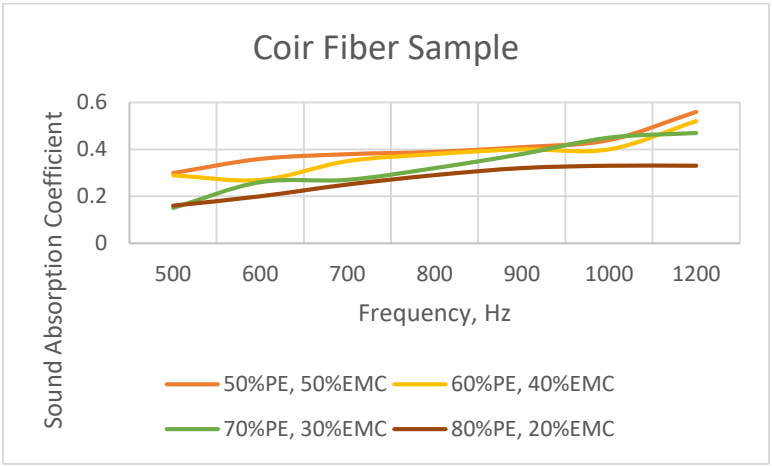

Figure 4.4: Sound Absorption Coir Fiber Sample

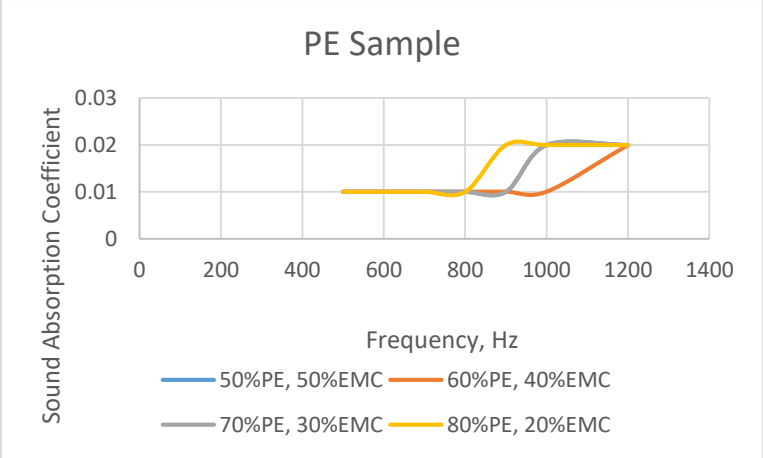

Figure 4.5: Sound Absorption Coir Fiber Sample

3.3 Tensile Strength Test

Based on Figure 4.6, coir fibre sample with ratio of 70% PE and 30% EMC shows the highest reading of stress which is 3.51 MPa. Based on Figure 4.7, a PE sample with a ratio of 70% PE and 30% EMC shows the highest reading of stress which is 4.21 MPa. Both figures show that all the samples had stressed over 3 MPa and that PE has tightly packed molecules. PE is an incredibly strong polyethylene with high tensile strength, rigidity, and impact of resistance [9]. Moreover, coir fiber also has a high lignin content making it resilient, strong, and highly durable [10]. Hence, adding EMC mixed with PE will improve the tensile strength between the layer because both coir fibre sample and PE sample contain 80% PE and 20% EMC and still get the best reading even though they had lesser EMC than other samples.

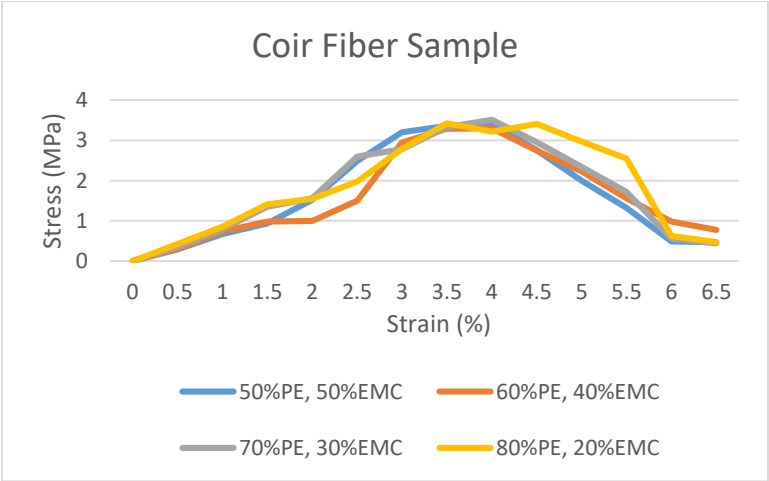

Figure 4.6: Tensile Strength Of Coir Fiber Sample

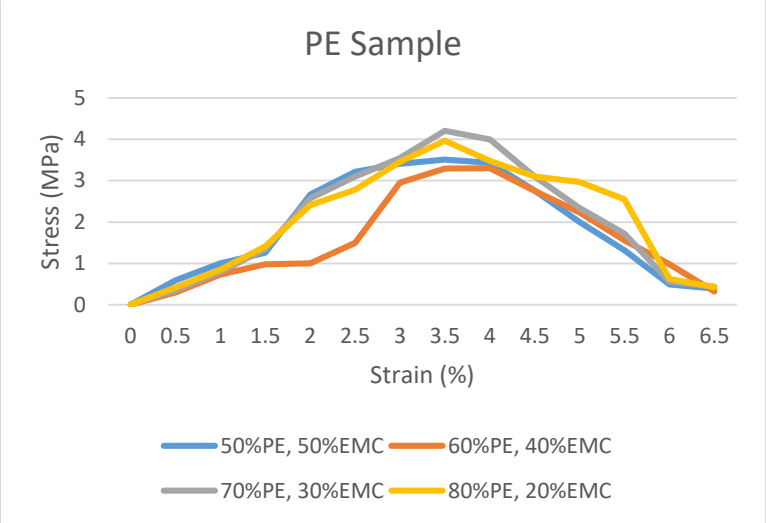

Figure 4.7: Tensile Strength Of Coir Fiber Sample

4. Conclusion

Based on the results and discussion, the technique of mixing the EMC and PE is a really important step. It helps to improvise the strength and reduce water absorption. The PE sample which contains 80% PE and 20% EMC had less water absorption of 2% compared to coir fiber sample which contains 80% PE and 20% EMC with water absorption of 60%. Both samples contain 80% PE and 20% EMC where more water absorption means more capillaries inside the material and will decrease the strength of the materials. The coir fiber sample shows the best sound absorption for frequency between 500 to 1200 Hz. Tensile strength analysis shows that both PE and coir fiber samples had stress over 3 MPa. The best tensile strength is from coir fiber sample and PE sample which contain 80% PE and 20% EMC which contain less EMC than another sample. By adding more EMC, it will improve the performance of the alternative ceiling board. Therefore, adding EMC can improve the sound absorption but reduce the performance for water absorption because of the pores that do not melt well with PE and for tensile strength it shows that using 30% of EMC has the highest stress compared to other samples.

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