

## High Voltage Durability of *Bambusa Vulgaris* as a Bio-composite Material

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### ABSTRACT

This study is conducted in order to measure and identify the ability of a bio-composite material to the high voltage. According to it, the developed bio-composite material is tested to ensure the maximum voltage that the material can hold. The bio-composite material which made from a mixture of *Bambusa Vulgaris* and a selected polymer named as High Density Polyethylene (HDPE). The *Bambusa Vulgaris* going through several processes before mixed together with HDPE using wood plastic composite (WPC) technique which also consists of several stages. There are several samples of bio-composite substance are fabricated. The difference among them is the composition of the raw materials (*Bambusa Vulgaris* and HDPE) used. In this research, the high voltage measurement which also called as breakdown voltage measurement of the bio-composite material is examined by using appropriate experiments. All the experimental results are presented and discussed in this paper.

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## 1. INTRODUCTION

Wood plastic composite (WPC) is a material combination technique of natural plant and polymer. Natural plant such as pulp and bamboo which is in sawdust from fibre filler is mixed with new or waste polymer such as polypropylene, polyvinyl and polyethylene using associated processes. Currently, WPC products are very demanding in many applications such as in building constructions. Many of them used WPC to replace the usage of solid wood in current building structures. This is because WPC can grant good strength even not stiff as a solid wood but the strength is acceptable to be used in their applications. In addition, WPC is becoming well known because of its other advantages such as low maintenance, environmental friendly, low cost and high durability. Furthermore, WPC technology not only needs to use good wood but it also can use decayed wood to produce bio-composite material [1]. This significant finding good for the many countries that faced the problem of lack of woody raw material because of their unproductive forest area to get expand in WPC field. WPC is very familiar in wood technology industry. However, it is never applied in the electrical industry. So, hopefully this research can give the new ideas to explore WPC technology in the electrical field.

In this research, a kind of bamboos is selected as raw material to be manipulated. Bamboo is considered as woody grass family [2]. Based on a report that has been made, over 1500 species of bamboos were available in this world such *Phyllostachys Edulis*, *Pseudosasa Japonica* and *Sinobambusa Tootsik*. Every kind of bamboos has their special properties and usefulness for living thing. Furthermore, bamboos need humid surroundings, good moisture and fertile soil in order to get larger. Southeast Asia is one of the

locations which have the best environment for bamboos [2]-[3]. Many of bamboos are well grown in this place. Essentially, bamboos are naturally grown abundantly in wet areas without the need for a careful supervision. Normally, the bamboos are considered mature and ready for harvest after 3 years of growing [4].

Utilization of bamboo in industrial is not new. It has been used widely for many applications such as structural applications [4] and household things [5]. At the moment, the inventions of using bamboo in daily life are reaching out to abundant of manufacturing applications. Due to many potential researchers advance in handling new innovation, so there are a variety of new discoveries in the uses of bamboos such as in paper technology [6], chemical industry [7] and robotic arena [8]. These inventions are good since it can give new ideas and replace the conventional method of each field. Consequently, by having many invention and innovation uses of bamboo, it can expand the exploitation of bamboo in the current industry. This study is manipulated a local bamboo called as “Buluh Minyak” or its scientific name is *Bambusa Vulgaris*. In addition, *Bambusa Vulgaris* was chosen because of it has good chemical and mechanical properties such as quick maturation rate and high prospective for carbon storage [3]. This *Bambusa Vulgaris* can be harvested after 3 years growth and it also has quick yearly re-maturation rate. Meanwhile, consuming high carbon storage is good for the lifespan of the *Bambusa Vulgaris*. Furthermore, *Bambusa Vulgaris* was chosen because it easy to be found and identified. Its culm looks like oily and glossy. It is also among the largest species of bamboo in the world [3].

As stated before, this exploration was used WPC technique to process the *Bambusa Vulgaris* become a board whereby WPC is a process of combining a plant with a polymer. So, the selected polymer is called High Density Polyethylene (HDPE). HDPE is selected due to high durability to temperature which it can hold up to 200 degrees Celsius [9]. In WPC, polymer is used to provide more strength to the developed board. Additionally, the WPC using bamboo is not new to the existing industry. There are several applications and studies had been accomplished using this type of mixture such as in wood technology and manufacturing [10]-[12]. However, this kind of mixture is not commonly used in electrical applications. Thus, hopefully this study can reveal the potential of this mixture in an electrical field such as to make a good insulator. Moreover, great insulators are really significance as to avoid any current leaking in the electrical systems. Not only the phases wire can cause to the current leak, ground and neutral wires also have potential of current leak [13]. This problem can occur due to improper wiring, bad insulator and poor grounding systems. Therefore, by having good insulator it can reduce the cause of current leak.

## 2. METHODOLOGY

This research consists of several significant stages. First stage is a board development and second stage is breakdown voltage measurement. All the details will be discussed below.

### 2.1. *Bambusa Vulgaris* Board Development

Well grown *Bambusa Vulgaris* was harvested and cleaned well from any unwanted substance such as dirt. Figure 1 shows the *Bambusa Vulgaris* that used in this research. Then, the *Bambusa Vulgaris* has been chipped and grinded into smaller size (sawdust). After that, the sawdust has been dried using oven. The sawdust was purposely dried to ensure minimal water content exists in the sawdust. The dried sawdust has been mixed with HDPE using hot mixer. The mixture of *Bambusa Vulgaris* and HDPE was extruded out from hot mixer as palette. In order to make the mixture become a board, the palette has been pressed using hot and cold pressure machine. Accordingly, Figure 2 shows as a summary of the steps which have mentioned before.



Figure 1. Well grown *Bambusa Vulgaris* used in this study

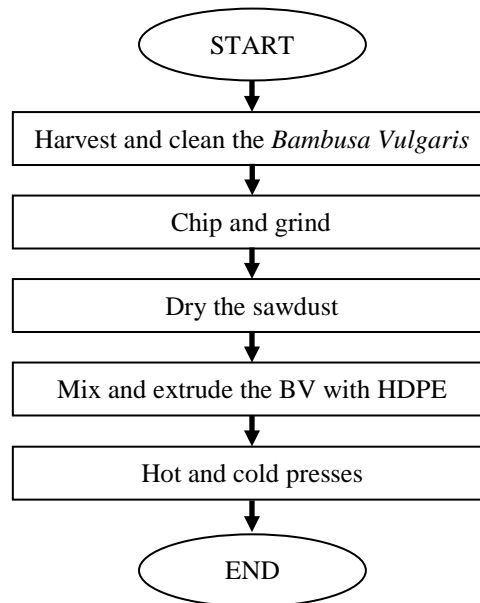


Figure 2. Processes of developing *Bambusa Vulgaris* board

## 2.2. Breakdown Voltage Measurement

Breakdown voltage or a few researchers called as partial discharge is defined as an electrical discharge that does not completely bridge the insulation between two electrodes or conductors [9],[14]. This testing method is used to measure the maximum voltage that can be held by the insulator. However, for a repeated breakdown voltage test, the board will be completely breakdown. Currently, there are several methods have been revealed on how to measure breakdown voltage of any substance. One of the techniques is partial discharges using harmonic orders.

In this experiment, a sample was tested continuously until the sample fully breakdown. For a sample which has been tested continuously, it might degrade physical and chemical properties of the sample. In this research, an experiment has been arranged for the proposed board with the intention of getting the value of breakdown voltage. Figure 3 shows the configuration of the experiment that has been applied to measure the breakdown voltage of the developed bio-composite board.

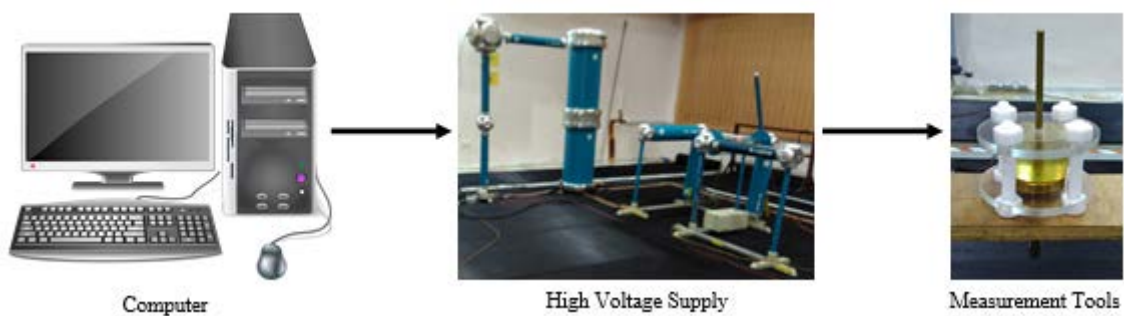


Figure 3. Configuration of experimental apparatus

The measurement of breakdown voltage of the proposed board is determined by using an electrical instrument by High Volt. It is capable to supply maximum voltage up to 200 kV. The setup consists of a unit of computer connected to high voltage supply. While the high voltage supply with special circuit (inductor, capacitor and resistor) is connected to the breakdown voltage measurement tools. Essentially, the experiment uses the computerize system. Whereby, all the obtained results can be observed through a computer which is connected to the system. All the obtained results also can be saved via using that computer.

Meanwhile, Figure 4 and Figure 5 show the layout of measurement tools. The electrodes is designed according to the American Society for Testing and Materials (ASTM) D149 standard [15]. Teflon is used to hold the feed electrode and grasp *Bambusa Vulgaris* sample between feed and main electrodes tightly. In addition, the Teflon is utilised to reduce the electrical spark which appears at the measurement tools. End of feed electrode is purposely sharpened to concentrate the high voltage supply into the *Bambusa Vulgaris* board. The size dimension of main electrode as describe in Table 1. Perspective view of measurement tools as shown in Figure 4.

Subsequently to measure the breakdown voltage of the proposed substrate, a sample of board is placed in between the two electrodes of measurement tools. Then, set the required parameters inside the application at the personal computer then start the measurement process. In order to check the accuracy of the obtained values, several pieces of the same composition are measured. According to ASTM D149 standard, at least 5 samples are needed in order to check its accuracy. In addition, the size of sample must be 15 mm away from edges of main electrode [15]. Side view of measurement tools as shown in Figure 5.

Table 1. Dimension of Main Electrode

Parameter	Length (mm)
Radius	51
Thickness	25
Edges Rounded	6.4

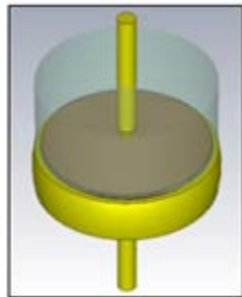


Figure 4. Perspective view of measurement tools

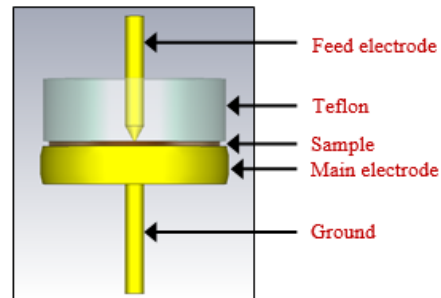


Figure 5. Side view of measurement tools

### 3. EXPERIMENTAL RESULTS

Four samples of *Bambusa Vulgaris* boards were developed using WPC method. These four samples have different composition of raw materials. The purpose is to determine the variation of breakdown voltage among the different compositions. The compositions of all developed *Bambusa Vulgaris* boards are as stated in Table 2.

The composition percentage is based on the overall weight of the mixture of *Bambusa Vulgaris* and HDPE. All of the *Bambusa Vulgaris* boards have been measured its breakdown voltage values by using the experiment setup as mentioned before. Furthermore, for reference and comparison, an existing board has been chosen to be tested which is Flame Retardant type 4 (FR-4) board. The FR-4 board was chosen because of its availability and common usage in printed circuit board (PCB) application.

Table 2. Composition of *Bambusa Vulgaris* Board

Substrate	Composition	
	<i>Bambusa Vulgaris</i> (%)	High Density Polyethylene (%)
Sample 1	0	100
Sample 2	10	90
Sample 3	20	80
Sample 4	30	70

The sample is injected with maximum voltage and tested repeatedly until it totally breakdown. This is to ensure how much the maximum voltage that the board (sample) can hold. For this testing, the example output signal of a tested sample is shown in Figure 6. Figure 6 shows several harmonics of the output signal.

First to fifth waves, it illustrates the *Bambusa Vulgaris* board try to hold the maximum voltage. Start from sixth wave onward, the *Bambusa Vulgaris* board already damaged and it cannot hold the higher voltage anymore. Highest peak of the signal is defined as the maximum voltage which the *Bambusa Vulgaris* board can hold. Thus, from Figure 6 the maximum or breakdown voltage for that sample is almost 18kV. In addition, Figure 7 shows a sample of *Bambusa Vulgaris* board which represent the state of sample before and after the breakdown voltage testing respectively.

Figure 7 (b) shows a black dotted which indicates the damaged area after the breakdown voltage testing. However, the breakdown voltage for that sample cannot be easily concluded by having a sample tested. As stated before, according to ASTM D149 for each composition there are 5 samples have been tested. Then, the final values of breakdown voltages are concluded according to mean value from 5 measurements. Table3 shows the summary of high voltage measurement to 4 different compositions *Bambusa Vulgaris* boards and a FR-4 board as a reference.



Figure 6. Output signal of a sample of *Bambusa Vulgaris* board

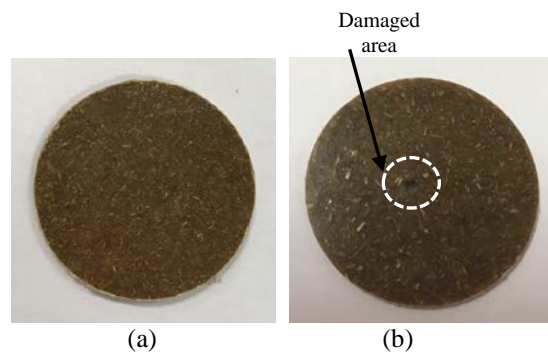


Figure 7. Sample of *Bambusa Vulgaris* board (a) before the experiment (b) after the experiment

Based on the obtained result in Table 3, it seems there are several deviations among the value of breakdown voltage. Thus, in order to choose the breakdown voltage result for each sample, mean value has been calculated. Furthermore, an existing board named FR-4 is also measured as a reference. Sample 1 and FR-4 is made from pure HDPE and fiber glass respectively. These two boards have higher breakdown voltage compare to *Bambusa Vulgaris* boards. Sample 2 with composition 10% of *Bambusa Vulgaris* and 90% HDPE can hold voltage up to 15.88kV, Sample 3 with composition 20% of *Bambusa Vulgaris* and 80% HDPE took breakdown voltage at 12.86kV meanwhile Sample 4 with substance composition 30% of *Bambusa Vulgaris* and 70% HDPE be able to take hold of 11.86kV. Thus, it can state that if there is some impurities exist in a mixture, it can reduce the voltage resistant capability of the board.

Table 3. Summary of Breakdown Voltage

Board	Breakdown Voltage Measurement (kV)					Mean
	1	2	3	4	5	
Sample 1	17.9	18.4	18.8	18.2	18.4	18.34
Sample 2	16.0	15.9	15.7	16.2	15.6	15.88
Sample 3	12.5	13.0	12.7	12.9	13.2	12.86
Sample 4	12.0	11.7	11.9	12.2	11.5	11.86
FR-4	16.8	17.4	16.9	17.1	17.0	17.04

Moreover, according to the mean values column at Table 3, the breakdown voltage values are inversely proportional to the amount of *Bambusa Vulgaris* filler that exist in the board. The breakdown voltage values are decreased if the quantity of *Bambusa Vulgaris* filler increased in the proposed board. The relationship of breakdown voltage and *Bambusa Vulgaris* filler is illustrated in Figure 9. Thus, based on the line of graph in Figure 9, it figures out that the graph is declined negative exponentially. If the amount of

*Bambusa Vulgaris* sawdust is increased to the board mixture, the values of breakdown voltage are decreased. So, it can be said that the *Bambusa Vulgaris* substances are affecting the insulation performance of the board.

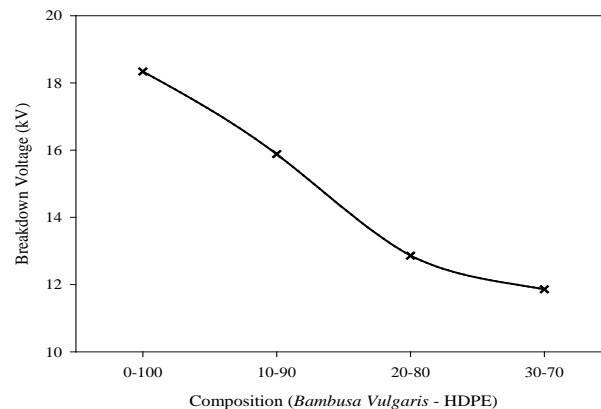


Figure 9. Relationship between breakdown voltage and mineral compositions

#### 4. CONCLUSION

A new potential insulation board entitled *Bambusa Vulgaris* board is successfully developed. The characteristic of electrical properties in term of breakdown voltage are measured, analyzed and presented in this paper. Furthermore, the obtained results for *Bambusa Vulgaris* boards are compared with familiar existing board which is FR-4 board. The results show the *Bambusa Vulgaris* fillers or sawdust are affecting the breakdown voltage performance of the bio-composite board. From the obtained results, it can state that if the amount of *Bambusa Vulgaris* filler existing in the bio-composite board is higher, the value of breakdown voltage is lower. This bio-composite board can be suggested to use in insulation applications since it can hold quite high voltage. Besides that, this bio-composite board also can be used in PCB applications. Further exploration on characteristics of this *Bambusa Vulgaris* board will be done. The other characteristics that can be investigate such as strength, water absorption and permittivity. More examination on this *Bambusa Vulgaris* board is important in order to reveal the prospect of the board to be used in other applications.

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