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**RESEARCH ARTICLE**

# ASSESSMENT OF BAMBOO LEAF ASH WASTE IN THE PRODUCTION OF CERAMIC ELECTRICAL INSULATOR

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**ABSTRACT**

Recycling is well known environmental solution for saving the raw materials and to consequently the contamination of zero waste environment. Bamboo leaf is one the forest waste materials, it has been utilized in the present study. Replacement of quartz by bamboo leaf ash in the production of ceramic electrical insulator was achieved as per industrial norms. The influence of bamboo leaf ash on the fabrication of insulator to enhanced the superiority of this product. Fabricated insulator was characterized by its physico-mechanical properties. Mineralogical study revealed that the formation of crystalline phases mullite and quartz is dependent to BLA addition. Functional groups were identified by using the Fourier Transform Infra-red Spectroscopy (FTIR). Microstructure development of the insulator was analysed through Scanning Electron Microscope (SEM). Higher dielectric strength was found in BLA addition specimen. Analytical characterization results are correlated with the observed physcio-mechanical parameter. It should be observed that high quality electrical insulator can be achieved from bamboo leaf ash originated ceramic materials.



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## INTRODUCTION

Global production of ceramic materials increases every year, and it is expected to reach 20.3 Mt in 2020 (Teixeira *et al*., 2008, Souza *et al*., 2011). Ceramic insulators are widely used in power system and distribution network. The ceramic insulators are made from nonconducting resources such as porcelain, glass and composite polymers. The ceramic insulators have light weight comparing to glass equivalents (Moya and Park., 2014) and high resistivity, high dielectric strength, low loss factor, good mechanical strength, excellent in heat radiation and insulating components even in humid or corrosive situation. The sustainable elimination of ceramic materials still remains as a challenge nowadays, worldwide many scientists are studying the wastes for recycling to make useful products. Bamboo resources are one of the forest materials among them India is the second largest in the world. Bamboo is probably the fastest growing and highest yielding natural resource and production material available to mankind. Nevertheless, the use of bamboo its generate a high volume of leaves disposable wastes, with suitable properties to use in new applications. These waste are often burnt in open landfills, negatively impacting the environment. The use of bamboo leaf ashes (BLA) for industrial applications is, at present, a novelty and little-known research line as reflected by the scarcity of available literature (Villar-Cocina *et al*., 2011). In incessant generation of solid waste materials represents serious environmental and technical problems. It is identified that, under controlled temperature of the BLA is constituted mainly of silica, aluminium, potassium, calcium with magnesium, iron, and alkaline earth oxides are the minor components (Amu and Aderuberu, 2010). In another purpose of this study is to provide a useful reference to peers in the field of insulator fabrication (Meng *et al*., 2014).

The aim of this work was to investigate the ceramic materials from quartz replaced by recycling bamboo leaf ash waste to evaluate the potential raw materials for production of ceramic electrical insulators.

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## MATERIALS AND METHODS

### Sample preparation

The bamboo leaves were gathered from the campus of the Annamalai University, Chidambaram, Tamil Nadu. Collected bamboo leaves were open fired and for complete combustion, and the obtained ash was cleaned, dried in air then calcined at 650 °C for 3 h at a heating rate of 300 °C/h in muffle furnace. At 500 °C an organic compounds are decomposed and higher amount of crystalline silica was obtained at 650 °C (Sivakumar *et al*., 2014, Singh *et al*., 2007). This treated (650 °C) bamboo leaf ash (BLA) was used to replacement of quartz in the production of ceramic insulator. Ceramic raw material such as clay, feldspar and quartz were purchased from M/s Oriental Ceramic Industry, Viruthachalam, Tamil Nadu. The composition anlaysis of the raw material (Table 1) was evaluated by using X-ray fluorescence technique.

### Specimen production

An industrial standard ratio of the ceramic material such as clay 60%, feldspar 25% and quartz 15% are used to preparing the ceramic electrical insulator [standard specimen (SC)]. The fully replacement of the quartz by calcined bamboo leaf ash (BLA) in the production of blended ceramic electrical insulator (15 BC). Each formulation was ground and water was added to the mixture adhesion. Then the slurry was milled for 12 h in a ball mill to ensure its homogeneous and the slip was filter pressed using pressing machine. Reel type cylindrical insulators (32mm X 16mm X 3mm) were made. The moisture content of the prepared reel ceramic electrical insulator was adjusted to 5-7% (Olupot *et al*., 2010) then shaping the insulator to attain smooth surface and dried for 48 hours. The dried ceramic insulator (green body) was fired at 1250 °C in an electrical kiln under controlled temperature. Fabricated insulator specimens are allowed to quality assessment test. Insulator specimens were subjected to physical test such as bulk density, porosity and water absorption according to the Archimedes method with water as the liquid medium as per ASTM 378-88 (Mostafa *et al*., 2010). The strength of the specimen was investigated by determing their failing load according to ASTM 1985b, by using an Universal testing machine. Microstructure of the specimens were observed through Scanning electron microscope (JEOL –JSM-5610LV). X-ray diffraction pattern (D/Max ULTIMA) was used to analyse the major crystalline phases present in the specimen. FTIR spectra was recorded in the range of 4000-400 $cm^{-1}$ employing a Perkin Elmer FTIR spectrometer (model RX1) to identify the functional groups present in the sample by KBr method. An industrial test method for dielectric strength of solid insulating material (ASTM D149) was used to determine the dielectric properties of the specimen.

## RESULTS AND DISCUSSION

### Physical, mechanical and dielectrical properties

The summary of the physico- mechanical and dielectric properties results obtained from the specimens are given in Table 2. Each value represented are average of four measurement of four different insulator is each composition. Water absorption (WA %) values were determined from weight differences between the sintered and water satured samples (immersed in boiler water for 2h) as per standardized procedures (ASTM 373). The shrinkage (S %) was determined by measuring the sample dimensions before and after sintering. From the results, (Fig.1) the properties of the standard insulator is differ from the blended electrical insulator. The shrinkage percentage of the blended ceramic insulator is higher due to slighter particles occupied less space and it gives the compactness under the sintering process. The porosity percentage (P%) of the BLA blended insulator is found to decreased. In line with the decreased porosity, the water absorption is also decreased due to closure of open pores (Liu *et al*., 2014). The bulk density (BD) increased from 2.0503 (SC) to 2.0712 $g/cm^3$ (15BC). It is well coincide with the fact that densification reduces pore spaces and hence volume upon which density depends (Chukudi *et al*., 2012). The mechanical strength (MS) of the blended specimen (3.59 MPa) becomes higher than standard (2.48 MPa) is due its high concentration of fluxing agents which lowers the sample plasticity and possibly suitable to the pozzolanic reaction activity of the BLA.

In ceramic materials, ions can be carriers to provide electrical conduction. The dielectric strength (DS) of the BLA blended ceramic electrical insulator has higher value (9.91 kV/mm) than standard specimen (8.65 kV/mm). The result of dielectric strength is increased for blended is mainly due to the porosity decreases at increase of the grain size. This is due to the crystallization and growth of secondary mullite from the molten crystalline aluminosilicate phase (Al-hilli and Al-rosoul 2010)

**Table 1. Chemical analysis of the raw materials (wt %)**

| Composition | $SiO_2$ | $Al_2O_3$ | $K_2O$ | $Fe_2O_3$ | $Na_2O$ | $TiO_2$ | CaO | MgO | Others |
|---|---|---|---|---|---|---|---|---|---|
| **Quartz** | 97.55 | 0.97 | 0.41 | 0.27 | 0.35 | 0.04 | 0.23 | 0.08 | 0.10 |
| **BLA** | 79.90 | 2.78 | 3.98 | 0.86 | 0.20 | 0.38 | 7.84 | 1.97 | 2.09 |

**Table 2. Physical, mechanical and dielectric parameters of ceramic electrical insulator**

| Specimen | S (%) | P (%) | WA (%) | BD ($g/cm^3$) | MS (MPa) | DS (kV/mm) |
|---|---|---|---|---|---|---|
| **SC** | 5.41 | 1.4052 | 0.6784 | 2.0503 | 2.48 | 8.65 |
| **15BC** | 7.74 | 1.2319 | 0.5932 | 2.0546 | 3.59 | 9.91 |

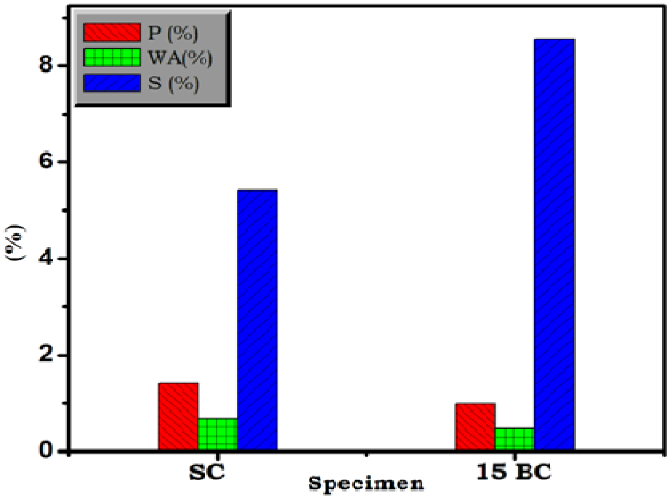
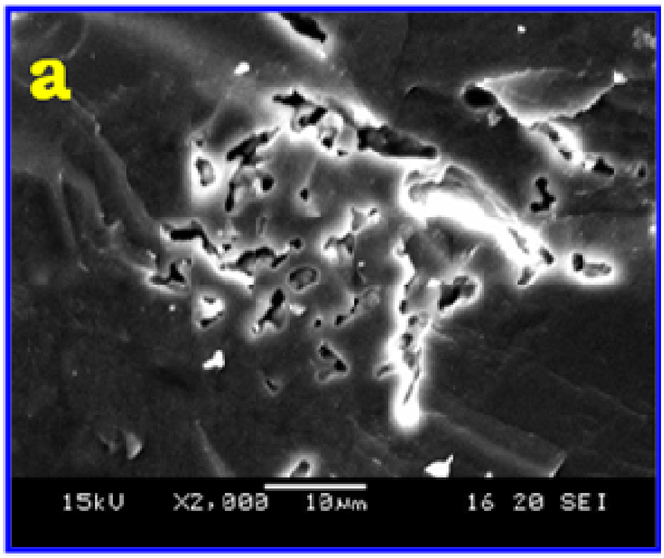



**Fig. 1. Physical properties of the ceramic electrical insulator**



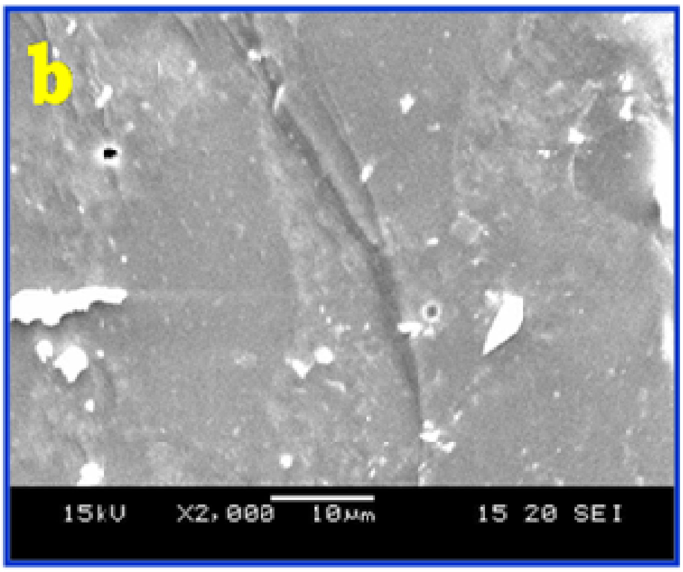




**Fig. 2. SEM images of (a) standard and (b) 15 BC ceramic electrical insulator**

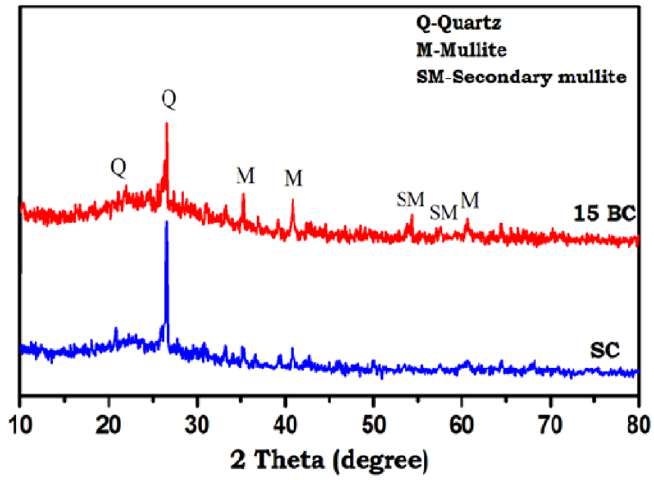



**Fig. 3. XRD pattern of ceramic electrical insulator**

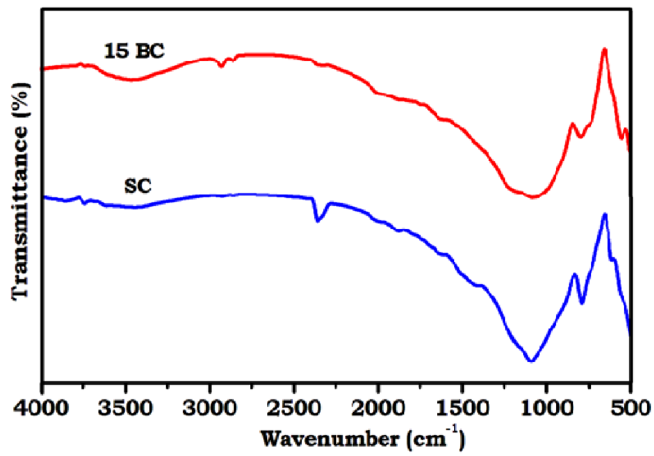



**Fig. 4. FTIR spectra of the ceramic electrical insulator**

## SEM study

The surface structure was viewed from the SEM micrograpgh of the standard specimen (Fig.2a). It can be seen that the irregular pores randomly distributed in the specimen and quartz and mullite glassy nature with unresolved clay matrix are observed. The presences of open pores is clearly seen and it is measured to be 1-5 µm in the size. Some abnormal pores are interconnected. High mullite content (needle shaped) with low quartz become more prominent in the the blended ceramic electrical insulator (Fig. 2b). No cracks and no other defects are observed in the specimen is due to BLA particles are tightly bonded to ceramic material. From the results, the blended specimen has high secondary mullite and more compact with dense microstructure due to better densification and pore reduction (Xu *et al*., 2015).

## XRD study

XRD pattern of the ceramic electrical insulator sintered at 1250 °C is shown in Fig. 3. The diffraction strong peak was identified as quartz (2θ= 26.26°) in the standard specimen. Besides, weak peaks could be identified as mullite (2θ= 40.80°). BLA blended specimen has more number of strong diffraction peaks were identified as mullite, and presence of the secondary mullite crystals (2θ= 54.0°). It is important noticed that the crystalline phases formed in blended specimen but there is a decrease in quartz content with the increases of mullite (Meng *et al*., 2014). The secondary mullite formation is foremost reason for higher strength of BLA blended insulator.

**FTIR Study**

Figure 4 shows the FTIR spectra of standard (SC) and BLA blended ceramic electrical insulator (15BC). The intensity of O-H stretching vibration (3440-3446 $cm^{-1}$) and H-O-H vibration of water molecules (1610-1625 $cm^{-1}$) in kaolinite are comparatively standard in importance is compared to standard specimen. The intensity of asymmetric stretching vibration of Si-O-Si (1070-1095 $cm^{-1}$) decreased in blended insulator is due to low quartz content. An intense bond appears at 788 $cm^{-1}$ due to the vibration of Si-O-Al (or) $Al_2O_6$ is attributed to mullite formation. The feature is consistent with superposition of Si-O vibrations in the $SiO_4$ tetrahedral of sintered specimen. It is important to note that the presence of mullite is also identified at 546 $cm^{-1}$. The proportion of the mullite is significantly higher due to crystalline silica involved. The FTIR analysis confirms that the blended insulator has higher mullite with low quartz content. Hence, the observed results can be directly correlated with XRD results i.e., the intensity of mullite increases while the intensity of quartz decreases in BLA blended specimen (Saikia *et al*., 2008).

**Conclusion**

Fully replacement of quartz by bamboo leaf ash waste in the production of ceramic electrical insulator is a feasible one. Less amount of porosity, water absorption decreases into enhanced bulk density are quality assessment of the blended specimen. The mechanical strength was greatly increased by the formation of higher amount of mullite which is identified from X-ray diffraction peaks. A good dielectric strength value can be determined and it is correlated with the SEM images. FTIR and XRD analysis confirmed that the blended insulator has high mullite with low quartz content. So it can be concluded that the physical, mechanical and dielectric properties can be enchanced for the addition of BLA in the ceramic electrical insulator production.

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