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RESEARCH ARTICLE

PRODUCTION AND PROPERTIES OF COFFEE HUSK ASH REINFORCED CERAMIC ELECTRICAL INSULATOR

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ABSTRACT

Recycling of the waste material plays an important role to preserve natural resources in the industrial world. Coffee husk ash is one of such forest industrial waste material. Replacement of feldspar by CHA in the production of ceramic electrical insulator was achieved as per industrial norms and augments the quality of the products. Physical and mechanical parameters water absorption, porosity, bulk density and strength of the sintered specimens were determined. The dielectric breakdown voltage was remarkably influenced by the porosity of the specimen. The structural characterization of the pure and CHA reinforced ceramic electrical insulator was performed using Scanning Electron Microscope (SEM) and X-ray diffraction (XRD), and thus results are correlated with physic-mechanical properties. The results indicate that the superior performance was achieved by CHA substituted insulator than an industrial standard insulator.

INTRODUCTION

India is responsible for approximately 65% of the world coffee production. Coffee is the second largest traded commodity in the world, after petroleum, and therefore, the coffee industry is responsible for generating large amount of residues such as, coffee husk, coffee pulp and silverskin, spent grounds (Orzua *et al*., 2009). Coffee husk is one of the forest industrial by product materials obtained as large amounts of solid wastes. It is disposed mainly by burning and the coffee husk ashes are used in landfill, which causes serious environmental issues. To overcome these problems the coffee husk ash can be converted into economically useful and environmentally friendly form of energy (Pallavi *et al*., 2013).

It is well known that, under controlled temperature of CHA is constituted mainly of potassium; calcium, aluminium and silicon with other oxides are the minor components (Saenger, Hartge, and Werther 2001). Recently, alternative methods have been developed to reuse several types of industrial waste materials (Al- hamaiedh 2010). Presently, many scientists worldwide is actively working on recycling or for reuse of wastes to make useful products including clay-based ceramic materials

Ceramic materials are primarily composed of clay, quartz, and feldspar. Each of these materials play its respective role in the properties of the blend formed from green to the fired body. Clay [$Al_2Si_2O_5$ $(OH)_4$] gives plasticity to the ceramic mixture; quartz (SiO_2) maintaining the shape of the formed article during firing, and feldspar [KxNa1-x ($AlSi_3$) O_8] serves as a flux to lower the melting point of the mixture (Segadães, *et al*., 2005). Ceramic is the most commonly used material for overhead insulators. Ceramics are resistant to high temperature, electricity, and harsh environment than polymers. Ceramic insulator has good mechanical and electrical properties and less expensive. The production of ceramic insulator is predominately based on available natural raw materials (Montoya *et al*., 2010). Thus, the aim of the present work was to study the fluxing effect of the coffee husk ash for the replacement of feldspar in clay based ceramic electrical insulator and are allowed to quality assessment test. To this end, clay-feldspar-quartz triaxial porcelain was prepared from locally available raw materials and are characterized then compared with previous specimen.

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Experimental

Raw materials

Coffee husk ash was collected from M/s Narasu's Exports & Coffee Industry, Salem district in Tamil Nadu. The industrial standard ceramic ingredients (clay, feldspar and quartz) were collected from M/s Oriental Ceramic Industry, Viruthachalam, Cuddalore district, Tamil Nadu. The collected coffee husk ash was cleaned, dried at 110 °C in of hot air oven for 3 h consequently. The air dried ash calcined at 650 °C for 3 h with a heating rate of 300 °C/h in a muffle furnace. In which the organic compounds are decomposed and coffee husk ash with high potassium content was obtained in crystalline nature (Alaneme *et al.*, 2013). The chemical composition of the calcined ash (CHA) was determined by X-ray fluorescence and its results are SiO_2 (14.65), K_2O (47.45), Al_2O_3 (12.07) and CaO (13.05) with other minor components.

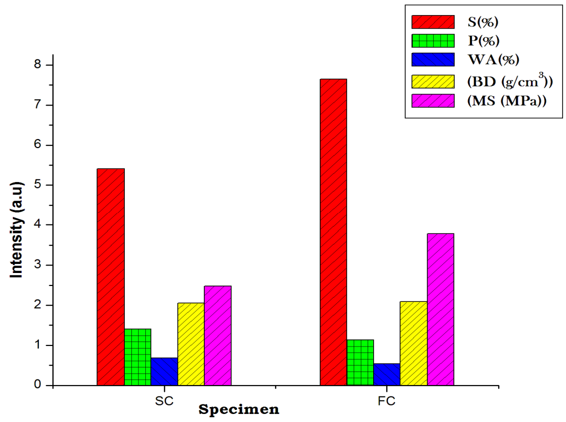

Figure 1 Physical, mechanical properties of the experimental ceramic electrical insulator

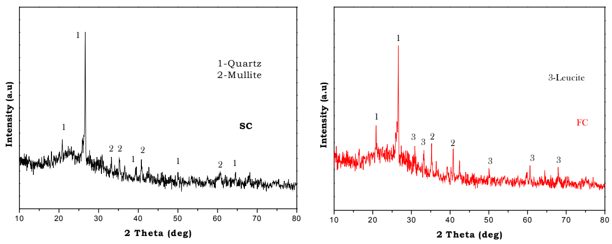

Figure 2 X- Ray Diffraction of the experimental ceramic electrical insulator

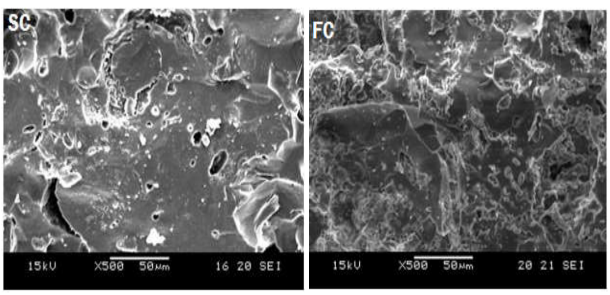

Figure 3 Microstructural of the experimental ceramic electrical insulator

Insulator Production

The ceramic electrical insulator was prepared by using an industrial standard ceramic ingredient (SC), such as 60% clay, 25% feldspar and 15% quartz. The feldspar was fully replaced by 25 wt% of calcined CHA as termed as FC and then dry mixed by using a ball mill to make homogeneous mixture. Water was added to the mixture adhesion, then the slurrymilled for 12 h in a ball mill to ensure homogeneous mixing and slip was filtered pressed using pressing machine. The moisture content of the prepared reel type ceramic electrical insulator (32mm X 16mm X 3mm) was adjusted to 4-5% (Peter olupot *et al.*, 2013) 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. This fabricated insulator specimens are allowed to quality assessment test

Characterization

Physical properties such as water absorption (WA), porosity (P), bulk density (BD) of the sintered specimens were carried out according to Archimedes principle (Boussois *et al.* 2013) and mechanical strength (MS) was recorded by using a universal testing machine. The microstructure was examined by using the Scanning Electron Microscope (JEOL –JSM-5610LV) and crystalline phases present in the specimens was analysed by using X-ray diffractometer (D/Max ULTIMA). The dielectric property of the specimen was carried out using standard test methods for dielectric breakdown voltage of solid insulating material (ASTM D149).

RESULTS AND DISCUSSION

Physical and Mechanical properties

Figure 1 shows the physical and mechanical properties of the sintered ceramic electrical insulator. The lowest value of the porosity (1.1363 %) and water absorption (0.5378 %) of CHA reinforced specimen when compared to standard insulator (P-1.4052% and WA- 6784%). In reinforced specimen, the concentration of fluxing increases and favors the formation of the liquid phase in the clayed material. The shrinkage of the reinforced specimen is higher (7.650 %) attributed to the closure of voids by CHA constituents, thus lead to the reduction in porosity (Sivakumar *et al.*, 2014). Consequently, bulk density increased for SC (2.050 kg/m^3) and for FC (2.1033 kg/m^3) which in turn enhanced mechanical strength. This significant increase in mechanical strength is due to the production. The mechanical strength of the CHA reinforced specimen is higher (3.79 MPa) when compared to SC (2.48 MPa). The mechanical strength is strongly dependent on the microstructure, especially on defects such as pores and cracks. The high CHA content of alkaline earth oxides (CaO + MgO) will strongly promotes the fluxing effect of the alkalis (Acchar *et al*, 2013).

XRD Analysis

The XRD pattern of the standard specimen and 25% CHA reinforced ceramic insulator are shown in Fig.2. The XRD pattern of CHA identified the existence of potassium aluminium silicate phases, which are in good agreement with the results obtained by chemical analyses. It is observed from the diffraction patterns of both specimen, the quartz (SiO_2) is identified at 2θ=26.61° (011) and 50.07° (112) and mullite peak ($3Al_2O_3.2SiO_2$) is observed at 2θ= 35.29° (111) and 40.89° (121). This result agrees well the standard JCPDS card no. 898935 and 150776. It is noticed that the intensity of mullite peaks increases while the quartz intensity decreases in CHA reinforced ceramic insulator when compared to standard specimen. From the results, the CHA reinforced ceramic insulator attained better mechanical properties due to crystallization of mullite and reduction of quartz content.

At 1250 °C, CHA reinforced will go through a peritectic reaction, causing a stable presence of leucite from mullite which is identified at 2θ=31.49° (323), 33.33° (242), 50.12° (525), 60.64° (183) and 67.98° (448) [JCPDS card no. 851626]. The CHA content promotes an increase in mechanical strength associated with an increase in the formation of leucite and mullite phase, indicated in the XRD pattern phase diagram with decreasing porosity (Acchar *et al*., 2012).

Micro structural Analysis

The morphology (Fig.3) of the specimens was observed by SEM on the surfaces of the standard and CHA reinforced ceramic electrical insulator. Fig. 3a shows the standard specimen that contains spherical isolated pores, a sign of gas evolution in the presence of a liquid phase. But no pores are seen on the surface of the CHA specimen, it represents the lower water absorption and porosity %. It was noticed that the amount of mullite increases while quartz decreases in the CHA reinforced ceramic electrical insulator and a lower secondary mullite ($2Al_2O_3.2SiO_2$) needles, is seen in the mixture with 25 wt% CHA. Ultimately, Fig. 3b shows numerous rounded leucite crystals.

The mixture with 25 wt% CHA contains sufficient densification leading to decreased water absorption and increased mechanical strength. The mechanical strength values found to be dependent on the presence of mullite crystalline phases and porosity values. From the results obtained in this study, it may be concluded that the CHA material can be incorporated ceramic body as an alternative to feldspar material (Acchar, *et al*., 2013).

Dielectric breakdown Voltage

The dielectric voltage of the ceramic electrical insulator was measured at room temperature (45 % virtual moisture). The dielectric strength is the maximum value of the field strength which can be applied to an insulating material just before the breakdown occurs (Ehsani 2004). The main mechanism of breakdown here is, a small number of carriers in the conduction band are accelerated in the electric field and these collide with atoms, ionizing them. The dielectric breakdown voltage of the CHA reinforced ceramic electrical insulator is found to be 9.13 kV/mm which is higher than standard (8.65 kV/mm) specimen, which are within the specified range (6.0 to 13kV/mm) of porcelain insulator. The highest value in CHA blend is mainly due to decreases in porosity. The augment of the dielectric breakdown voltage for CHA reinforced ceramic electrical insulator could be accredited to crystallization and growth of secondary mullite and presence of leucite (Kitouni and Harabi 2011).

CONCLUSION

Fully replacement of feldspar by CHA in the production of ceramic electrical insulator was achieved as per industrial norms. The mechanical and dielectric break down voltage was remarkably influenced by porosity of the specimen. The 25% CHA substitution material was responsible for the occurrence of leucite and mullite crystals. The results concluded that the superior performance was achieved by CHA substituted insulator than industrial standard insulator. Hence, agroforestry waste material coffee husk ash is a potential candidate to replacing the costly and scarce feldspar used as a fluxing component in clay- based ceramic formulations.

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