Indigenous Production of Electrical Porcelain from Nigerian Mineral

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Abstract- In power systems, there is an ever-increasing demand placed on porcelain insulators especially for outdoor applications. Additionally, the huge cost of importation has resulted in a growing need for the local manufacture. To this end, an electrical porcelain insulator was manufactured from Ukpor Clay and other locally available raw material. Universal Composition of triaxial porcelain (kaolin, 45%; ball clay, 5%; feldspar, 25% and quartz, 25%) was used to produce a test piece. The pulverized and thoroughly mixed composition was compacted and fired at a temperature of 1200°C. The physical and Electrical properties were investigated. The results show that the sample has a breakdown voltage of 26kV/mm, low water absorption and dielectric constant between 9.0 and 10.9 within the frequency range considered. These results when compared with those of the commercial variety show that the locally manufactured sample satisfies the stringent requirements of a good insulating material.

Introduction

Indigenously developed technology is considered an essential index for exploring and promoting underutilised resources, technological and economical potential of a nation's industrialisation processes. It has been established that abundant raw materials are available for the manufacture of electrical porcelain insulators as well as heated ceramic wares in Nigeria (FMS,2004).

Insulators are extensively used for high and low voltage applications in generation, transmission and distribution of electrical power.

Statement of Problem

In spite of the enormous wide range of application and availability of raw materials in Nigeria, mostly used insulators are still imported into the country due to manufacturing of electrical insulators in small quantities.

In addition dependence on foreign products is susceptible to sabotage and more often than not the manufactured products may not be the most ideal product for the importing country's climate which invariably affects efficiency. Standardization is difficult if not impossible since the raw materials and the manufacturing technology are non-resident in Nigeria.

Motivation

Nigeria is blessed with abundant mineral resources, which are from time immemorial formed the backbone of the nation's economic and industrial development aspirations. Prior to independence, the nation's mineral raw material resources contributed immensely to the export earnings of the nation.

For over decades now, the Country has continued to depend entirely on oil for her revenue and the volatile nature of the oil market has made it imperative for us to diversify the mono-product economy through exploitation and processing of our abundant solid mineral resources.

Non-metallic Minerals account for the major part of the value of global non-fuel mineral production. They are produced and consumed in virtually all countries and are utilized in the production of all manufactured goods, as well as in construction, agriculture and environmental protection. Mining of Non-metallic minerals is one of the oldest professions of the world and grew with the evolution of man and the civilization. Against this background, it may seem paradoxical that the production and utilization of Non-metallic Minerals are rarely accorded a commensurate level of priority in our national development plans.

Materials

Kaolin

Kaolin is a clay mineral made up of aluminum, silicon and water. It is a hydrated aluminum silicate, with an approximately 46% Silicon, 30% aluminium and about 14% is made up of calcium, iron, magnesium sodium and water. It has a melting temperature of about 1700℃ and it is triclinic in its crystal system (Birks,1960). Kaolin as a mineral is described technically as a white alumina-silicate. It does not react with other materials and is insoluble in water (Egbai, 2013).

Occurrences of kaolin have been recorded in different parts of the country and specific abundant deposits have been identified in parts of Anambra, Enugu, Kaduna, Katsina, Plateau, Ondo, Ogun, Oyo, Bauchi, Sokoto, and Borno States. Of these reserves, about 800 million tones of probable/proven deposits have been quantified (FMST,2010). Kaolin was obtained from Ukpo deposit for this research.

Feldspar

Feldspar is a group of closely related, rock forming alumino-silicate minerals, which contain varying proportions of potassium, sodium and calcium. Feldspar is the most abundant of all minerals, comprising over 50% of the earth's crust. It forms the major constituent of most igneous and metamorphic rocks, as well as arkosic sediments (Anih,1988).

They are characterized by low iron oxide content; little variation in composition and a white colour. They are used mainly in the production of tableware, electrical and sanitary porcelain, glazes, porcelain enamels and frits (Anih 2005).

There are wide occurrences of feldspar in the granite and pegmatite rocks of Nigeria. Feldspar occurs in the feldspar rich pegmatite of the older granites around Egbe, Udiarehyu, Okene and Lokoja in Kogi State; Osogbo in Osun State; Ijero-Ekiti in

Ondo State; Abeokuta in Ogu state; Gwoza in Borno State and parts of Taraba/Adamawa State (Ibrahim, 2000). Feldspar used in this work was obtain from Kogi state

Quartz

Quartz constitutes one of the most readily available geological materials used in industries and factories such as glass manufacturing companies. Silica (Sand/Quartz) are said to consist of high optimal percentage of silicon dioxide (SiO_2) which is a very good chemically stable element and it remains almost the same no matter the series of cycles it may have gone through, either in transportation or re-deposition. Quartz is silica occurring alone in pure state. Silica/glass sand on the other hand are products of weathering, erosion and transportation by rivers or/and the sea.

Nigeria has extensive deposits of good quartz silica sands in almost all the states of federation. For this work Quartz material was obtain from Odo river in Amaokpala.

Ball clay

Ball clay is an earth material of very fine particle size which forms as an end result of the residue due to weathering or by hydrothermal action which is a result of sedimentary deposit. Clay is cohesive and usually plastic when wet. It serves as a primary binder and fires in different colours depending on the types and compositions. It shrinks when dry and expands when wet. It is a poor conductor and that is why clay materials are used as thermal insulators. Clay materials are usually stable at high temperatures and this makes them have good thermal shock, i.e. ability to retain their original forms without cracking, spalling or flaking under sudden thermal changes and to have good resistance to environmental attack. It has appreciable amounts of organic matter.

Various grades of ball clay occur in Nigeria. It occurs in commercial quantity in Enugu state (Nsu, Isi-Uzo, Uzo-Uwani, Oji River, Udi), Ebonyi state (Ohaukwu, Ezza North, Abakaliki, Ezzi, Afikpo south, Ohaozara), Abia state (Isikwuato, Ikwuano, Umuahia, Bende, Arochukwu), other areas include

Niger Delta and coastlines, Akabuka, Komo-Boue, Kwawa etc. in Rivers State. Iguioriaki, Aboh and Uzere in Edo State and, Eket and Etinam in Akwa Ibom State and Okija, Umuchu, Ekwulobia, Ozubulu and other places in Anambra state (FMST,2010).

METHODOLOGY

Processing of Kaolin, Quartz and Feldspar

Kaolin was first washed to remove some deleterious materials followed by sun drying. The dried material was broken into smaller pieces and soaked in water for two days to slake.

The sample was mixed with water and sieved with a 100µm sieve. The filtrates were allowed to settle and were decanted after two days. The remaining material was dried and milled into powdered form.

Quartz was sun dried to remove water and milled, while Feldspar and ball were obtained in processed form.

Manufacturing Process

Universal composition of Triaxial porcelain was used. 45% of the processed kaolin was weighed out. 5% of Ball clay was added to make up the composition of Clay material to 50%. 25% of feldspar and 25% of quartz were carefully weighed out in accordance with Birks [2] and mixed thoroughly with about 8% of water in a bowel using a stirrer. The mixture was manually kneaded until it became homogenous. The kneading was also aimed to exclude as much trapped air as possible in the mixture before compaction.

The slightly damp mixture was collected into the steel mould lubricated by paraffin oil and was well compacted. The shaping was done with a mould fabricated from hardened steel. A rectangular and circular mould were used in the shaping with dimension of (25x15x5)mm and 25mm diameter and 5mm thickness respectively, punch was fabricated to match the internal dimensions.

The samples were allowed to dry for 48 hours before firing; the samples were fired in an electrically operated furnace with a gradually rising temperature up to 1200°C. At the end of the firing period, the samples were gradually cooled.

RESULT AND DISCUSSION

The physical and electrical properties of the porcelain produced was obtained as shown in the table below

Table 1. Physical properties of the produced porcelain

Properties	Sample
Total shrinkage (%)	6.60
Apparent porosity (%)	10.37
Apparent density (g/cm^3)	2.12
Bulk density (g/cm3)	1.79
Water absorption	5.49
Modulus of Rupture	16.85

Table 2. Electrical properties of the produced porcelain

Frequency (Hz)	Dielectric constant	Loss angle	Dissipation factor
50	10.9	7.01	0.122
100	10.4	4.21	0.073
1000	9.7	3.80	0.066
10000	9.0	3.20	0.055

Breakdown voltage : 26kV/mm

The maximum value of the dielectric constant of the kaolin-feldspar-quartz (kfq) sample is 10.9, suggestive of a good insulating material. Good insulating materials are materials with dielectric constant below 12 (Anih, 1988). The significance of the low dielectric constant is that the charge storage capacity of the insulator is low and this is the main difference between dielectrics for insulator and capacitors.

Thus the insulator could be used as capacitor bushings where low charge storage capacity is very desirable. Materials with dielectric constant above 12 are generally materials for capacitors and transducers.

This characteristic of the kfq sample shows that the insulator might be more efficient for high frequency applications such as pulse coils in radar, insulating member in induction heating, etc.

Based on the experimental results obtained in this study and in comparison with commercial porcelain, the following can be inferred:

(a) That using the locally available raw materials, electrical porcelain with good dielectric properties can be produced since it has dielectric constant below 12.

(b) That the characterized universal composition, kaolin from Ukpor, locally obtained feldspar and quartz has the potentialties of good electrical insulator.

(c) That the insulator might be more efficient at high frequencies where the dissipation factor is correspondingly lower.

Conclusion

The raw material availability and processing requirements have been ascertained for successful production of high quality porcelain from Nigerian's minerals. There exists a big potential for development of small and big scale manufacturing enterprises in the sector with multiple benefits to the economy.

Insulator manufacturing business is a labour intensive one and hence can create employment opportunities for the skilled and unskilled. It is highly expected that local production of insulator will improve not only the economy but the power sector tremendously.

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