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Full Length Research Article

STRUCTURAL ANALYSIS AND SURFACE MORPHOLOGY OF KAOLIN

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ABSTRACT
The structural analysis and surface morphology of kaolin has been studied. Kaolin is a soft white mineral that has a large array of uses. Kaolin as found in nature usually contains varying amounts of other minerals such as muscovite, quartz, feldspar, and anatase. Microscopic techniques, such as X-ray fluorescence (XRF), X-ray diffraction (XRD) and scanning electron microscopy (SEM) were used to observe the surface and internal structure of the kaolin. The results among other things revealed that kaolin consist of mainly SiO_2, with crystal structure, Microscopic examination showed that has a porous cellular structure and consists of irregular-shaped particles.

KEYWORDS: Quartz, Kaolin, Surface Morphology, XRF, XRD, SEM

INTRODUCTION

Kaolin is a soft white mineral that has a large array of uses. Kaolin is named after the hill in China (Kao-ling) from which it was mined for centuries (Rytwo, 2008; Wallenfeldt, 2013). In its natural state kaolin is a white, soft powder consisting principally of the mineral kaolinite, which, under the electron microscope, is seen to consist of roughly hexagonal, platy crystals ranging in size from about 0.1 micrometre to 10 micrometres or even larger (Carroll, 1970; Ciullo 1996; Aleanizy *et al,* 2014). These crystals may take vermicular and booklike forms, and occasionally macroscopic forms approaching millimetre size are found. Kaolin as found in nature usually contains varying amounts of other minerals such as muscovite, quartz, feldspar, and anatase (Richerson, 2005). In addition, crude kaolin is frequently stained yellow by iron hydroxide pigments. It is often necessary to bleach the clay chemically to remove the iron pigment and to wash it with water to remove the other minerals, in order to prepare kaolin for commercial use (Byrne and Deasy, 2002; Sparks, 2003; Weil and Levchik, 2008).

Kaolin, or china clay, though relatively scarce in nature, is of particular interest to the potter. It is indispensable in the making of pure white porcelain or china. The management of kiln temperatures up to about 1200°, and the manufacture of vitrified white ware, using kaolin as the chief clay, dates, in China, to as far back as A.D. 600. In China, wares made from white clays were fashioned at least from the beginning of the Han Dynasty, 200 B.C., or earlier.

This antedates the manufacture of porcelain in Europe by 1000 years. In China, china clay or white burning kaolins are more commonly found than elsewhere; furthermore they are more plastic and workable than the white clays of other regions (Doherty, 2002). Early Chinese potters at first made soft white earthenware from kaolin. Gradually, over a period of development lasting several hundred years, they learned to reach higher temperatures in their kilns and to make the proper additions to their clays to achieve the hardness, whiteness, and translucency of true porcelain. This discovery of porcelain was a technical triumph in the development of ceramics (Ganse, 2008).

The whitest-burning kaolin clays, and hence the most pure, are primary clays that were weathered at the site of the feldspar (Zakin, 2011). They are coarse in particle size and are therefore less plastic compared to most sedimentary clays. In chemical composition kaolins approach the formula of the mineral kaolinite ($Al_2O_3.2SiO_2.2H_2O$) (Hendricks, 1936; Hendricks, 1939). Kaolin is a highly refractory clay and has a melting point above 1800°C. Used by itself, kaolin is difficult to shape into objects because of its poor plasticity, and also, because of its refractoriness, it is difficult to mature by firing to a hard, dense object. In practice, therefore, kaolin is seldom used by itself; other materials are added to it to increase its workability and to lower the kiln temperature necessary to produce a hard; dense product. As would be expected, the shrinkage of kaolin is low because of its relatively coarse grain structure, and it has little dry strength (Matsushima *et al,* 1967).

However, literature on structure and morphology of kaolin is scarce here in Nigeria. Therefore, this paper reports the results of an investigation into the structural analysis of feldspar using X-ray fluorescence (XRF), Scanning electron micrographs (SEM) and X-ray diffraction (XRD). The aim is to study the structure and surface morphology of feldspar collected from a local supplier (Maju Saintifik Sdn Bhd, Malaysia).

MATERIALS AND METHODS
The following tests were conducted to characterize the kaolin.

X-ray Fluorescence (XRF)
X-ray fluorescence (XRF) is the emission of characteristic "secondary" (or fluorescent) X-rays from a material that has been excited by bombarding with high-energy X-rays or gamma rays. The phenomenon is widely used for elemental analysis and chemical analysis, particularly in the investigation of metals, glass, ceramics, building materials and for research in geochemistry, forensic science and archaeology.

The kaolin used in this study was from the local supplier (Maju Saintifik Sdn Bhd) Malaysia, which is in powder form. The powders were pressed into pellets with ratio 8:2, powder to wax. The MP used in producing the pellets is 8 tonnes and hold time is one minute. The samples were placed in the XRF machine for elemental analysis. The machine (XRF Bruker S4 Pioneer) was operated at 60 KV.

Scanning Electron Microscopy
JOEL-JSM-6380 Instrument was used to study the morphology of the kaolin which is available at Mechanical Laboratory, Universiti Tun Hussein Onn Malaysia. Small amount of kaolin powder was poured on the carbon tape which is attached to the holder. Then the excess powder was blown with air gun to ensure that small pieces of the powder remain on the tape. After that it was put into in the SEM chamber for analysis. The SEM is machine was operated at operated at 10kV. The magnification of X1000 is used to capture photo of the sample.

Kaolin X-Ray Diffraction (XRD)

The kaolin powder was subjected to X-Ray Diffraction (XRD) analysis using an X-Ray Diffractometer to determine their silica structure. Prior to analysis, the samples was ground to a powder form by simple pounding using a mortar and pestle due to its brittle nature.

The ground samples were analyzed by Cu Kα radiation with a scanning rate of 0.05º per second 40kV/20A, speed 0.05º/min and scanning at $3^o \geq 2\Theta \leq 90^o$. The X-Ray Diffractometer (Model Bruker D8 Advance) is available for use at the Faculty of Civil Engineering, Universiti Tun Hussein Onn Malaysia.

Thermogravimetric Analysis (TGA)
TGA of the kaolin was determined by using Lenseis Thermobalance instrument, in Ceramics and Polymer laboratory UTHM. Information about the thermal properties of kaolin especially the point is of great importance to this study. The TGA observation can give the temperature change of the sample to obtain suitable sintering temperature. To do the test little amount of feldspar powder (33.1mg) was used for the heating and cooling. The speed of the test was 10ºC/minutes and the maximum temperature 1000ºC.

RESULTS AND DISCUSSION
The chemical composition of the kaolin is shown in Table 1. The presence of various compounds within kaolin raw material can be seen in the Table. This table shows the result of XRF analysis of kaolin. It is evident that SiO_2 is the major component with 69.30 wt% followed by alumina with 24.30 wt%.

Table 1: Chemical analysis of Kaolin

Sample	Content (%wt)											
Composition	SiO_2	Al_2O_3	FeO_3	CaO	K_2O	P_2O_5	MgO	SO_3	Na_2O	MnO	TiO_2	CO_2	LOI
Kaolin	69.30	24.30	0.27	-	2.44	-	-	-	-	-	0.27	0.10	0.36

Figure 1 shows the kaolin particles; the particles were irregular in shape and having porous texture. There is an agglomeration of the particles.

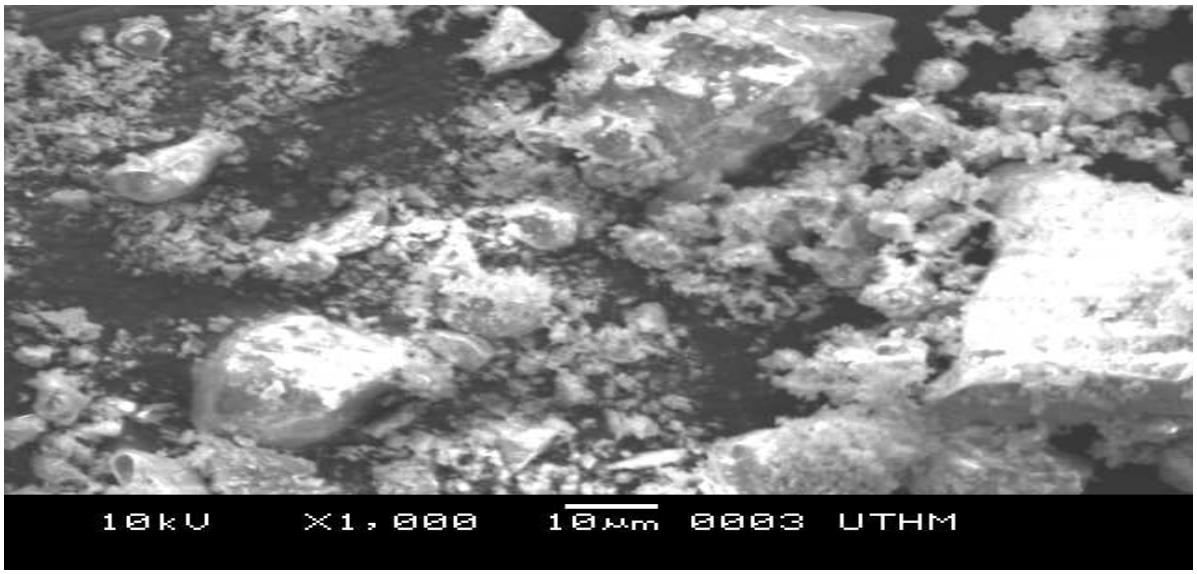

Figure 1: SEM of Kaolin

XRD patterns of the kaolin raw material (Figure 2) show the presence of five crystalline phases namely: quartz hexagonal (ICDD 070-3755), kaolinite triclinic (ICDD 001-0527), montmorillonite hexagonal (029-1499), koenite hexagonal (ICDD 0073-6118) and potassium silicon hydride cubic (023-0467). This result is in line with XRF result presented in Table 1.

Figure 3 depicts the TGA analysis results for the kaolin raw material. For the kaolin raw mterial at 12 °C weight loss is 0.07 mg due to both kaolinite dehydroxylation reaction and quartz phase transformation. At the temperature of 925 °C the weight loss is 0.01 mg which is attributable to mullite crystallization.

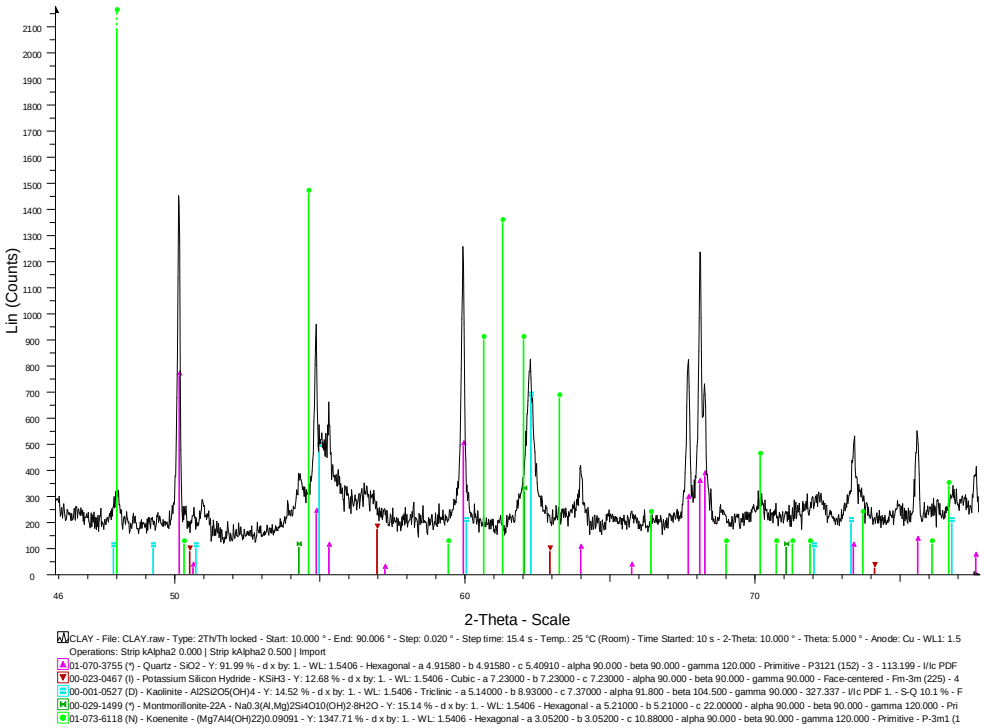

Figure 2: XRD of Kaolin

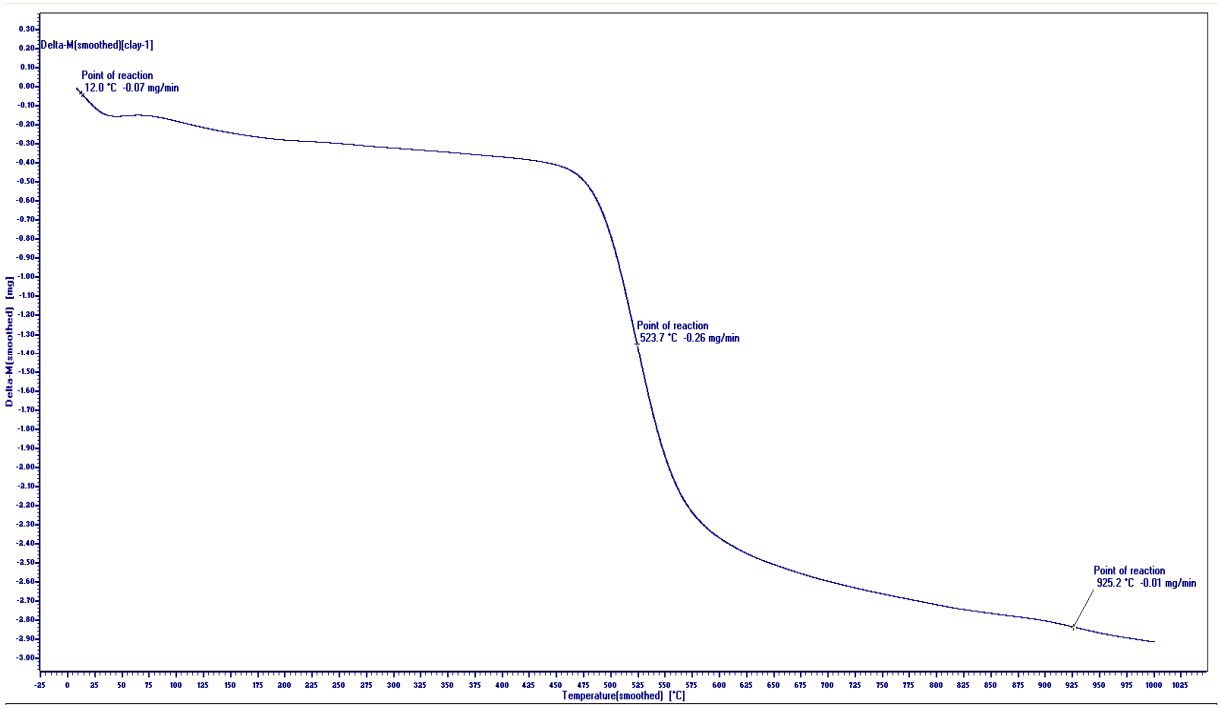

Figure 3: TGA of Kaolin

CONCLUSION

Kaolin is a valuable natural resource not only as a good source of silica, but also as a source of lignocellulosic material which can be potentially used to produce an array of valuable products. However, product development will require greater understanding of the kaolin. The information provided here could form both a useful background on the compositional and morphological characteristics of the kaolin surface as well as its internal tissues. Therefore the extension of knowledge on structural analysis and surface morphology of the kaolin is very important for the determination of which type of kaolin can be used by industries.

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