Dielectric Properties of Iraqi Clay; Effect of Alumina Content

Dr. Qasid Abdul Sattar
Nahrain University/College of Science / Physics department

Dr. Talib Saloom Hamadi
Nahrain University/College of Science / Physics department

Abstract

In order to investigate the alumina effect on the low frequency dielectric constant of fire clay manufacture from Iraqi clay. Fire clay products have been powder pressed with different alumina content ,sintered ,then dielectric constant and dielectric loss(*tan* δ) has been measured at low frequencies which extend from 30 kHz to 100kHz.There is a significant difference in their properties were observed between samples made with different alumina content added to the fire clay product where these differences were measured as a function of alumina content. This confirm that the insulating properties of the fire specimen from the electrical view point was affected by the crystallization of mullite and cristobolite .

Keywords: dielectric constant, alumina, fire clay, mullite.

Introduction

Iraqi clay is a sedimentary material consisting of fine particles of crystallized aluminium hydro-silicates with a layer structure. The most important clay minerals for use in refrectories are; kaolinite. Kaolinite is one of the most clay minerals for use refrectories. The composition is $Al_2O_3.SiO_2.2H_2O$ which belongs to kaolin group. They have two layered crystal lattice. Fire clay is a non-white burning which is free from fluxes such as larger quantities of iron ,alkaline earths, alkalis and excess silica. Our work has been based on clays from Dewechla deposites. This raw material had a number of promising properties which justified a more extensive evaluation concerning its use in the manufacture of fire clay refrectories, where the largest consumer of this type of clay will be the metallurgical industries for electric-furnace roofs and in high structural applications, because of its low dielectric constant

Theory

When heating clay to 150 C˚, residual free water is removed. In the range between 450 to600 C˚, chemical decomposition take place and the so-called combined water is driven off [1].

$$(OH)_8\,Al_4\,Si_4\,O_{10} \longrightarrow 2Al_2O_3 + 4SiO_2 + 4H_2O$$

Vitrification range starts at about 900 C˚ and extends up to the highest temperature , the clay can withstand without melting where the upper limit of vitrification range depend upon the kind of clay minerals and the impurities present. During the vitrification period the porosity of the product decreases and its strength and hardness increases. Some volume change accompanied vitrification process with no distortion. The area of main interest in the study of the physical and insulated properties of fire clay product is in the range from 35% to 55 % Al_2O_3. When fire clays with composition within this range are heated beyond 900 C˚, the reaction between Al_2O_3 and SiO_2 result in the formation of mullite especially above 1400 C˚[2] . So the reason for the consolidation of the material and the resulting reduction in porosity is the formation of a viscous liquid or the development of sufficient atomic mobility in the solid which allows the forces of surface tension to effect a reduction in volume as well as the mechanism of mullite formation [3].This formation depends upon the method of combining the alumina and silica-containing reactants [4].

Experimental procedure

Specimens preparation and sintering

Local kaolin clay used (94% purity) in this study was obtained from the Dewechla in western region of iraq. Five specimens of different AL_2O_3 content were selected to be 0, 5,10,15,20 wt % relative to kaolin clay. Mixing was carried out through ball milling for 6 h to verify the homogeneity. The green specimens were prepared by using one of conventional shape- forming method such as semi- dry pressing method with water content 6-9 % using hydraulic press under 300 kg/cm. The specimens had a disc shaped 50 mm diameter and 10 mm thick for test the dielectric properties were fired at 1100,1200, 1300,1400,1500 C° with firing rate 3C°/min for soaking time 2 h .

Table.1 Chemical composition and loss on ignition LOI of Iraqi Clay, wt %.	
SiO_2	46.88
AL_2O_3	34.99
Fe_2O_3	00.85
Na_2O	00.69
K_2O	00.68
TiO_2	02.88
LOI	12.94

Dielectric Measurement

The fired specimens were investigated for apparent density, apparent porosity, compressive strength and dielectric constant. Densities of the sintered specimens were determined by Archimedes method with water as immersion medium and the effect of porosity was excluded for the dielectric properties measurement .At low frequencies 30Hz – 100 kHz, both dielectric constant and dielectric loss were measured at different heating temperatures 25, 90 C° by using the device WTW- type DKO5 for low frequency with cell test MFM5T which consist of capacitance bridge of Schering type.

Result and Discussion

Table.2 and 3 show the only selected physical properties of fired clay insulator with different amount of alumina and at firing temperatures 1200 and 1500 C°. It is noted that the addition of Al_2O_3 decreases the firing clay densities while apparent porosity and compressive strength increases. On the other hand, these selected physical properties at 1200 C° temperature are lower than those at 1500 C° which was consider an indication of progress steps in densification process. Also from the same tables; it was noticed that the increasing of Al_2O_3 content and the increasing in firing temperature 1200 to 1500 C° leads to an improvement in the mechanical properties whereas the density and porosity are not. This is due to the sintering of the matrix is not completed and also due to the fact that the total porosity of the specimens increased with increasing the firing temperature.

Table.2 Selected physical properties of fire clay, firing temperature 1200 C.

AL_2O_3 content Wt %	Appar. Density g /cm³	Appar. Porosity %	Comp. Strength kg/cm³
0	1.92	18.3	75.1
5	1.86	20.8	93.3
10	1.83	23.2	107.2
15	1.80	25.9	124.5
20	1.78	28.4	136.0

Table.3 Selected physical properties of fire clay, firing temperature 1500 C°

AL_2O_3 content Wt %	Appar. Density g /cm³	Appar. Porosity %	Comp. Strength kg/cm³
0	2.15	0.99	88
5	2.06	3.25	135.6
10	1.88	5.68	185.0
15	1.85	11.01	199.8
20	1.80	16.55	218.4

Fig.1 show the effect of different alumina addition on the dielectric constant of the clay at temperatures 1200 and 1500 C°. It was noticed that when the alumina content increased the dielectric constant increased. This due to that the increasing of the porosity with increasing alumina content make the dielectric constant of the product will affected. In other hand fig.2 shows the effect of firing temperature on the fire products dielectric constant for heating temperatures 25 and 90 C°, where Dielectric constant increased slightly with increasing firing temperatures. This is due to some reduction in percentage porosity and also due to the formation of mullite which exhibit low dielectric constant especially at low firing temperatures [5]. Fig.3 and 4 show the effect of frequency of the applied voltage at different heating temperatures on the dielectric constant and dielectric loss respectively. We notice from both figures that dielectric constant and dielectric loss decreases with increasing the frequency. This due to the fact that the response of the dielectric constant to an increase in temperature is slow especially above room temperature 25 C° also the decreasing of dielectric loss is due to the localized accumulation of heat under heating condition leads to the rapid destruction of the dielectric properties of the fire clay products [6].

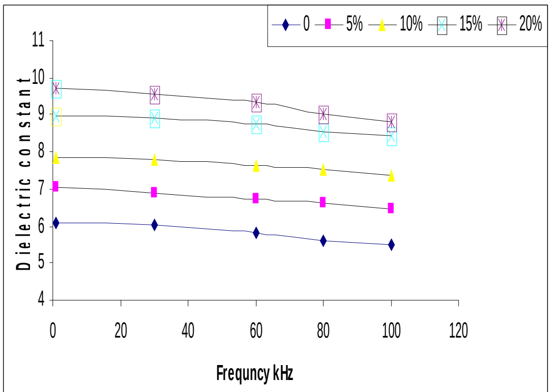

Fig.1 Effect of frequency on the dielectric constant for different alumina content at firing temperature 1500 C° , at room temerature

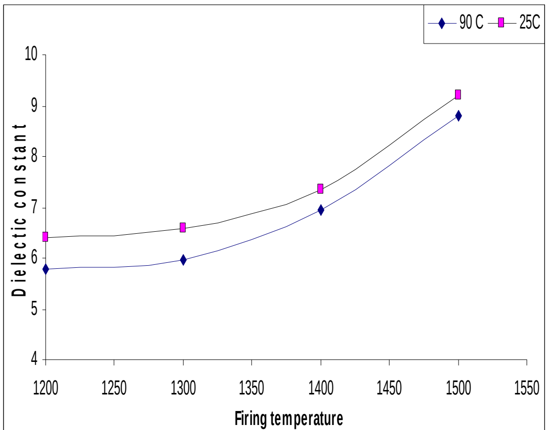

Fig. 2 Effect of firing temperature on the dielectic constant at room temperature and 90 C° at 100 kHz and 20% alumina

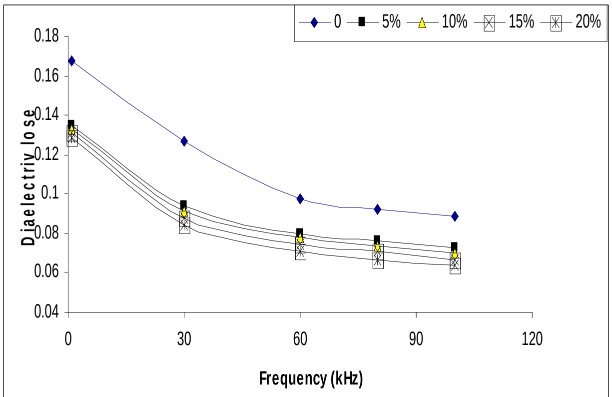

Fig.3 Effect of frequency on the dielectric lose for different alumina containt at firing temperature 1500 C° at room temperature

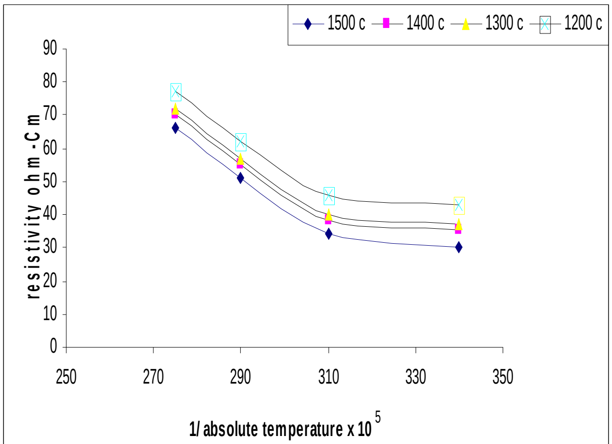

Fig.4 The resistivity temperature relation for high alumina insulator at frequency 100 kHz at different firing temperature

Conclusions

It was found that Iraqi kaolinite clay was suitable for mullite production through reaction sintering with pure Al_2O_3 where formation of mullite completely occurred at 1350 C°. From electric view point, the insulating properties was affected by the crystallization of mullite and cristobolite as would expected appear at this temperature(1350 C°) according to silica-alumina phase diagram . As mullite characterized by low dielectric constant, therefore fire product from local Iraqi clay is consider as insulator because it is exhibit the same insulating behavior. Finally, the results showed that the porosity increased with increasing alumina content; this increasing resulted in the spacing charges which will exist in this kind of the fire product.

References

1- Al-Taie.M.H., Hamid.T.N. , 1975, Manufacture Of Refractoy Clay Brick (Chamotte) From Local Material, Building research center, Baghdad, pp.11.

2- Anggono.J., 2005, Mullite Ceramic, Journal technique Mesin,Vol(7) ,

3- Sahnoune.F., Chegaar. M., SahebN., 2007,Applied Clay Science,Vol.38.

4- Bowen. H., Greig.j.j., 1933 , J.Am.Society, Vol.(16), No(20) .

5- Souto, P.M., Menezes.R.R. Kiminami.R.H., 2008, Sintering Of Commerical Mullite Powder, Journal of Material Processing Technology,Vol.(8),No(11) .

6- Pampuch R., 1976. , Ceramic Material an Introduction to Their Properties, Elsevier Scientific Puplisher Company.

تأثير المحتوى الألومني على خصائص العزل الكهربائي للأطيان العراقية

قاصد عبد الستار صالح   طالب سلوم حمادي

قسم الفيزياء / كلية العلوم/ جامعة النهرين/ الجادرية، بغداد، العراق

الخلاصة

للتحقق من تأثير الألومينا على ثابت العزل الكهربائي لمدى الترددات الواطئة للمنتج الناري المصنوع من الأطيان العراقية حيث تم تشكيل تلك النماذج التي تحتوي على نسب ألومينا مختلفة (20%,15%,10%,5%) ومعاملتها حراريا ثم قياس ثابت العزل والفقدان العزلي لمديات التردد الواطئة (100kHz-30kHz) . حيث لوحظ وجود تحسن في خواص تلك النماذج (الفيزيائية والعزلية)بسبب زيادة محتوى الألومينا المضافة الى نماذج الطين الناري . وقد أعتمد في هذا البحث التغير في ثابت العزل الكهربائي كدالة لتغير محتوى الألومينا وهذا مايؤكد تأثر خاصية العزل الكهربائي من وجهة النظر الكهربائية بظهور كل من المولايت والكرستوبولايت كأطوار في تلك النماذج مما يجعل سلوكها كعازل مقترن بسلوك تلك الاطوار والتي عادة ما تتصف بثابت عزل منخفض .