The Effect of the Mullite Phase on Some Properties of Hard Porcelain

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Abstract

In this study, hard porcelain (with different ratio of mullite phase) has been perpetrated this type of traditional ceramic uses in much different applications because of their properties like chemical stability and high hardness and electrical resistivity.

Conventional ceramic techniques (The powder technology) were used to fabricate this type of ceramic because of its low cost and mass production uses as compared with other techniques.

Four mixtures from hard porcelain has been used from present available raw materials (flint ,clay mineral and flux) , the mullite phase state and calculated by using X-Ray diffraction techniques, sample tested at different sintering temperatures.

The effect of increasing of mullite phase on properties like density, porosity, hardness and M.O.R (Modules of rapture) were studied.

From this study has been shown the increasing of mullite phase lead to increasing density ,hardness , M.O.R and decreasing the porosity because of exist of mullite phase in ceramic matrix.

ملخص البحث

يهدف البحث إلى دراسة تأثير طور المولايت على بعض الخصائص الفيزيائية والميكانيكية للبورسلين الصلد (احد أنواع السيراميك التقليدي) الذي يستخدم في كثير من التطبيقات الصناعية، لما يتميز به من خواص كيميائية كمقاومة المحاليل الكيميائية القوية وميكانيكية كالصلادة ومقاومة البليان العاليتين وكذلك خاصية العزل الكهربائي الجيدة.

تم في هذه الدراسة استخدام التقنيات السيراميكية التقليدية (تكنولوجيا المساحيق) في تصنيع النماذج وذلك لقلة كلفتها مقارنة مع التقنيات الصناعية الأخرى، وإمكانية استخدامها في حقل الصناعات الهندسية خاصة في نمط الإنتاج الكبير.

استخدمت في هذه الدراسة أربع خلطات من البورسلين الصلد تتكون هذه الخلطات من مواد أولية متوفرة في القطر (رمل الزجاج، معادن طينية، معدن الفلدسبار كمساعد صهر ومصدر الالومينا Al_2O_3) تم تحديد وحساب طور المولايت المتكون بعد عمليات التلبيد بواسطة تقنية حيود الأشعة السينية، اختبرت النماذج عند مديات تلبيد مختلفة ثم تم دراسة تأثير زيادة طور المولايت على خواص الكثافة والمسامية وكذلك على معيار الكسر والصلادة.ومن خلال هذه الدراسة تبينَ أن زيادة طور المولايت تؤدي إلى ارتفاع قيم الكثافة وانخفاض المسامية وكذلك زيادة قيم الصلادة مع ارتفاع قيم معيار الكسر بزيادة طور المولا يت لما يتميز به هذا الطور من خصائص تحسن هذا النوع من السيراميك التقليدي.

1-Introduction

Porcelain is the term that used to describe white-vitrified ceramic ware, translucent in thin layers, impermeable to fluids, and manufactured from a fine mixture of kaolin, quartz and plastic white firing clay.

As a technical material, porcelain posses a number of valuable properties, high mechanical and electrical strength, good chemical resistance and spalling resistance [1].

The mechanical strength ,spalling and chemical resistance of porcelain increase as the amount of mullite increasing due to the greater contain of kaolin in the mixture .

However, kaolin can only be added within certain limits, because of the plasticity losing of the mixture and to avoid reaching to the ware firing temperature when the amount of kaolin is increased [2].

Recrystallized mullite and liquid phase containing unreact quartz and cristobalite define the strength and behavior of vitrified porcelain.

During the firing of triaxel porcelain, the quartz dissolves partly in the feldspar melt with the attendant formation of liquid phase as well as

the appearance of mullite. The un reacted residual quartz crystal have a higher coefficient of thermal expansion as compared to that of the surrounding glassy phase , hence giving arise to thermal stress which remarkable effect to the strength of porcelain [3,4].

Clay (kaolin) are the most important ceramic raw material, their applications in the various fields are determined by their compositions, purity and homogeneity [5].

Equations (1) and (2) explain the formation of mullite from kaolin during sintering. [6]

$$Al_2O_3.2SiO_2.xH_2O \xrightarrow[-xH2O]{980C^o} \quad \ldots\ldots\ldots (1)$$

a) $3\ Al_2O_3.2SiO_2$
   Cubic mullite (Si- Al spaniel, major phase)
b) $3\ Al_2O_3.2SiO_2$
   Orthorhombic mullite (weakly crystalline) minor phase
c) Alumina silicate phase (amorphous)
d) SiO_2 (amorphous).

$$3\ Al_2O_3.2SiO_2 + SiO_2 \xrightarrow[-SiO_2\text{ amorphous}]{\text{Alkali leaching}} \quad \ldots\ldots\ldots (2)$$

Si-Al spinal

Kaolin heated at 980C^o

Leached residual 1250 C^o mullite.

Fig.(1)explain the ternary phase equilibrium diagram for system flint ,feldspar and clay the diagram state the range of mullite formation and different type of porcelain.

Fig.(1):- The ternary phase equilibrium diagram for system flint ,feldspar and clay[7]. 2-Experimental Procedure

For the preparation of the samples, the following raw materials have been used: Kaolin, feldspar and quartz, whose chemical compositions are included in table (1).

The batch compositions of experimental bodies calculated depending on chemical analysis are shown in table (2).

The raw materials were ground separated to pass (-10) µm sieve and mix to make the experimental composition in table (2).
Discs of (30) cm diameter and (15) mm thickness were fabricated under pressure, dried at 110C^{o} and fired between (1250- 1350) C^{o} (Temperature –intervals of 50C^{o}) in electrical furnace. Moreover, the specimens were soaked for (1) hr at the respective firing temperature.
Bulk density and porosity were determined according to ASTM (20-74) sample in the form of bars (3.5*4*50) mm were processed under the same conditions and fired at the selected maturing temperature to measure the hardness and modules of rapture [8,9,10] .
To determine the amount of mullite phase used quantitative X-ray diffraction analysis of compositions [11].The X-ray diffraction analysis results of samples are shown in the figure no.(2) .

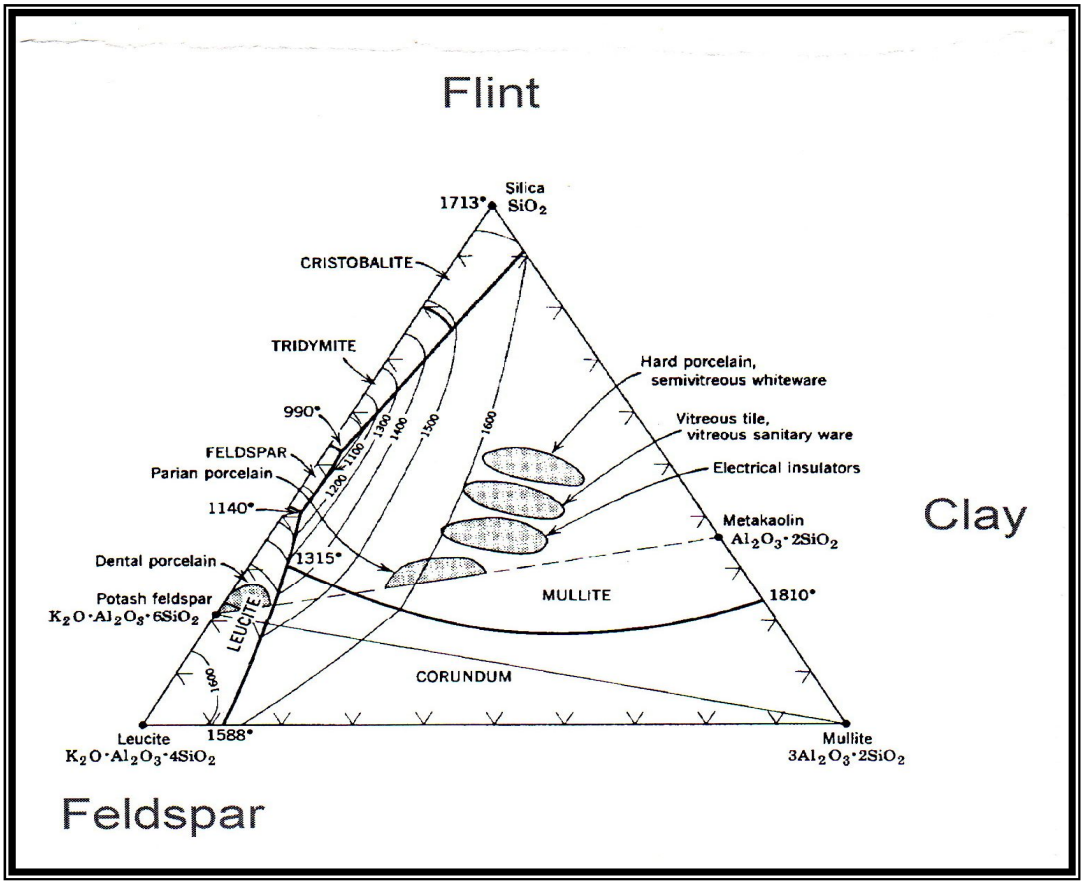

Table (1):- Chemical composition of raw materials.

Materials ↓	Compositions			
	SiO_2	Al_2O_3	K_2O	Na_2O
Kaolin	51	32	0.4	0.4
flint	98	0.5	-	-
feldspar	66.27	17.9	11	2.5

Table (2):- The batch compositions of experimental bodies calculated depending on chemical analysis.

Mullite Code	Mullite phase *%	SiO_2	Al_2O_3	KNaO
M1	17	69.95	19.49	2.45
M2	20	75.4	16.3	3.7
M3	27	66.7	21.2	3.8
M4	30	72.2	17.20	4.4

*The characters spacing of X-Ray Diffraction are (200)d and 2.69A^o

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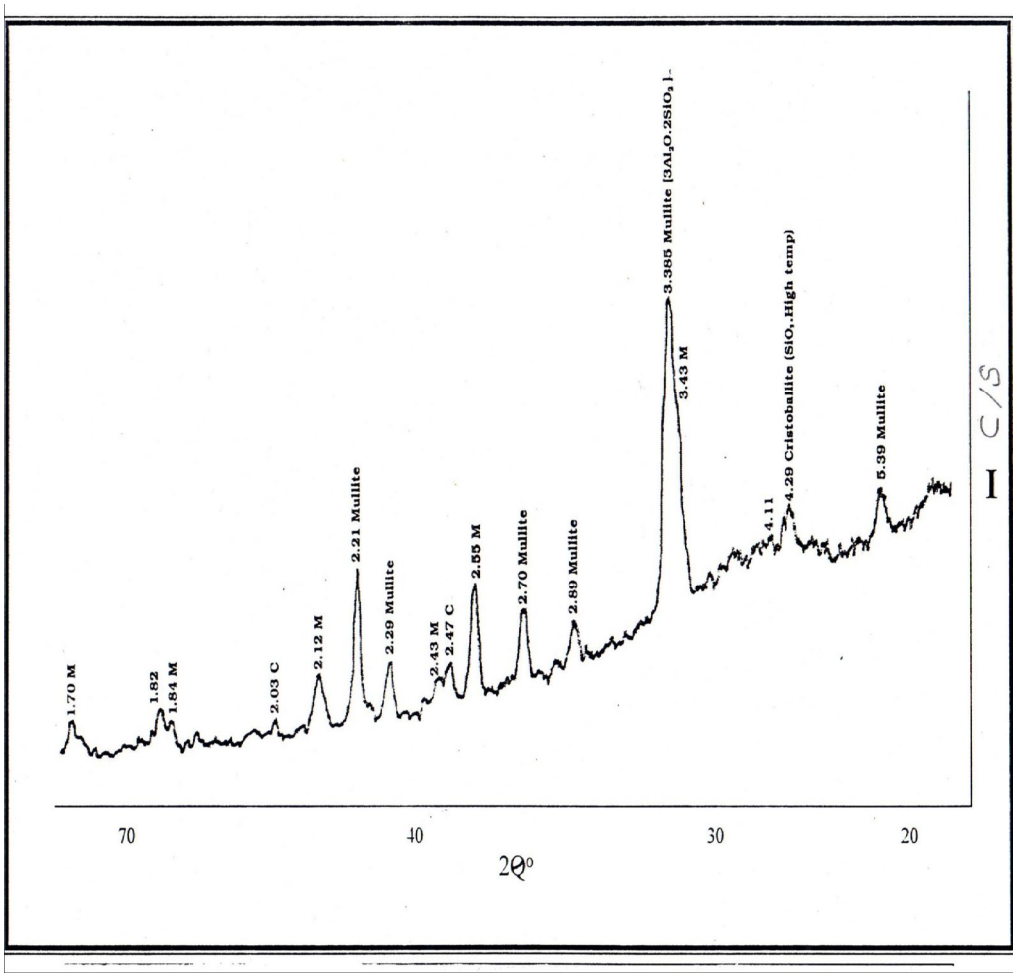
Fig. (2):- The X –Ray diffraction analysis for Sample(M1) at 1300C^{o}.



3-Results and Discussion

Fig. (3) show the relationship between sintering temperature and bulk density for sintering body with different mixture in mullite phase , from the figure all of mixtures reach their maximum bulk density at 1300C^{o} which indicated that samples approach their theoretical density value for this type of ceramic .

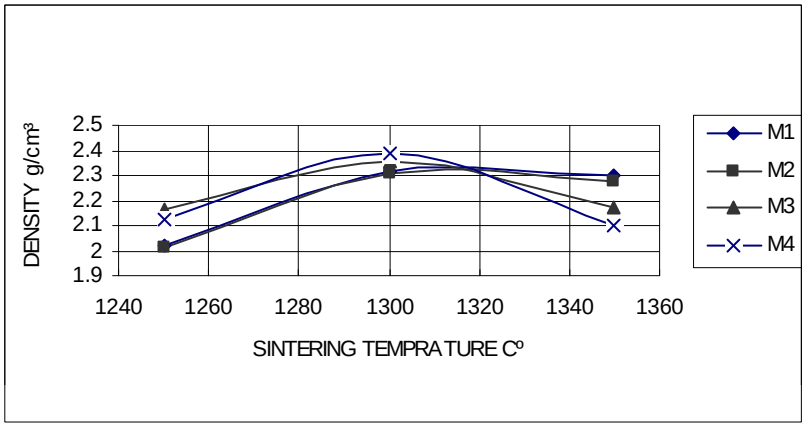


Fig.(3):- The relationship between sintering temperature and density.

Figures(4,5)explained the relationship between mullite phase containing, bulk density and porosity respectively , the figures shows with the increasing of mullite phase the density value increase and the porosity value decrease because of the mullite phase having high value of density and increasing the glassy phase that produce from (KNaO) containing in mixture having (30)% mullite and that' s lead to close the pores and increase density value [12].

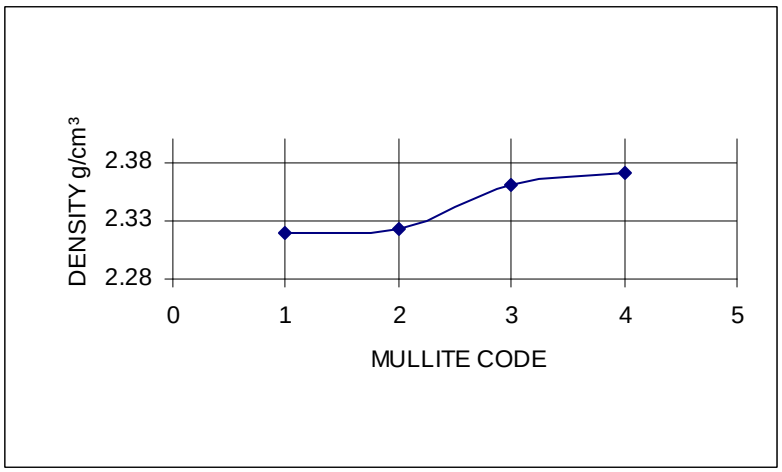


Fig.(4):- The relationship between mullite code and density.

Fig.(5):- The relationship between mullite code and porosity.

Figures (6,7) explained the relationship between contain of mullite phase the value of hardness and modules of rapture , the figure shows increasing the hardness value and modulus of rapture because of growing fine needle structure of mullite phase above 1250C^{o} and this structure having high mechanical properties and also increasing of packing factor of the atoms for ceramic body during sintering under suitable thermal range [2,12] .

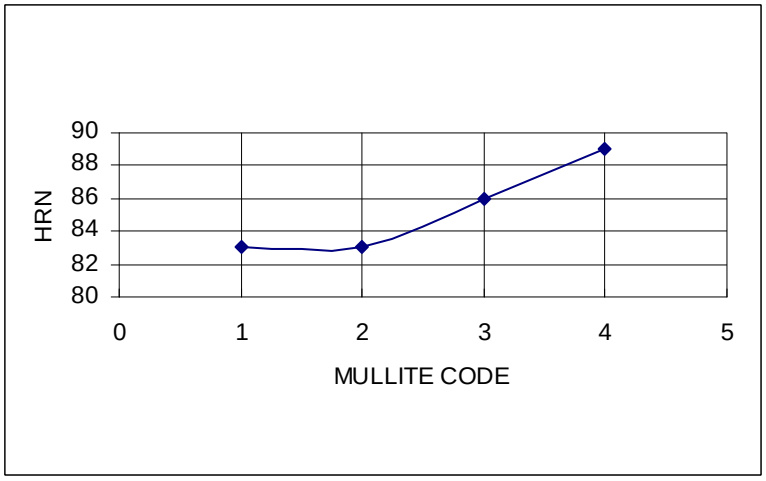


Fig.(6):- The relationship

between mullite code and hardness.

Fig.(7):-The relationship between mullite code and modules of rapture.

4-Conclusions

1. Sintering temperature for this type of ceramic body at 1300C^{o} with soaking time 3hr.
2. Increasing mullite phase with glassy phase contain increase the value of density and decrease the value of porosity.
3. Maximum value of hardness reaches to 89HRN and with modules of rapture reach to 32M pa.
4. This type of ceramic body needs high accuracy for manufacturing.

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