SYNTHESIS OF FELDSPAR SUBSTITUTES VIA UTILIZATION OF LOCAL MATERIALS

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Abstract:

Four varieties of sodium feldspar substitutes have been prepared. Different percentages of kaolin, silica and sodium salts are milled, mixed and submitted to heat treatment. The reacted powders are then grinded and tested by x-ray diffraction. The results show the existence of feldspar phase. The densities were measured and show close agreement to the reported values. The final result is establishing a technological root for the synthesis of feldspar substitute utilizing local materials.

Keywords: feldspar substitute, sodium feldspar, solid reaction, local materials, technological root.

تحضير بدائل الفلدسبار باستخدام مواد محليه

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الخلاصه:

تم تحضير اربعة انواع من بدائل الصوديوم فيلدسبار. وقد تم طحن نسب مختلفة من الكاؤولين والسيليكا واملاح الصوديوم تم الخلط والتعريض للمعالجة الحرارية. وتم طحن المساحيق المتفاعلة وفحصها بحيود الاشعة السينية. وقسيت الكثافات الناتجة ووجد انها قريبة جدا من القيم الموثقة. وتم الوصول الى نتيجة نهائية باستحداث مسلك تكنولوجي لصناعة بدائل الفيلدسبار باستثمار المواد المحلية.

INTRODUCTION

Broad ranges of triaxial ceramic compositions are used in ceramic and glass industries. These are including white wares, insulators, pots, filters, fillers and every aspect of glass applications. These products are essentially contains kaolin, quartz and feldspar. (**Bhattacharyy 2005, Dannert 2001**)

The kaolin is a source of alumina and silica and it is usually of fine particle size that brings plasticity necessary to assist forming. Feldspar acts as a flux, forming a viscous liquid at firing temperature that aids vitrification. Thus, the feldspar is vital to successful sintering, i.e. forming the final ceramic body. The quartz is mainly an inexpensive filler material which remains un-reactive at low temperature of firing and forms a highly viscous liquid at higher temperatures. The main differences between the compositions are in relative amounts and kinds of feldspar and kaolin used. Mullite ($3Al_2O_3.2SiO_2$), *a*-quartz and glass contribute major portion of porcelain microstructure in triaxial based kaolin–quartz–feldspar system. (**Andreeva 2003, Saiintawong 2008**).

In addition to the major role in sintering porcelains, the feldspar is also very important low temperature component in glass receipts. The feldspar helps forming balanced amounts of alumina, silica and fluxing alkalizes that improves the mechanical properties of the produced glass.

The feldspar itself is not naturally stoichiometric for the alumino-silicates and alkalizes. It is naturally occurring as mineral mines or volcanic rocks. It is often exists together with the quartz or, occasionally, with mica and some silicates. Feldspar precipitates that are found in desert areas are usually less abundant to be of economical amounts. (**Britton, 2003**)

The well-known types of feldspars are potassium, sodium, calcium, barium, lithium feldspars and else. The ratio of the alkaline oxides to the alumina and silica content was 6:1:1; and it was 2:1:1 for the alkaline earths oxides. **Table (1)** illustrates some physical and chemical properties for a number of feldspars. The melting point was in the range of (1118-1532°C), the densities falls in the range of (2.53-3.37g/cm^3) and (6-6.5moh) for hardness. (**Sikalidis, 1977**)

The alkalize in the feldspar decreases its melting point, e.g. when the porcelain (kaolin-feldspar-silica) is subjected to high temperature, the feldspar converts to viscous vitreous state and then melts while the other components stays in the solid state. The feldspar melt assists wetting of solid particles which then agglomerates by surface tension. On a second stage, the melt diffuse in remained body pores and enhance partial melting during the heat treatment. The feldspar of finer particle size accelerates this process. (**Rasmussen 1971, Singer 1984**)

The feldspars are usually used in fine ceramics with weight ratio of 10-50%. The potassium feldspar is distinguished for its relatively low melting point (1150°C) where the Lucite phase ($K_2O.Al_2O_3.4SiO_2$) starts evolving with extra silica. The Lucite phase has high viscosity (10 dpoise) at temperature of 1400°C, where, the sodium feldspar has lower melting point (1118°C) and has low viscosity (10^{-1} dpoise) at 1425°C. Therefore, the sodium feldspar proves also useful in glazing and glass technology (**Rasmussen, 1971**).

The employment of feldspar in the composition of ceramics has obvious effect on plasticity, transparency, thermal and mechanical properties. In addition, the feldspar has noticeable benefit in the production of glass due to its role in melting of silica, thermal expansion, chemical resistance, scratch resistance and compressive strength of the final product. (**Budnikov, 1982**)

The feldspar is sometimes substituted by (nepheline syenite) in some countries like America and Canada. The nepheline syenite has chemical composition compared with that of feldspars and it can be found within the volcanic rocks almost free of extra silica. The density of the nepheline syenite is around 2.54 g/cm^3 and its hardness is 6 moh. (**Britton, 2003**)

The feldspar plays a very important role in ceramic and glass industry. Substitutes of feldspars can be utilized as a replacement. Finally, due to the lack of feldspars and its substitutes in Iraq and the imported materials is usually expensive, the porcelain and glass industry need alternatives. The goal of this project is to establish a technological root for the synthesis of feldspar substitute utilizing materials locally available.

Experimental part:

Iraqi Duekhla kaolin and Iraqi Urdhuma flint (silica) was brought from the Department of Geological Mining of the Ministry of Industry, Baghdad. The chemical analysis was performed at the same department for both the kaolin and the flint and shown in **tables 2 and 3**.

Commercial grade sodium carbonate (purity 98%) was utilized. The remaining (impurity) parts of the carbonate were mainly kaolin and silica. Pure alumina (99.5% purity) is also utilized. The impurities were also kaolin and silica.

The powders were milled and sieved via laboratory milling and sieving system. Powder below 75μm was used for the subsequent steps. Different weight percentages for powder recipes is experimented to prepare the feldspars. Each recipe was mixed for 6hrs by means of a planetary mill and porcelain balls to assure homogeneous mix. The weight percentages for the best results are shown as four recipes in **table ٤**.

After mixing, steel dies and hydraulic press was used to prepare the powder compacts. Single action die compaction is utilized. The compacting of powder mixes is performed to increase

the contact area of mix components and accordingly, to enhance solid-solid reaction. The compacting pressure was 7MPa and the resulting dimensions of the cylindrical compacts were 3cm diameter and 2cm height.

Numerous heat treatment experiments were performed to achieve the best heat treatment schedule. The criterion is to obtain complete solid-solid reaction. Straus (Germany) muffle type furnace has been used for heat treatment. The final heat treatment schedule is shown in **table 5**.

X-ray diffraction of the reacted powders is utilized to evaluate the results. Cu-kα radiation was used to obtain x-ray diffractograms on Phillips diffraction system at Al-Raya Company. ASTM diffraction data files, vol.7 dec1897) (**McClune, 1987**) was employed to compare and to define the resultant phases. The densities are also evaluated by means of both the geometrical and Archimedes methods.

Results and Discussion:

The reacted powders shown by **table (4)** by means of the heat treatment shown in **table (5)** is given the same code numbers and referred below as sample no.1, 2, 3 and 4.

The sample no.1 has greenish color and a relatively low melting point compared with the other feldspars. This agrees with the literature when examining its x-ray diffractogram presented in **fig.1**. The diffractogram shown in **fig.1** illustrates that an obvious amount of silica does not reacted. The low melting temperature indicates the existence of the glassy phase Na_2SiO_3 which cannot be detected by x-ray diffraction and also explain the greenish color.

The major part of the used alumina was replaced by the kaolin for the sample no.2. The x-ray diffractogram in **fig.2** shows that the amount of the free silica is reduced. The introduction of kaolin as a starting material and a source of alumina prove advantage. The sample color is now more bright or cream. The melting temperature is higher than the sample no.1, explicitly, 1150°C. Thus, samples no.1 and 2 is very close to the pegmatite ore. The pegmatite is composed of silica and feldspar and usually found applications in porcelain industry when the iron oxide impurity does not exceed 0.5%. The pegmatite is also used in glass industry and the iron oxide impurity is accepted up to 2%. (**Gülsoy2005, Sikalidis 1977**)

When the kaolin content is further increased at the expense of silica for the sample no.3, the x-ray diffractogram (**fig.3**) did not show evidence for the silica phase. This indicates that some sort of stoichiometry is achieved. Thus, sample no.3 can be regarded as single phase sodium feldspar. On the other hand, the high background scatter displayed in the diffractogram may indicate deficient crystallinity. The poor crystallinity may encourage early disintegration when used as part of porcelain content. The early disintegration of the feldspar when firing the porcelain body may initiate the formation of the mechanically weak phase Na_2SiO_3. Therefore, attempts are made to have better crystallinity by trying to improve the stoichiometry of the starting recipe.

The improved recipe is attained and reflected as sample no.4. The x-ray diffractogram for that sample (**fig.4**) shows sharper peaks and enhanced intensities. The d-spacing values better fits the ASTM standard for the sodium feldspar. The high angle peaks are displayed clearly which is resembles other indication for good crystallinity for the synthesized sodium feldspar.

It remains to state that the measured densities for the four types of the synthesized feldspar are 2.5-2.52g/cm^3 which agrees with the reported density values for sodium feldspars.

CONCLUSIONS

Four types of sodium feldspar substitutes have been prepared which can find applications in glass and porcelain industry. The starting materials are mainly local raw materials. The first and second type has free silica and close to the pegmatite ore. The third type show no evidence of free silica and the forth shows better crystallinity. This give broad range of materials choices of the feldspars.

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Table (1): physical and chemical properties for some feldspars (Sikalidis , 1977)

Minerals	Formula	Density g/cm^3	Hardness moh	Melting point $^{\circ}C$	Color	Crystalline form
Potash feldspar	$K_2O.Al_2O_3.6SiO_2$	2.54	6	1150	White	Monoclinic
Soda feldspar	$Na_2O.Al_2O_3.6SiO_2$	2.63	6-6.5	1118	Grey	Triclinic
Lime feldspar	$CaO.Al_2O_3.6SiO_2$	2.7-2.76	6-6.5	1552	White	Triclinic
Barium feldspar	$BaO.Al_2O_3.6SiO_2$	3.37	>6	----	----	Triclinic
Lithium feldspar	$Li_2O.Al_2O_3.6SiO_2$	2.64	5.5-6	----	White	Monoclinic

Table (2): Chemical analysis of Duekhla Kaolin

Oxide	Weight %	Oxide	Weight %
SiO_2	47.26	CaO	0.15
Al_2O_3	34.84	MgO	0.38
Fe_2O_3	1.32	NaO_2	0.25
TiO_2	1.4	K_2O	0.61
Loss of Ignition L.O.I. 12.91			

Table (3): Chemical analysis of Urdhuma Flint

Oxide	Weight %	Oxide	Weight %
SiO_2	98.4	CaO	o.3
Al_2O_3	0.4	MgO	0.3
Fe_2O_3	0.05	L.O.I.	0.55

Table (4): wt% for the powders included to prepare the feldspars

code	sodium carbonate	kaolin	Silica	Alumina
1	20.2	----	19.4	60.4
2	20.2	34.4	41.4	4.0
3	20.2	48.8	28.8	----
4	20.2	51.3	26.3	----

Table 5: Heat treatment schedule used for preparation of feldspars

Heating rate	2°C/min
Max. temperature	1100°C
Firing time	2hrs
Cooling rate	5°C/min

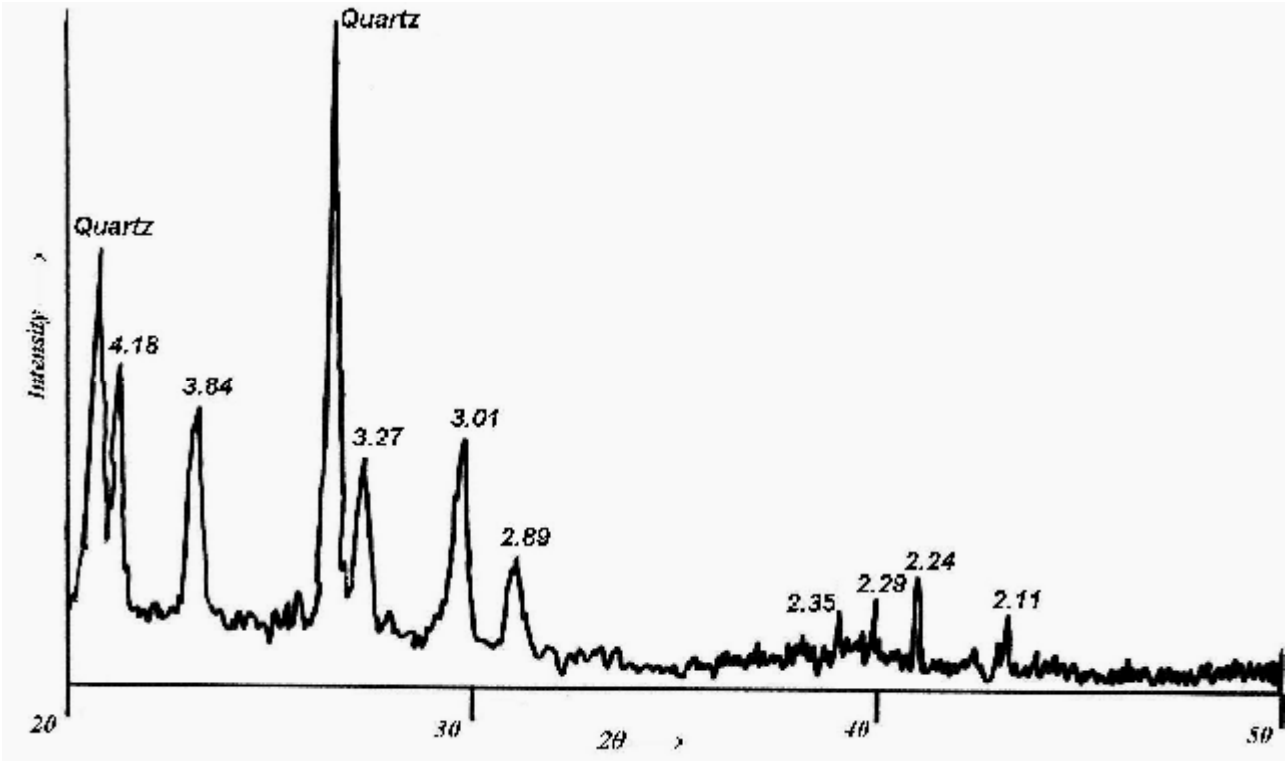

Fig.1: X-ray diffractograms for sample no.1, the d-spacing value of the mean peaks for the sodium feldspar are shown. The peaks that indicates the silica (quartz) phase is marked, as well.

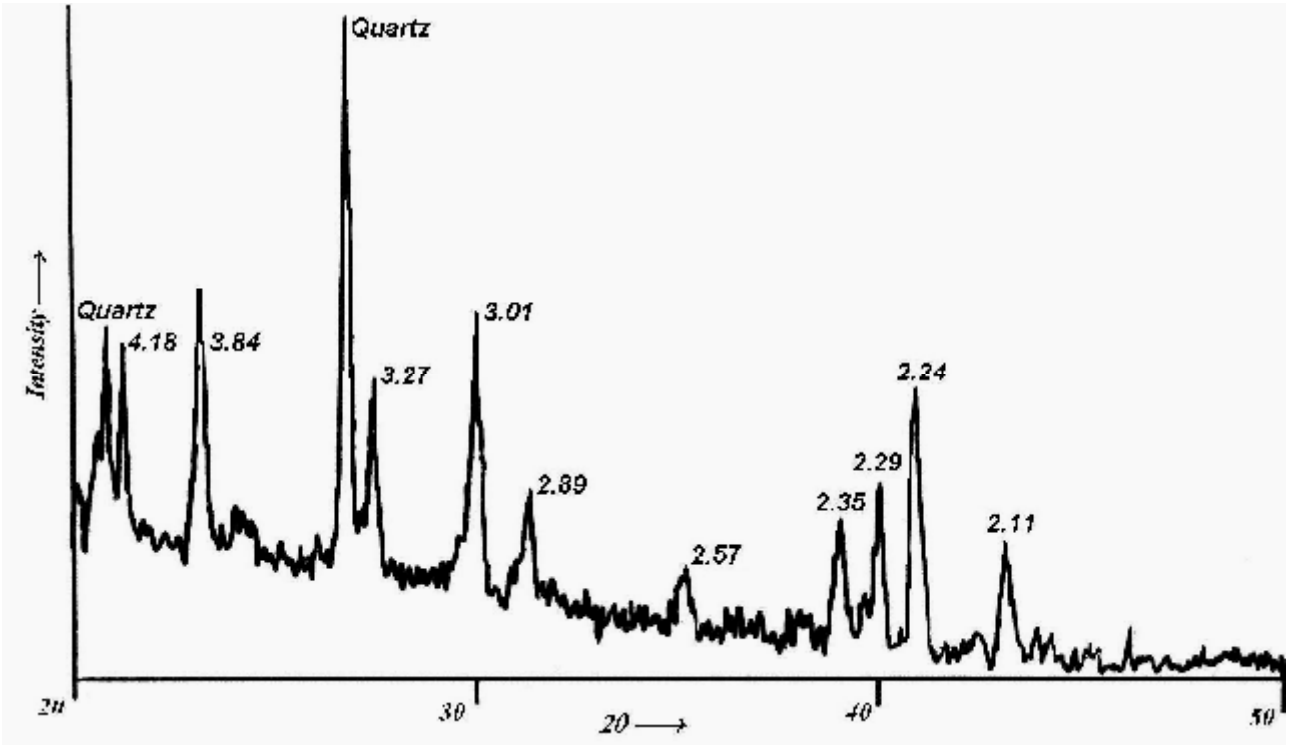

Fig.2: X-ray diffractogram for sample no.2. The peak areas of the silica (quartz) are reduced.

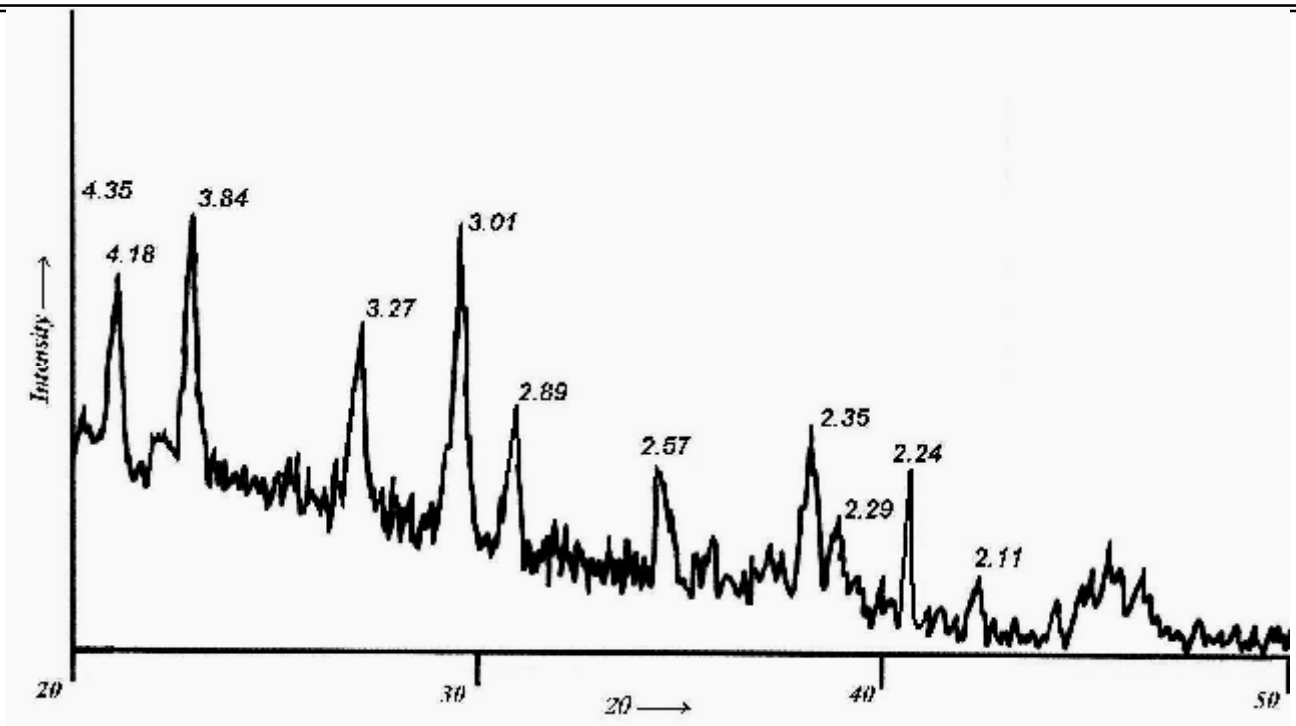

Fig.3: X-ray diffractogram for sample no.3. The quartz phase begins to disappear, but the background at low angles is high.

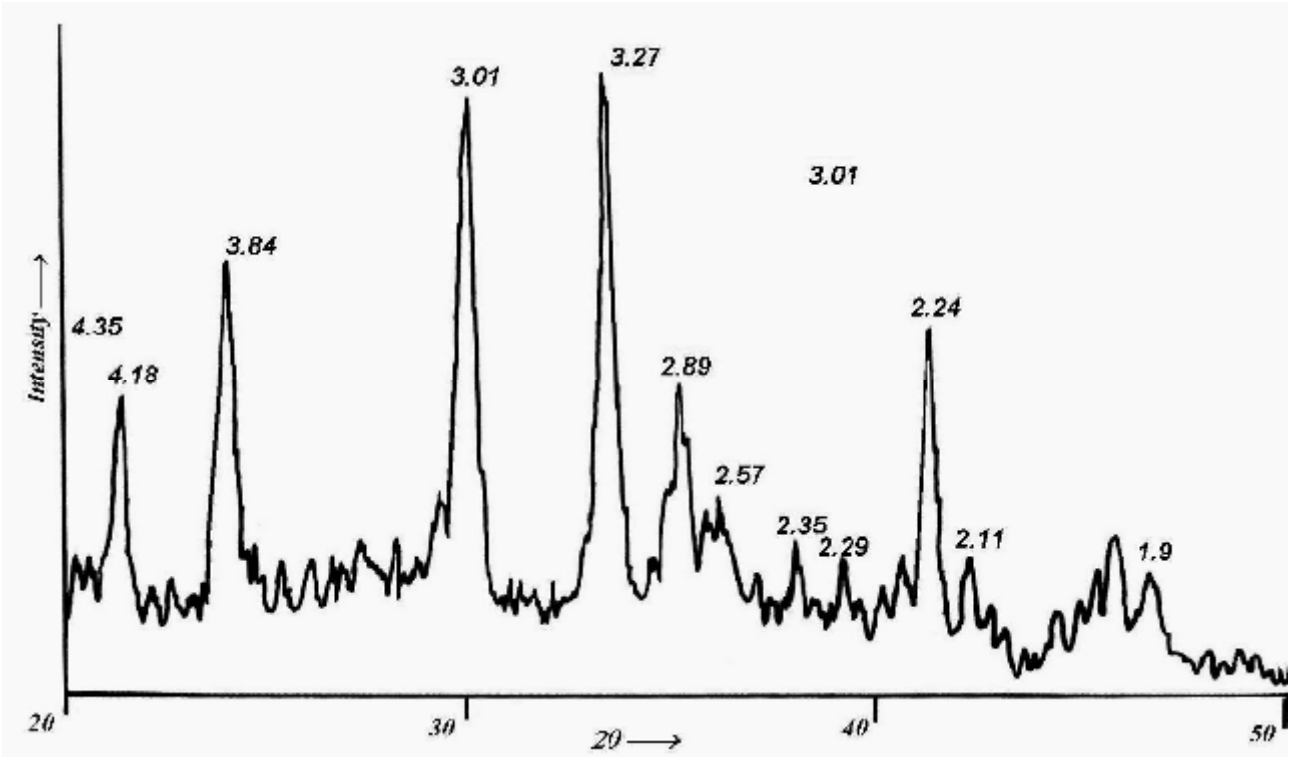

Fig.4: X-ray diffractogram for sample no.4. The background is reduced indicating higher crystallinity.