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A Review of Feldspathic Raw Materials' Incorporation in Glass and Ceramics

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Feldspathic raw materials-feldspars and nepheline syenite are the essential ingredients of glass and ceramics compositions. In ceramics these materials exhibit valuable fluxing properties by lowering the melting point and bonding the other constituents together on solidification. The incorporation of these materials in the glass batch adds alumina to the glass and at the same time serves as a solvent for silica grains.

Key words : Feldspar, Glass, Ceramics

Introduction

Feldspar is the name given to a group of alumino-silicates containing one or more of the metals potash, sodium, calcium and barium as bases. They form isomorphous mixtures and consequently may vary very greatly in composition especially as regards the metals present (Worrall 1986).

The principal feldspars are: (i) orthoclase $K_2OA1_2O_3$ $6SiO_2$ or potassium feldspar, (ii) albite $Na_2OA1_2O_3$ $6SiO_2$ or sodium feldspar, (iii) anorthite, $CaOA1_2O_3$ $2SiO_2$ or calcium feldspar and (iv) celsian BaO $A1_2O_3$ $2SiO_2$ or barium feldspar. Mixtures of sodium and calcium feldspars form a sub class known as plagioclase feldspar(Pottar 1992).

The feldspars vary in crystalline structure, orthoclase and soda orthoclase are monoclinic whilst microline and plagioclase feldspars are triclinic. When pure, the felspars are colourless or white but most specimens are tinted reddish grey, green or bluish on account of the presence of impurities. They have a hardness of about 6 and a specific gravity from 2 to 3. As the properties of different feldspars are similar, it is often convenient to regard feldspars as a single mineral. (Knight 1928).

For ceramic purposes, the value of a feldspar depends chiefly on its power to dissolve quartz and other forms of silica at high temperatures. Its chemical composition is of minor importance. It is known to depend on the amount of RO (CaO, MgO) materials, present but chemical analysis alone does not indicate the usefulness of a feldspar. The best single test is the determination of its melting point which should be equivalent to that of seger cone 6—9. Fine grinding of feldspar is also assential as coarse particles shorten thevitrification rang, have a higher initial melting point, and tend to form blobs or blisters (Ian Watson 1981).

Nepheline syenite is a sodium postassium aluminosilicate occurring as white, yellowish green or brownish hexagonal crystals with hardness of 5.5—6 and a specific gravity of 2.5—2.6. It is of rare occurrence (Anon 1979).

Experimental

The introduction of feldspathic materials in glass formulation provides Na^+ and K^+ ions. The ions disrupt the silicone network and make melting of glass batch easy without resorting to too high temperature. The glass batches of some typical glasses (Table 2) using raw materials of chemicals analyses (Table 1) are melted in grog crucibles. The melting and refining of these batches occurred at 1325°C to seedless, bubleless and cordless products (Charan1956; Doering 1984).

Composition. Feldspars consist of a group of most important rock forming minerals. Their general composition is aluminosilicates of potassium, sodium and calcium. The chemical formulae of the three main types of the feldspars orthoclase, albite and anorthite are $K_2OA1_2O_3$, $6SiO_2$, N_2aO, $A1_2O_3$ $6SiO_2$ and CaO A_21O_3, $2SiO_2$ (Potter 1992).

The most improtant source of commercial feldspar is pegmatite, a coarse grained lenticular or tabular body of acid igneous rock. The potassium feldspars and soda rich forms of plagioclase are the types generally needed. Coarse grained perthite, intergrowth of orthoclase and microcline with albite is an important commercial feldspar. Fine grained pegmatites may also be mined and a mixture of potassium

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Table 1
Chemical analyses (percent by weight)

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O
Sand	99.75	traces	0.002	-	-	-	-
Limestone	0.8	0.8	0.002	55.1	0.19	-	-
Dolomite	0.7	0.5	0.003	30.03	21.6	-	-
Soda-ash	-	-	-	-	-	61.5	-
Nepheline Syenite	57.2	23.6	0.02	1.5	-	10.8	4.0
Feldspar	67.2	21.0	0.01	0.8	-	7.2	3.0

Table 2
Glass batch compositions

	Windo glass	Table ware	Windo glass	Container glass	Table ware	Container glass
Silica Sand	1000	1000	1000	1000	1000	1000
Soda -ash	360	281	347	337	349	390
Feldspar	140	280	-	153	-	215
Dolomite	237	-	-	-	-	-
Nepheline Syenite	-	-	49	-	92	-
Limestone	-	414	264	279	268	263

and sodium feldspar may be recovered by milling and floation (Ian Watson 1981).

Nepheline Syenite, the most important member of feldspathic mineral series, begins with quartz rich granites, passes through syenites with a blance amount of quartz and ends with quartz deficient nepheline syenite. It consists essentially of nepheline $NaKA1SiO_4$, feldspar and is used particularly as an alternative to feldspar in the glass industry (Herglich 1984).

The incorporation of feldspathetic materials in some ceramic composition is shown below:- (Taylor and Bull 1986).

Ceramic compositions (wt per cent) fired at 1250-1300°C

S. No.	Product	Clay	Quartz	Flux	Fedspar/ Nep.Syenite
1.	White ware	65	25	10	Nepheline syenite
2.	Sanitary ware	65	25	10	Nepheline Syenite
3.	Kitchen ware	60	25	15	Feldspar
4.	Procelain	50	30	20	Feldspar
5.	Vitreous china	55	30	15	Nephaline Syenite
6.	Table ware	63	25	12	Nephaline Syenite

In the preparation of those compositions, the raw materials containing less than 0.04 percent of Fe_2O_3 were used. The products were white, semi-vitrified and free from cracks and pinholes.

Results and Discussion

Occurrence in Pakistan. In Pakistan, the occurrence of commercially exploited feldspathic rock have been reported only from the pegmatites of Rajdhawri, district Hazara, Zidig Gol in Chitral State, Bunji in Gilgit Agency at Kaki Doga, Trangi and Giddapur near Mansehra. In Quetta and Kalat Division, Feldspars occur in pegmatites and as viens in ultra-basic rock in the Raskoh range or Nushki Dalbadin. These deposits are at a height of approximately 2000 meters. The quantity is fairly large and pure (Table 3) but the transportation is extremely difficult. Anorthosite consisting of lime rich plagioclase also occurs at Zarghun in Quetta Division.

Nepheline Syenite has been reported at Koga in Swat. The estimated deposits are about 6000 m tonnes. The beneficiated material finds its successful use in the manufacture of glass (Din *et al* 1984)

A number of feldspathic raw materials are available to the potters and glass makers but the final choice depends upon certain consideraions. In ceramics different whiteware bodies require different degrees of vitrification and therefore different types and amounts of fluxes. In glass manufacture,

Table 3
Range of composition %

	Feldspar			Nepheline Syenite	
	Potassium	Sodium	Calcium	Raw	Beneficiated
SiO_2	65-67	62-68	61-65	58-55	59-55
$A1_2O_3$	18-16	23-21	23-22	22-24	23-24
Fe_2O_3	0.05-0.03	0.06-0.02	0.06-0.02	2.8-1.2	0.06-0.04
TiO_2	0.02-0.01	0.02-0.01	0.02-0.01	0.008-0.002	0.005-0.002
CaO	0.08-0.05	0.5-0.1	4-3.5	1.5-3	1.5-3.5
MgO	0.066-0.04	0.2-0.3	0.5-0.2	0.8-0.5	0.8-0.1
K_2O	14-13	2-1	2-1	4-6	4.5-6.5
Na_2O	2-3	12-9	8-7	10-9	10-9
L.0.1	0.2-0.1	0.5-0.3	2-1	0.8-2.5	0.8-2.5

mostly local raw materials are used where technical requirements allow.

The role of fluxing materials in ceramics is to melt the composition at an early stage to form a glass matrix that will bond together the other constituents on solidification. Generally, it may be said that different whiteware bodies require different degrees of vitrification. Hence the amount and type of flux required for a particular body will vary accordingly. The factors that can affect the fluxing properties include the content of free silica and the composition of the body into which it is introduced. The most important consideration is the total alkali content and ratio of alkali oxides will be Na_2O and K_2O.

The greater the alkali content the greater the fluxing action and the melting point will be correspondingly lowered. That is why only the alkali feldspars of the solid solution series from soda rich albite to potash rich orthoclase are used in the ceramic industry. (Alfred and Searle 1933).

The plagioclase feldspars which are also the members of solid solution series from albite to calcium rich anorthite are not suitable as fluxes. Ceramic grade fluxes are usually ground to around 200-300 mesh to permit thorough mixing with other body constituent.

The incorporation of feldspathic materials into the glass batch adds alumina to the glass. The presence of alumina in the glass improves strength and durability, inhibits vitrification and increases the viscosity during the glass forming process. The alkali contents act as a flux to assist in the melting at lower temperatures. The selection of the fluxing raw materials feldspars or nepheline syenite depends upon the factors (a) the relative delivery cost per unit of contributed alumina (b) melting rate (c) type of glass to be manufactured (d) consistency of composition and (e) the relative contents of undesirable oxides Fe_2O_3, TiO_2 and Cr_2O_3 etc. The amount of alumina is generally of the order of 1.5 - 2% in container glass, 2.0% in flat glass, 6.2% in thermometer tubing glass and of a variable amount in glass fibres (in some cases upto 15%) depending on intended use of the fibre. The introduction of feldspathic materials improves the quality that can be claimed excellent for structural glass, sheet glass, plate glass, float glass, glass wool, glass containerware and table glassware. (Blackwood and Klein 1982; Edwards 1984).

In case of ceramics, the use of these materials is equally good in the production of sanitary, porcelain, low and medium tensioned electroporcelain, vitreous china, earthenware, glazed wall and floor tiles enamels and even as a frit component. Strict quality control to ensure the chemical composition with regard to alumina and alkalies is important for the glass and ceramics manufactures.

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