Research Paper

Effect Of Addition of Tio2 As Dopant On The Physico-Mechanical Properties of Triaxial Porcelain

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ABSTRACT

Present investigation was undertaken to study the effect of addition of TiO2 as dopant on the physico-mechanical properties of triaxial porcelain. Fabricated samples are sintered at different temperatures ranging from 1250 to 1400°C. Magnitude of sintering was determined by measuring some fired characteristics including shrinkage, apparent porosity and true density. The evolution of crystalline phases and the microstructures have been studied using X-ray diffractometry and scanning electron microscopy. The results obtained clearly demonstrate that TiO2 may be added up to 2% to obtain a porcelain body with good physic-mechanical properties when sintered at 1300oC.

KEYWORDS : Porcelain, Titania, Dopant, flexural strength.

Introduction

A considerable portion of fine ceramic bodies produes today is of triaxial type, which means the principal ingredients are clay, quartz and feldspar and the microstructure is a composite mixture of crystals and glass. The crystalline phases are mainly mullite and quartz but crystoballite, tridymite and corundum are seldom found in it. Mullite is formed by solid state decomposition of clay compound and also by the nucleation and crystallization of feldspathic glass within the body [1-6]. In the last decade, the growth rate of the global production of porcelain stoneware increased more than other ceramic products; in fact, the excellent technical properties [7], together with the even more improved aesthetic appearance [8], gave porcelain stoneware a prominent role in the market [9]. This great commercial success made it possible to concentrate considerable resources in developing different types of porcelain stoneware tiles, which can be classified on the basis of their different surface or bulk properties. Both the surface (rough, textured, polished, lapped, glazed, etc.) and the bulk appearance (i.e. translucency, whiteness, etc.) influence, though in a different way, the product performances [10,11]. The developments have demanded not only redical improvements in the more usual properties and combination of properties. Mineralogical compositions of porcelain bodies have been widely studied with special references to the influences of crystalline and glassy phases at higher temperatures. The mineralizers enter the glassy phase of the porcelain samples and modify the solubility mullite in glass.

In the present investigation TiO_2 was gradually incorporated into the parent triaxial porcelain composition and its effect on the physic-mechanical properties was studied.

Experimental

For this purpose Birbhum china clay, Jharkhand feldspar, Gujrat quartz and pure TiO_2 powder were collected as raw materials. One base composition was taken following three other compositions, were compiled by substituting quartz by TiO_2 in the order of 2, 4, and 6 wt% respectively. The chemical analysis of the raw materials, determined by X-ray fluorescent spectroscopy is reported in Table I.

Constituents (%)	China clay	Feldspar	Quartz
SiO2	44.68	64.37	98.97
Al2O3	37.02	18.46	0.08
Fe2O3	1.98	0.35	0.04
CaO	0.36	0.59	-
MgO	0.27	-	tr
K2O	0.52	12.02	-
Na2O	0.31	3.11	-
LOI	14.86	0.21	0.91

Table-I: Chemical analysis of raw materials

Requisite amount of raw materials for each batch was taken and milled for a specified time. Rectangular shaped bars were fabricated by unixial pressing in hydraulic press. The shaped bars were properly dried and sintered at 1250, 1300, 1350 and 1400°C respectively for a fixed soaking period of two hours. The fired shapes were tested for the properties like linear shrinkage, apparent porosity, bulk density true density and flexural strength.

The crystalline phases in the fired specimens were identified by X-ray diffraction analysis using a Philips PW (1790) x-ray difractometer.

The evolved microstructure was analyse through scanning electron microscope Model S530, Hitachi.

Result & Discussion

The results of linear shrinkage are graphically represented in figure1. It may be noted from this figure that the temperature effect was not linear.

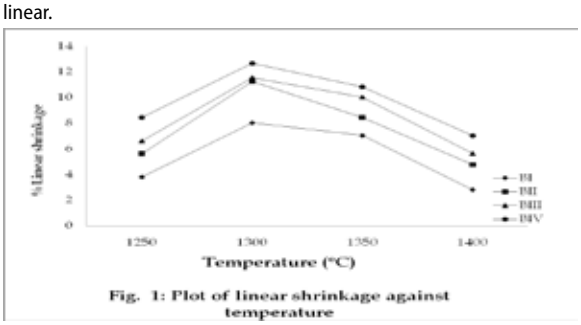

Fig. 1: Plot of linear shrinkage against temperature

Linear shrinkage increased with temperature up to 1300°C followed by significant decreasing trend up to 1400°C. This might be related to the formation of more liquid phase causing bloating. This trend was observed with all the compositions. It may also be observed that shrinkage increased with increase in TiO_2 content. This may be explained in the way that TiO_2 increased the rate of reaction. In presence of TiO_2, shrinkage increased significantly which might be due to enhanced crystallization (mullitization) and formation of more flowable glassy phase. TiO_2 containing samples exhibited similar nature of curves. Initial rate was slow compared to without TiO_2. From the physical appearance of the fired samples, no distortion or sagging was observed.

Apparent porosity against temperature has been given in figure 2. It is revealed from the figure that porosity decreased with firing temperature due to material transport into the pores as well as migration of glassy phase therein also.

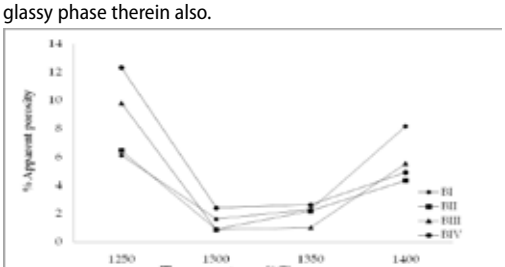

Fig. 2: Plot of linear shrinkage against temperature

This trend was followed up to 1300°C beyond which it increased again. The latter phenomenon was due to bloating action leading to pore formation in a vitrified mass. Minimum porosity was noticed at 1300°C. Thus it may be said that in this particular system, 1300°C appeared to be the optimum temperature at which apparent porosity was almost negligible in presence of TiO_2. Maximum density (2.78 gm/cc) was observed with batch II at 1300°C. Beyond which true density decreased with temperature due to generation of pores.

The variation of flexural strength with temperature (Fig. 3) for all the compositions follows the same nature with that of their densities.

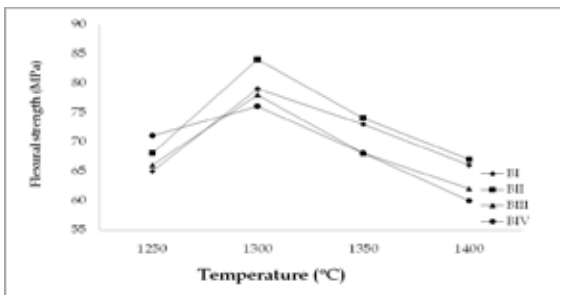

Fig. 3: Plot of linear shrinkage against temperature

The highest flexural strength (that corresponds to the highest densities) was 84 MPa for batch II (1300°C). The decreasing densification at higher firing temperatures could explain the decreasing tendency of flexural strength.

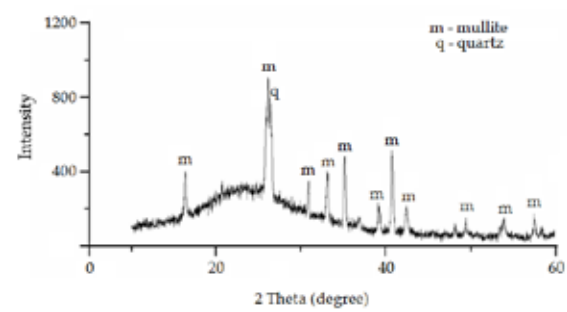

Fig. 4: X-ray diffraction pattern of batch-II sample sintered at 1300°C

The XRD patterns of the samples with 2% TiO_2 additive additive fired at 1300°C is represented in the figure 4. From the x-ray diffraction study it was found that mullite and quartz are the major phases present in the body.

Fig. 5: SEM of batch-II sample sintered at 1300°C

The microstructure (fig. 5) of the etched surface of the batch-II samples sintered at 1300°C was recorded by scanning electron microscope. Few cuboidal shaped primary mullite needle shaped secondary mullite were observed in the glassy matrix. Secondary mullite are needle shaped and properly interlocked, which is the reason for their higher strength.

Conclusion

The standard triaxial porcelain body either presence or absence of titania showed optimum properties and maximum strength was achieved with 2% TiO_2 addition sintered at 1300°C following which the properties deteriorated. The effect is more pronounced in case of TiO_2 containing samples due to excess formation of glassy phases.

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