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Controlled process of liquid-phase sintering due to low-fusible melt forming

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Abstract

The article presents the analysis results of known state-transition diagrams of two- and three-component systems. Triple aluminosilicate and silicate systems have been investigated. Considering two-component systems the CaO ones have been analysed. Oxides, providing binary and ternary low-fusible eutectic are defined. Fluxing power of fluxing oxide in aluminosilicate systems, including argillous raw material is determined. Compositions in three-component silicate system are defined, providing the formation of low-fusible melt at less than 500 °C, that is 200°C lower than low-fusible clay. The results are used for controlled process of liquid-phase sintering: ceramic material production; composition development of raw batches, which neutralize harmful influence of carbonated impurities.

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Keywords: liquid-phase sintering; state-transition diagrams; ceramic materials; neutralization of carbonated impurities.

1. Introduction

A large group of construction materials is produced with the process of heating raw materials or special raw batch. For some materials heating provides obtaining of active elements from dissociation of raw material. These materials include: gypsum binder, lime, magnesian binder. Heating is essential for forming new elements and a necessary structure for many materials. These construction materials include: ceramic brick, tile, roof tile; portlandcement clinker and alumina cement. For above-listed ceramic materials the formation of ceramic body starts with solid-state sintering and continues with liquid-phase sintering.

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2. The factors influencing liquid-phase sintering

The main factors influencing liquid-phase sintering are: chemical and mineral composition; dispersability and degree of raw material homogenization, granulometric distribution; degree of densification; heating temperature; atmosphere; retention time, etc. The defining factor is melt quantity .

If 20...35 % of melt is formed with heating, then there are partially sintered materials, such as: ceramic brick; wall tile; drain pipes. Such amount of melt is enough for contact adhesive bonding of refractory elements and fractional void-filling there. Heated materials have opened porosity of more than 5 %.

Fully sintered materials are characterized by 35...50 % melt enough for void-filling and formation of a single-piece die. Water absorption capacity of materials from this group is less than 5 %: ceramic roof tile, floor and building tile - 2-5 %; clinker brick, stoneware drain < 2 %. And sintering degree is increased due to increasing quantity of new-forming melt.

Pyroplastic mass is formed if there are more than 50 % of melt. If there is gas evolution in this phase, bloating of mass can occur, that is possible while producing keramzite gravel. If there is no gas evolution, then melting of heated pieces takes place with a loss of form.

It is possible to calculate the quantity of melt for two- and three-component systems in homogeneous mass using the known data of state-transition diagram [1, 2].

Binary and triple state-transition diagrams can be used to define: temperature of initial eutectic melt formation ; interrelation between the melt and a solid phase at any temperature; temperature of system transition into melt.

Eutectics with more than four components cannot exist in homogeneous masses. The formation of two- and three-component eutectics which are well-studied is more possible. The analysis of more component systems has purely applicable nature and can be applied only in a few fields of industry.

Amount of melt for multi-component homogeneous aluminosilicate systems can be calculated with the suggested method [3-5]. This method also allows to define melt composition and undissolved residue composition in ceramic batches while heating.

The method is based on usage of known state-transition diagrams of triple aluminosilicate systems [1] and on the results of numerous researches on phase transformation of aluminosilicate raw materials at a wide range of temperatures. The research was first conducted by U.D. Kingeri and A.I. Augustinik, then continued by S.P. Onatsky, V.F. Pavlov, V.V. Eremenko [6-11]. This method is also based upon theoretical and practical research made by G.V. Kukolev, A.A. Novopashin, etc. [12-18].

3. Fluxing power of fluxing oxides

3.1 Fluxing power of fluxing oxides in aluminosilicate systems

Alkaline oxides are usually found in argillous raw materials. The quantity of initial eutectic melt for homogeneous systems is defined by the type of fluxing oxides and their amount. If K_2O oxide is present in raw material, then the first aluminosilicate melt is formed at 710 °C. With the lack of K_2O oxide, oxide Na_2O provides the formation of initial eutectic melt at 740 °C. If the temperature is increased up to 985 °C (for K-containing systems) or up to 1050 °C (for Na- containing systems), compositions of alkaline melts will be varying according to eutectic lines in corresponding systems $K_2O - Al_2O_3 - SiO_2$ or $Na_2O - Al_2O_3 - SiO_2$ [1]. Fluxing power of fluxing oxides in aluminosilicate systems is given in Table 1.

It is suggested to divide fluxing oxides according to fluxing power: the first group - high fluxing power , the second- low fluxing power. The first group - K_2O (K^+) и Na_2O (Na^+). The second one - CaO (Ca^{2+}), MqO (Mq^{2+}) and Fe_2O_3 (Fe^{2+}). K_2O (K^+) has the highest fluxing power. The presence of 1 % K_2O oxide in chemistry of aluminosilicate raw material can provide the formation of 15 % alkaline aluminosilicate melt at 985 °C. The second one is Na_2O . The other fluxing oxides can provide a lot lesser quantity of melt. Fe_2O_3 (Fe^{2+}) has the least fluxing power (2,20 %).

Table 1. Fluxing power of fluxing oxides

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