# COMPOSITE CERAMICS BASED ON ELECTRO-MELTED CORUNDUM WITH EUTECTIC ADDITIVES IN THE $Al_2O_3$-$TiO_2$-MnO, $Al_2O_3$-MgO-MnO, $Al_2O_3$-MgO-$SiO_2$, $Al_2O_3$-$SiO_2$-$TiO_2$ SYSTEM

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## Abstract

Composite ceramic materials made from oxides occupy a significant proportion in the total production of composite materials.

Among all oxide materials and their compounds, corundum ceramics stands out the most widely used ceramic in many fields of technology due to its physico-mechanical, thermal and electro-physical properties.

Electro-melted corundum is the basis corundum refractory material produce for the clay or alumina binders to be used as furnace lining zones working at high temperature range 1600 - 1800°C. In addition, electro-melted corundum is used for the manufacturing of refractory parts for firing of ceramic products and calcination of alumina powders.

Using electro-melted corundum with any particle size fractions to obtain dense ceramics is never famous because it can be consider that, even very fine particle size fraction of electro-melted corundum do not sinter to a dense state due to its inert condition of the grain surface. There is only baking of the grain contact zones, which leads to some hardening of the ceramics.

However, the idea to use electro-melted corundum as an initial matrix component to obtain dense composite ceramics constantly arises due to the fact that such ceramics will have high hardness, determined by the hardness of grains, no crystal growth, amazing strength and high wear resistance.

In addition, the technology of dense composite ceramics based on electro-corundum is simple. There is no need to use a rather complex technology for powder preparation by using various types of alumina as a starting material. Electro-melted corundum in the form which it is produced in industry can be used directly without any additional processing. Of course, must use only high-purity white electro-melted corundum. The fabrication of dense composite ceramics using electro-melted corundum is possible only with the addition of eutectic oxide additive, which form a melt during sintering that promote the good wetting on corundum grain surfaces and constricting the grain to maximum dense packing and fill the remaining pores. In this way, a dense ceramic can be obtained using electro-melted corundum.

Conducting of this research is interesting from a scientific and practical point of view and can be considered highly relevant in terms of the possible application of such ceramics in important fields.

**The aim of this work** is to study the processes of highly densification, phase formation, microstructure formation and strengthening of composite ceramic based on electro-melted

corundum with the use of submicron eutectic oxide additive powders in the $Al_2O_3$-$TiO_2$-MnO, $Al_2O_3$-MgO-MnO, $Al_2O_3$-MgO-$SiO_2$, $Al_2O_3$-$SiO_2$-$TiO_2$ systems which providing the liquid-phase sintering mechanism and $ZrO_2$-$Y_2O_3$ system.

**To achieve goal of work the following objectives need to determine**.

1. Obtaining of dense and durable composite materials based on electro-melted corundum at sintering temperatures of 1550°C.
2. Selection of initial oxides that used for eutectic additive systems.
3. Fabrication of submicron powders of eutectic additives based on their compositions.
4. Preparation of ceramic samples with eutectic additives, including mixing, molding, determination of the density of compacts.
5. Studying on the influence of eutectic additive amounts in the $Al_2O_3$-$TiO_2$-MnO, $Al_2O_3$-MgO-MnO, $Al_2O_3$-MgO-$SiO_2$, $Al_2O_3$-$SiO_2$-$TiO_2$ systems in the composite compounds and the influence of sintering temperature on their densifications.
6. Determination of physico-mechanical properties and microstructures of the obtained corundum composite materials depending on the amount of additives and sintering temperature.
7. Studying on the influence of the addition of partially stabilized zirconium dioxide (PSZ) on the formation of microstructure, strengthening and hardening of ceramic composite material based on electro-melted corundum.

**Scientific novelty**

1. Studies of research have shown that character of change in shrinkage and porosity of composites depending on the firing temperature is determined by the composition of the eutectic additive of the various oxide systems, the amounts of additive and melt formation temperatures. The minimum porosity of composites 0.2-1% at a density of 3.80 - 3.89 g/cm$^3$ is achieved at 7% wt. or 15% wt. additives at a firing temperature of 1550°C.
2. Sintering of composite samples for all compositions is carried out according to the liquid-phase mechanism. During firing, a eutectic melt is formed, which wets the surface of electro-melted corundum grains and pulls the grains to the maximum dense packing due to the surface tension forces of the melt. The displacement of corundum grains into the pore volume is indicates the existence shrinkage of samples and change in porosity. The melt located on the surface of the corundum grains crystallizes upon cooling with the formation of the corresponding phases that determine the strengthening of the composites.
3. When using a eutectic additive in the $Al_2O_3$-$TiO_2$-MnO system at all firing temperatures of 1450-1550°C, uniform compaction occurs at every amounts of the additive introduced, which is due to the formation of the same amount of melt with the same amount of

additive. Properties of melts are the same, as evidenced by the shrinkage curve similar to the curve of the porosity. Apparently, the viscosity of the melt changes little with increasing temperature, which may be associated with the simultaneous presence of MnO and $TiO_2$ oxides in the melt.

4. The microstructure of the obtained composite materials has a lamellar structure, around the grains of the electro-melted corundum – submicron equiaxed inclusions of the crystallized eutectic additive are localized, forming a continuous framework of crystallizing compounds. Electro-melted corundum composite with nanoparticles of partially stabilized zirconium dioxide, modified with a eutectic additive has a homogeneous uniformly crystalline structure and intermediate layers between corundum grains form the “Composite in the Composite” structure types.
5. The flexural strength of composite samples depends on the type of phases crystallizing from the melt and their interaction with the surface of the corundum grains. The magnitude of strength is 200 - 330 MPa. Introduction of additional partially stabilized zirconium dioxide into the composite composition with the eutectic additive in the $Al_2O_3$-$TiO_2$-MnO system makes it possible to obtain strength up to 400 - 420 MPa.

**Practical significance**

1. A simple technology has been developed for new dense composite ceramic materials based on electro-melted corundum with a sintering temperature of 1550°C using various eutectic additives of oxide systems.
2. The obtaining composite ceramics are characterized by porosity less than 1%, flexural strength up to 330 - 420 MPa and high hardness.
3. Composite ceramics based on electro-melted corundum can be used as wear-resistant products, electronic equipment parts, and armor protective elements.

**Defense Provisions**

1. Justification of the choice of eutectic additives compositions of oxide systems for the manufacture of composite ceramics based on electro-melted corundum.
2. Results of the study of densification and strengthening of composite samples depending on the firing temperature and the amount of eutectic oxide additives in the $Al_2O_3$-$TiO_2$-MnO, $Al_2O_3$-MgO-MnO, $Al_2O_3$-MgO-$SiO_2$, $Al_2O_3$-$SiO_2$-$TiO_2$ systems.
3. Results of studying the microstructure and structural features of ceramics depending on the compositions.
4. Provisions regarding the sintering mechanism of composite ceramics based on electro-melted corundum with submicron eutectic additive compositions of oxide systems.