ZIRCONIA CONTAINING REFRACTORY FOAM CERAMICS

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ABSTRACT

General

Zirconia is an excellent candidate for high temperature applications because of high melting point, good corrosion resistance and high mechanical properties. Zirconia, alumina and kaolin containing foam refractory materials were prepared from water suspension. This material is characterized with high value of modulus of elasticity, thermal shock resistance at temperature 1000^{0}C. Zirconia containing foam refractory ceramics will be applied as gas sensor, filter for metal melts, furnace lining material or constructional material .

INTRODUCTION

The poster presents results of investigations of zirconia, alumina and kaolin refractory foam ceramics. Samples were prepared from commercially available partially stabilized zirconia or zirconia that is stabilized in process of synthesis. Pure zirconia it is difficult to use because of the cracking phenomenon induced by the tetragonal to monoclinic phase transformation (so called matrensitic transformation) that occurs on cooling from the fabrication temperature. Additive of Y_2O_3, CeO, MgO, CaO etc. decrease this phenomenon.

Technical

Zirconia – based materials are well known and frequently used as high temperature resistant materials because of its high melting point, excellent corrosion resistance and small thermal expansion coefficient. During experimental work zirconia, alumina and kaolin refractory foam ceramics from concentrated water suspension were prepared and studied. The addition of alumina to zirconia – based ceramics improves mechanical properties and shock resistance, but it is generally accepted that the solubility of alumina in the fluorite type lattice of zirconia is low. Kaolin works as a binder in the structure of non-fired material and as result of firing process mullite is formed. As a pore former Al powder was used. Reaction between Al and water provide formation of hydrogen that ensures process of the pore development.

EXPERIMENTAL RESULTS

To compare influence of different raw materials of zirconia: commercially available 5,3% yttria stabilized zirconia, non – stabilized zirconia were uzed and in process of synthesis it was stabilized with 5,3% yttria. there is In all compositions constant amount of kaolin, zirconia and alumina (1:1:1) and samples contain 0,1 wt% additive of Al powder. Samples are fired at temperature 1600^{0}C.

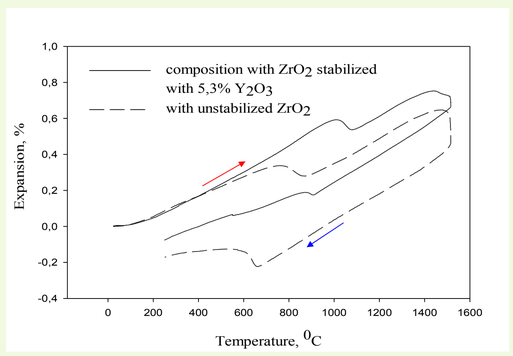


Fig.1. Thermal expansion of samples with stabilized and unstabilized zirconia

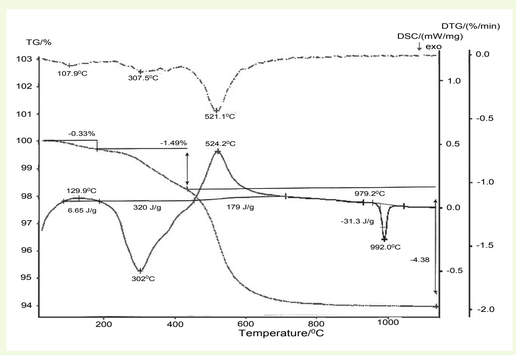


Fig.2. Thermal analysis of the raw material with unstabilized zirzonia

Processes that occur at firing time:

- Evoporation of humidity (< 130^{0}C)
- Dehydroxylation of $Al(OH)_3$ (~ 300^{0}C)
- Dehydration of kaolin and formation of mullite

$$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O \xrightarrow{400\text{-}500^0C} Al_2O_3 \cdot 2SiO_2 + 2H_2O$$
(kaolinite) (metakaolinite)

$$3(Al_2O_3 \cdot 2SiO_2) \xrightarrow{\sim 950^0C} 3Al_2O_3 \cdot 2SiO_2 + 4SiO_2$$
(metakaolinite) (primary mullite) (amorphous)

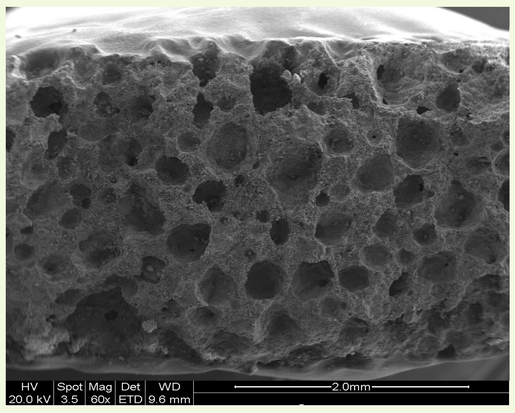
$$3Al_2O_3 + 2SiO_2 \xrightarrow{> 1300} 3Al_2O_3 \cdot 2SiO_2$$
(amorphous) (secondary mullite)

- Phase transformation of ZrO_2

$$ZrO2\ (monoclinic) \xleftrightarrow[\sim 950^0C]{\sim 1170^0C} ZrO2\ (tetragonal)$$

Porosity of fired ceramics

Applied ZrO_2	**Apparent porosity (%)**
Unstabilized ZrO_2	47,9
ZrO_2 stabilized with 5,3 % Y_2O_3 (in process of shynthesis)	55,1
ZrO_2 stabilized with 5,3 % Y_2O_3(comercial)	61,2



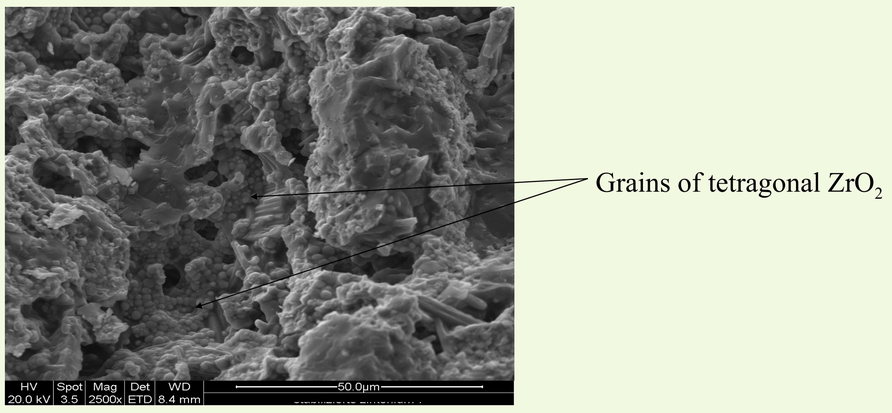


Fig. 2. SEM analysis of ceramics with 5,3% yttria stabilized ZrO_2

Methods of investigation

DTA Analysis (company Paulik, Hungary)
Thermal analyzer NETZSCH model STA 409 PC Luxx®
X-ray Diffractometry (SIEMENS-5000R)
Scanning Electron Microscopy (Oxford Instrument)
Mechanical Properties: Pressure Strength (UTS 100)
Open porosity (based on Arhimed's Principle, EN623 - 2)
Elastic modulus measurements (Buzz – O – Sonic Elastic modulus and sound velocity tester)

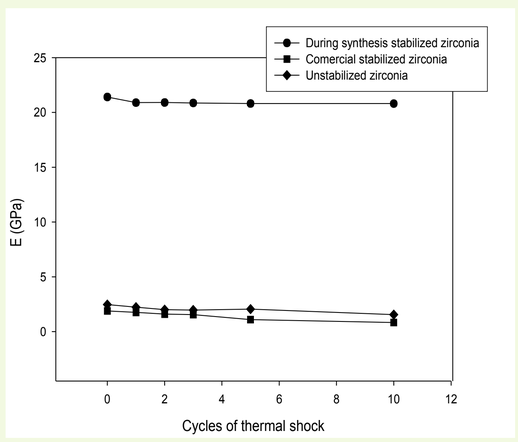


Fig.3. Modulus of elasticity depending on the applied zirconia and cycles of thermal shock

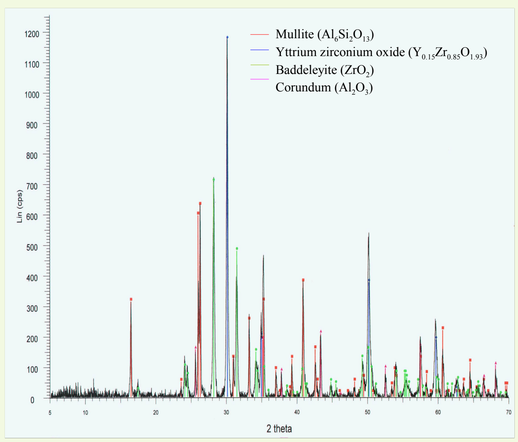
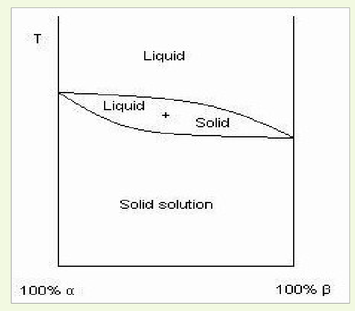


Fig.4. X-ray diffraction of stabilized ZrO_2 ceramics (in process of synthesis)

GLOSSARY

Solid solution A solid solution is a solid-state solution of one or more solutes in a solvent. Such a mixture is considered a solution rather than a compound when the crystal structure of the solvent remains unchanged by addition of the solutes, and when the mixture remains in a single homogeneous phase. The solute may incorporate into the solvent crystal lattice *substitutionally*, by replacing a solvent particle in the lattice, or *interstitially*, by fitting into the space between solvent particles. Both of these types of solid solution affect the properties of the material by distorting the crystal lattice and disrupting the physical and electrical homogeneity of the solvent material..



A binary phase diagram displaying solid solutions over the full range of relative concentrations.

Foam A dispersion of bubbles in a liquid or solid. Foams can be stabilized by surfactants. Solid foams are made by chemical reaction of Al with water.

Martensitic transformation A martensitic transformation is a first order displacive structural transition exhibiting lattice invariant strain, essentially composed of a shear strain. The first order displacive term means that the transformation involves atomic displacements small but finite (about a tenth of the atomic spacing), and perfectly correlated for a large number of atoms. No atomic diffusion is occurring during the transition, so that it may occur at any temperature, without changing either the atomic order or the chemical composition.

CONCLUSIONS

Zirconia, alumina and kaolin containing foam ceramics was investigated. Porosity of fired body is depending from used raw ZrO_2 material and additives.

Presence of 5,3% Y_2O_3 stabilizer in ceramics decreases temperature of phase transformation and thermal expansion during cooling time. In process of synthesis stabilized ZrO_2 containing ceramics shows very high value of modulus of elasticity. All compositions have good thermal shock resistance at testing temperature 1000^{0}C.

Results of X-ray diffraction show presence of yttrium zirconium oxide , mullite, baddeleyite and corundum

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