Synthesis and Properties of Porous Bricks Obtained with the Use of Spherical Expanded Polystyrene Particles of Packaging Material

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Abstract:
In the present work, the prospects of using wastes of a packaging material consisting of spherical expanded polystyrene (EPS) particles for the manufacture of porous ceramics/bricks are considered. Ceramics were obtained from mixtures of red clay-grinded cullet - EPS particles. To reduce the release of toxic products of thermal destruction of EPS, two sintering modes have been developed. During sintering in the atmosphere, the two-stage temperature regime was carried out, which ensured preliminary dehydration of the clay and a quick transition to sintering at 1000 °C. During sintering in conditions of oxygen deficiency in firing furnaces, the temperature gradually rises to 1000 °C. At that, the sintering process is characterized by the absence of release of toxic products, and the carbonization of porous bricks. It has been established that, depending on the composition of the mixtures and the sintering conditions, it is possible to obtain durable wall ceramics with good thermal and sound insulation properties. Carbonized ceramics have enhanced strength properties due to the formation of forsterite. The presence of free carbon in the pores imparts adsorbing properties to carbonized ceramics and contributes to the appearance of electrical conductivity.

Keywords: Red clay; Glass; Expanded polystyrene particles; Sintering; Ceramics; Properties.

1. Introduction

Nowadays, production engineers dealing with ceramics are facing an important problem of the development of new ceramic materials for structural and functional applications with the integration of wastes of organic and inorganic origin into the technological cycle [1-8]. The last requirement is caused by the fact that the ecology of the environment was substantially impaired because of human vital activity [9]. At the same time, progress made in the production of ceramic materials for special application promotes the transition to the synthesis of composite ceramics, which makes it possible to obtain improved properties and extend the fields of the traditional application of ceramics. This concerns the development of modern efficient building materials, combining the properties of wall structural, heat-insulating, and sound-insulating materials. Moreover, the production of such

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ceramics must be based on an energy- and resource-saving technology to provide a substantial reduction in the production costs of bricks and building costs on the whole [10-12]. Porous bricks exhibiting sound- and heat-insulating properties are of great interest.

One of the methods to obtain porous ceramics is the introduction of decomposable inorganic compounds or combustible additives into clay mass [11-15]. Among organic additives that are burned out in sintering are biowastes consisting of aerobic and anaerobic bacteria. In this case, pores with a size ranging from ~3 mm up to ~10 mm form. Most often, they have a slot-like shape [16]. It is thought that for the formation of the single-type shape of large pores, e.g., a spherical shape, expanded polystyrene (EPS) spherical particles can be introduced into clay blanks. Their burn out in the sintering of blanks must provide the formation of porous ceramics with a large pore diameter [17]. However, it should be noted that EPS particles do not find wide application as a pore-forming component in the production of lightweight bricks. According to research results presented in [18], this is explained by the fact that, during the burn of EPS at \( T \leq 900 \) °C, toxic substances are evolved. However, the problem of processing EPS packaging material becomes more and more urgent in view of the increase in the volume of wastes.

At present, there exist rather limited methods of processing of packaging materials, namely, grinding of wastes of this type and their use as fillers of concretes [19, 20]; remelting of EPS wastes with the following milling of the cooled product into powder, and then using it as additives in subsequent technological processes; depolymerization of EPS wastes and introduction of the obtained polystyrene powder into other materials as additives [21, 22]. Practically all types of processing of EPS turn to be expensive from the economical viewpoint, which retards its large-scale processing.

The aim of the present work is to use wastes of milled EPS packaging material in the synthesis of coarse-pored composite building ceramics (bricks) and modify it subsequently into a new type of composite material for different applications. Note that, at \( T \geq 1000 \) °C, the thermo destruction products of EPS are CO\(_2\) (as exhaust gas), water vapor, and soot. In this case, heat is released, which will make it possible to maintain a temperature above 1000 °C in a firing furnace.

2. Materials and Experimental Procedures

In the present work, porous ceramics (bricks) were obtained based on mixtures of red clay, milled bottle glass, and EPS spherical particles obtained by the destruction of EPS packaging material. To prepare these mixtures, glass particles with a size of 0.125 mm and EPS particles with a diameter of 1 and 3 mm were used. To obtain ceramics, two main compositions were chosen: 90 wt.% clay–10 wt.% glass and 50 wt.% clay–50 wt.% glass, into which EPS was introduced in amounts from 0.3 wt.% up to 4.8 wt.% (or from 0.25 to 5 g). Water was added to the obtained homogenized mixtures, and blanks with sizes 8 × 2.3 × 1.8 cm were formed. After drying in the air for 2 days, the blanks were sintered. Obtained ceramics by sintering in the air at 1000 °C for 8 h was denoted specimens of type I. To minimize the evolution of detrimental thermo destruction products of EPS, which are released in the range 300–500 °C, the heat treatment of the blanks was carried out in two stages. In the first stage, the heating from 24 °C to 200 °C was carried out. On the second stage, these specimens were introduced into a hot zone in which temperature from 850 to 1000 °C was increased. The rate of temperature rising up to 1000 °C was 50 °C/min. In the sintering of blanks under conditions of oxygen deficiency in the furnace (in vacuum or argon), ceramics denoted specimens of type II were obtained. The rate of temperature rising from 24 °C up to 1000 °C was 30 °C/min. Sintering was performed for 8 h.
The obtained ceramics was investigated by the X-ray diffraction (XRD) method in Cu $K_\alpha$ radiation (Siemens D-500 diffractometer). Electron microscopy study and electron-probe microanalyses were performed with a LEO 1450 VP type and SU 5000 Hitachi scanning electron microscopes. Water absorption was determined by the formula: $W, \% = 100 - \left[\frac{(P_1 - P_0)}{P_0}\right] \cdot 100$, where $P_0$ is the initial weight of a specimen and $P_1$ is the weight of the specimen after water absorption. The adsorption properties were studied by the UV-Vis method with the use of an USB4000-XR1 Ocean Optics spectrometer. For the determination of the adsorption properties of the carbonizate, a 30 ppm aqueous solution of methylene blue (MB) was used. The MB content was evaluated from changes in the intensity of the band of UV-Vis spectra with $\lambda \sim 665$ nm and preliminarily prepared calibration graphs: $C = f (I)$, where $C$ is the dye concentration, $I$ is the intensity of the band of the UV-Vis spectra. Mechanical properties of the ceramics were investigated by standard techniques. For the evaluation of the sound-absorbing properties of ceramics, the formula for the acoustic absorption coefficient $\alpha = \frac{\text{absorbed energy}}{\text{incident energy}}$ was used. For standard bricks, $\alpha = 0.63$, and for porous bricks, $\alpha = 0.36$. For the determination of the heat-insulating properties of the ceramics, the expression $k = \frac{(q\cdot\Delta x)}{(A\cdot\Delta T)}$ for the thermal conductivity coefficient of bricks (where $q$ is the heat flux, $\Delta x$ is the distance from the source of heating, $A$ is the transverse area perpendicular to the heat flux, and $\Delta T$ is the temperature difference) was used. For standard bricks, $k = 0.87$ W/mK, and for porous bricks, $k = 0.49$ W/mK. To measure the electric resistance, an ohmmeter (with BK Precision Model 16880D power supply) was used.

3. Results and Discussion
3.1. Properties of ceramics obtained under traditional sintering conditions (specimens of type I)

Due to the rapid increase in temperature from 850 to 1000 °C, the evolution of gaseous thermodestruction products of EPS was reduced.

3.1.1. X-ray diffraction data

According to the XRD data, the sintered ceramics consists of the following crystalline phases: sillimanite, cristobalite, and quartz (Fig. 1 a). All peaks are located on a wide halo, which indicates the presence of an amorphous phase, namely, a glass phase. From the semi quantitative evaluation of the contents of the phase shown in Figs. 1 b, c it follows that the contents of some phases in the specimens depend upon the clay content in the initial mixtures:
the higher the clay content in the initial clay–glass mixtures, the larger the sillimanite content in the ceramics. Moreover, the higher the amount of glass introduced into the initial mixtures, the higher the intensity of the halo recorded in the X-ray diffraction patterns. The contents of quartz and cristobalite in the ceramics depend not only on the decomposition of the clay mineral, which can be described by the formulas:

\[
\begin{align*}
550 \, ^\circ C: & \quad Al_2O_3 \cdot 2SiO_2 \cdot H_2O \rightarrow Al_2O_3 \cdot 2SiO_2 + H_2O; \\
850 \, ^\circ C: & \quad Al_2O_3 \cdot 2SiO_2 \cdot H_2O \rightarrow \gamma Al_2O_3 + SiO_2; \\
900 \, ^\circ C: & \quad \gamma Al_2O_3 + SiO_2 \rightarrow 3Al_2O_3 \cdot 2SiO_2,
\end{align*}
\]

but also on the inhomogeneity of the composition of red clay, which, along with montmorillonite and kaolinite, contains quartz and cristobalite in the form of inclusions of sand [23, 24]. Nevertheless, the quartz content in the ceramics is influenced by the following factors: the participation of quartz in the formation of the glass phase of new composition (as evidenced by some shift of the maximum of the halo in 2θ) and the transition of a part of SiO₂ (quartz) into SiO₂ (cristobalite).

Note that the content of EPS spherical particles in the mixtures does not influence the phase composition of the ceramics because they burn out at \( T < T_{\text{sintering}} \).

3.1.2. SEM data

Fig. 2. Micrographs of a fracture of the porous ceramics at different magnification (a–c) and local microanalysis of elements (b’) at the places indicated in (b).
During the fracture of ceramics with any content of EPS introduced into the initial compositions, places of burning out of EPS spherical particles are seen (Figs. 2 a, c, d). Note that the size of formed pores correlates with the diameter of introduced spherical particles. Fine pores of different size and shape (Figs. 2 b, c) pierce the entire ceramics. On the walls of large pores, finer pores, which indicate the places of release of gaseous combustion products of EPS, are present. Local microanalysis at different places showed the presence of elements that are characteristic of places of localization of silica (Figs. 2 b, b’, place 1), aluminum silicate (Figs. 2 b, b’, place 3), and glass (Figs. 2 b, b’, place 2).

3.1.3. Absorption data

![Fig. 3. Change in the water absorption of porous ceramic specimens.](image)

In Fig. 3, results on water absorption of the porous ceramics synthesized from the clay–glass–EPS mixture with different contents of components and different diameter of EPS spherical particles are shown. Results of evaluation of the porosity of the ceramic material are presented in Table I. It was established that, with an increase in the content of EPS particles, the absorbability of the material rises, which is caused by an increase in the porosity of the material. A substantial difference in the absorbability of the porous ceramics synthesized with different contents of glass and EPS particles 1 mm in diameter was not registered (Fig. 3 a). It is seen from Table I that, with an increase in the glass content in the mixtures, the number of pores on an area of the ceramics of 1 cm² changes insignificantly. However, in the case of using EPS particles with $d = 3$ mm, with increase in the glass content in the initial mixtures, the water absorption decreases more substantially (Fig. 3 b), though, in this case, the number of pores at the place of burnt-out EPS spheres also changes insignificantly (see Table I). As should be expected, the introduction of EPS spheres of equal weight but of different size is accompanied by an increase in the number of pores per 1 cm² of the ceramics in the case of using EPS spheres of smaller diameter (see Table I). However, the water absorption turns to be smaller than that in the case of introduction of EPS particles with a diameter of ~3 mm. The cause consists in the fact that the surface of pores and the walls between them are pierced by macro- and micro pores of different configuration (see Fig. 2 d). The total surface of pores with $d \sim 3$ mm turns to be larger than that in specimens with $d \sim 1$ mm (see Table I). A characteristic feature of this ceramics is an insignificant release of drops during removal of specimens from water and the gradual egress of water from specimens during their subsequent storage. This means that the main absorption occurs due to the penetration of water into open macro- and micro pores.

**Tab. I** Characterization of the powder mixture and ceramics.
3.1.4. Mechanical properties

The analysis of the mechanical properties of specimens showed (Fig. 4) that the compression strength increases in specimens prepared from the mixtures with a glass content of ~50 wt.%. A similar effect was noted in [13]. It was caused by an increase in the content of the fusible glass phase in this sintering regime and the transition from the process of solid-phase sintering to sintering by the liquid–solid-phase mechanism [23]. With an increase in the...
EPS content and, hence, in the number of pores in the ceramics, the compression strength ($F_{\text{compr.}}$) decreases (Fig. 4 b, curves 1, 2). In the case of introduction of EPS of larger diameter ($d \sim 3$ mm), these changes manifest themselves more clearly. Note that, in the case of using EPS with $d \sim 1$ mm, it is possible to synthesize ceramics with $F_{\text{compr.}} \sim \text{const}$ if the content of EPS is changed within certain limits (Fig. 4 a). According to standard requirements, ceramics with $F_{\text{compr.}} \sim 80$ kg/cm$^2$ can be used for the brickwork of exterior walls, ceramics with $F_{\text{compr.}} \sim (70-40)$ kg/cm$^2$ can be used for the brickwork of interior walls, and ceramics with $F_{\text{compr.}} < 30$ kg/cm$^2$ can be used as expanded clay aggregate and filtering ceramics. Porous ceramics with $F_{\text{compr.}} \sim 30-20$ kg/cm$^2$ is, in turn, is heat-insulating ceramics. From the obtained data, (see Fig. 4) it can be concluded that, by addition of EPS particles of smaller diameter, it is easier to synthesize stronger ceramics.

3.1.5. Heat-insulating properties

Fig. 5. Generalized character of change of the temperature in the porous ceramics (a), temperature of specimens of different composition at a distance of 1.9 cm from the source of heating (b), and the thermal conductivity coefficient (c). (1) for 90 wt.% clay + 10 wt.% glass mixtures; (2) for 50 wt.% clay + 50 wt.% glass mixtures. The diameter of EPS particles is 1 mm. The heating time is 60 min.

The general character of temperature decrease during the passage of a hot air flow through a porous specimen is shown in Fig. 5 a. For all specimens, at a distance of 7.6 cm from the source of heating, temperature did not exceed 25 °C. In other words, in passage of air through the ceramics, the temperature decreased by 50 °C. Taking into account that the width of a standard brick is equal to 120 cm, the synthesized material is classified with heat-insulating ceramics. Depending on the composition of the ceramic specimen and its porosity, the thermal conductivity and thermal diffusivity of the brick changes. Since at a small content of glass in the initial mixtures, as the porosity of the ceramics rises due to an increase in the EPS content, the efficient decrease in the heating temperature of the specimen occurs. This is caused by an increase in the porosity of the material (see also Fig. 3). However, at a large glass content, a reverse tendency is observed (Fig. 5 b), though the porosity (water absorption) increases. Correspondingly, the thermal conductivity coefficient changes (Fig. 5 c). This difference is explained by the following: (1) a substantial increase in the thermal conductivity of specimens with increase in the content of the glass phase (the thermal conductivity of the porous brick ranges from $\sim 0.23$ to $\sim 0.44$ W/(m·K) and the thermal conductivity of glass ranges from $\sim 0.7$ to $\sim 1.3$ W/(mK)); (2) the filling of a part of open pores by glass melt (see Fig. 3). It is seen from Fig. 6 that, by increasing the contents of EPS and glass in the initial mixtures and the diameter of EPS particles, the heating of the ceramics is intensified. All these changes can be explained by the change in the content of the glass phase in the ceramics and by the pore-filling capability of glass melt during sintering of specimens. The data presented in Table I confirm the fact that, in the case of introduction of a
larger amount of glass into the initial mixtures, the number of pores in the ceramics somewhat decreases.

![Fig. 6](image)

**Fig. 6.** Temperature in the porous ceramics of different composition at a distance of 1.9 cm from the source of heating versus the time of heating. In (a, c): ceramics obtained from a 90 wt.% clay–10 wt.% glass mixture. In (b), ceramics obtained from a 50 wt.% clay–50 wt.% glass mixture. In (a, b), the diameter of used EPS particles is 1 mm. In (c), the diameter of EPS particles is 3 mm.

Thus, it was established that to provide good heat-insulating properties of the ceramics, it is desirable to use EPS particles with $d = 1$ mm and introduce at least 50 wt.% of glass into the initial mixtures.

### 3.1.6. Sound-absorbing properties

| Tab. II Average values of the sound absorption coefficient in porous ceramics. |
|---------------------------------|-------------|---------|---------|
| Type of ceramics               | $d_{pores}$, mm | Weight, g | $\alpha$ (average value) |
| 90 wt.% clay + 10 wt.% glass   | 1           | 1.0     | 0.122   |
|                                | 2.0         |         | 0.137   |
|                                | 3.0         |         | 0.140   |
|                                | 3           | 0.3     | 0.134   |
|                                |             | 0.5     | 0.150   |
|                                |             | 1.0     | 0.170   |
| 50 wt.% clay + 50 wt.% glass   | 1           | 1.0     | 0.173   |
|                                | 2.0         |         | 0.182   |
|                                | 3.0         |         | 0.188   |
|                                | 3           | 0.3     | 0.139   |
|                                |             | 0.5     | 0.149   |
|                                |             | 1.0     | 0.162   |

It is known that looser materials exhibit larger sound absorption than dense materials. It was established that, in the synthesized ceramics, predominantly high-frequency vibrations are reduced (Figs. 7–9). In the case of using mixtures with a large content of the glass phase and a smaller pore diameter, the absorption of sound vibrations at $f = 15000$ Hz intensifies (see Fig. 9). The mean values of sound absorption coefficient ($\alpha$) during the passage of sound through a wall with a thickness of 2.3 cm are presented in Table II. It is seen from Table II that the values of $\alpha$ rise as the porosity of the material and pore diameter increase. The content of the glass phase in the ceramic material also influences the sound absorption. Note that, for standard bricks and brickwork, $\alpha \sim (0.04–0.07)$, which is much smaller than $\alpha$ in the given porous bricks. Thus, the synthesized ceramics has improved sound-absorbing properties.
Fig. 7. Generalized character of decrease of sound frequencies in the synthesized porous ceramics.

Fig. 8. Change in the sound absorption coefficient ($\alpha$) at different frequencies in ceramic specimens synthesized with different EPS contents. The diameter of used EPS particles is 1 mm.

Fig. 9. Change in the sound absorption coefficient ($\alpha$) in ceramic specimens of different composition with different pore diameter. The amount of EPS in the mixture is 1 g.

3.2. Properties of ceramics obtained under conditions of oxygen deficiency (specimens of type II)
During sintering under conditions of oxygen deficiency, evolution of gaseous thermo destruction products of EPS from the furnace was not detected.

3.2.1. X-ray data

After sintering of blanks under conditions of oxygen deficiency, in the X-ray diffraction patterns of the ceramics, a halo with a maximum at $\Theta \sim (26 \text{–} 27)\degree$ (Fig. 10 a) is observed, which indicates the appearance of an amorphous carbon phase [13]. Note that, in the ceramics synthesized in air, a halo is also present, but its maximum in a value for $\Theta \sim 22\degree$ (see Fig. 10 b). This halo is due to the presence of the glass phase in the ceramics [28, 29]. In the carbonized ceramics, a narrow line is recorded at $\Theta = 26.5\degree$ (Fig. 10 a). According to [30], it is assigned to graphitized carbon micro beads. The presence of a broad low-intensity peak in the XRD patterns at $\Theta = 44\degree$ may indicate the formation of a specific form of carbon, namely, carbon bulbs [28, 29]. The peak at $\Theta = 23.77\degree$, which is assigned to forsterite (ideal formula is M\text{g}_2\text{Si}_4\text{O}_{10} \text{ or } (\text{Mg}_{1.81} \text{ Fe}_{0.18} \text{ Ni}_{0.01})_{2} \text{ Si}_{1.00}\text{O}_{4}$), indicates that processes of interaction between glass and the components of clay, containing metal oxides, including iron and magnesium oxides, occur.

![X-ray diffraction patterns of the ceramics obtained from 50 wt.% clay + 50 wt.% glass + 1g EPS mixture in argon atmosphere (a) and air (b) at $T_{\text{sint.}} = 1000 \degree$C for $t_{\text{sint.}} = 8$ h. $d_{\text{glass}} = 1$ mm.](image)

3.2.2. SEM and EDS data

During the sintering under conditions of oxygen deficiency, porous ceramics (Fig. 11 a, b) containing carbon (Fig. 11 c, c’, c”) forms. Note that carbon is registered not only on the
surface of pores (Fig. 11 c, d, d‘), but also in spherical particles present inside pores (Fig. 11 d, d’, c, c‘). These data correlate with the XRD data on the formation of graphitized carbon micro beads. It is worth noting that spherical particles with $d \geq 10 \mu m$ have the form of bulbs (Fig.11 c, c‘) with irregular location of petals, which leads to the formation of a porous structure. Note that the presence of such carbon formations improves the electro conductive properties of even activated coal materials [30].

![Fig. 11. Micrograph of the surface of the carbonized porous ceramics (a). In (b), the surface of a pore. In (d, e), spherical particles in a pore. In (c, c‘, c‘‘, d‘, and e‘), the carbon distribution on the surface of a pore and in spherical particles.

3.2.3. Mechanical properties

It was established that the sintering of specimens under condition of oxygen deficiency leads to a substantial increase in the compression strength of specimens if the content of EPS spherical particles did not exceed 1.5 g (see Fig. 4 a, curve 3). As in the case of sintering in air, with a further increase in the content of EPS particles in the initial mixtures, the compression strength of specimens decreases. Taking into account the XRD data, the increase in the strength of the specimens is caused by the formation of forsterite, which has hardness equal to that of quartz [31]. Note that, for the glass phase, the hardness on the Mohs scale is 5½.

3.2.4. Adsorption properties of carbonized bricks

Since in the given porous ceramics, low-ordered carbon is present, it must possess adsorption properties [12, 13]. The performed investigations showed (Fig. 12) that this ceramic absorbs the dye. Note that, for the efficient fast purification of water from the dye, it is necessary to use an appropriate amount of carbonized ceramics.
3.2.5. Electro conductive properties of carbonized bricks

It is known that standard wall ceramics (building bricks) are insulators. The electric conductivity of the ceramics is ionic in native. After the addition of glass additives containing ions of alkali metals (e.g., Na\(^+\) and Li\(^+\)), the electric conductivity increases. Since in the present investigation, glass containing ~14 wt.% Na\(_2\)O was introduced into clay (see Table III), and burning was performed under conditions providing the formation of carbon in the ceramics, even in the porous material, electric conductivity must show itself.

| Component | Composition, wt.% |
|-----------|------------------|
| Glass     | SiO\(_2\) 72.03  |
|           | Al\(_2\)O\(_3\) 1.989 |
|           | Fe\(_2\)O\(_3\) – |
|           | Na\(_2\)O 13.964 |
|           | CaO 7.006 |
|           | MgO 4.005 |
|           | TiO\(_2\) – |
|           | K\(_2\)O 1.001 |
|           | Σ\(_{rest}\) 0.005 |
| Clay      | 56               |
|           | 33               |
|           | 2.8              |
|           | 0.65             |
|           | 1.5              |
|           | 0.6              |
|           | 0.85             |
|           | 2.5              |
|           | 2.1              |

The investigation of the resistive properties of the carbonized ceramics showed that it has electric conductivity (Fig. 13). At the chosen composition of slurry, the porous ceramics with a pore diameter of ~ 1 mm is classified with high-value resistors. In the direction \(l_1\), the change in the electric resistance practically follows the expression \(R = \rho l/S\), where \(\rho\) is the resistivity of the material, \(S\) is the cross-sectional area of the conductor, and \(l\) is the length of the conductor. In the present case, \(\rho\) and \(S\) are constant quantities, whereas \(R\) changes practically proportionally to the length of the conductor. The spread in values of \(R\) in the directions \(l_2\) and \(l_3\) in the case where, in the formula presented above, all quantities are
constant reflect the specificity of passage of current through the system of ceramic channels between pores containing electro conductive carbon components. It can be concluded that it is possible to obtain ceramics with different electric conductivity by changing the content and size of EPS particles in the initial mixtures.

![Graph](image)

**Fig. 13.** Change in the electric conductivity (a) at local places of carbonized ceramics with a pore diameter $d \sim 1$ mm and in the current (b) in the direction $l_1$ (see the measurement scheme in Fig. 13 a).

4. Conclusion

The performed investigations have shown that by the introduction of milled packaging material consisting of EPS spherical particles into red clay–fusible glass mixtures, preparation of blanks by plastic molding, and subsequent sintering in air at 1000 °C for 8 h, it is possible to obtain strong porous wall ceramics. Depending on the ratio of the components in the mixtures (clay : glass : EPS particles) and the size of introduced EPS particles, this ceramics can be used for the brickwork of interior walls, as expanded clay aggregate, and as filtering ceramics. The porous ceramic with a pore diameter of 1 mm and 3 mm has good heat- and sound-insulating properties.

During the sintering under oxygen deficiency conditions, carburized ceramics that has not only good strength characteristics, but also adsorption properties and can be used to purify water from dyes is formed. The presence of different forms of carbon in the ceramics imparts the electro conductive properties to the material, which is promising for the development of resistors of different rating and electrically heated ceramic tiles.

An important result of sintering in furnaces with limited access of oxygen/air is the minimization of the release of detrimental gaseous thermo destruction products of EPS and carbon oxides into atmosphere, which opens the way to large-scale processing of this type of wastes.

5. References

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**С kính**

У овом раду, разматране су могућности употребе отпада материјала за паковање састављеног од честица полистирена за производњу порозне керамике/цигле. Керамике су добијене из смеше црвена глина-млевене честице полистирена. Два мода синтеровања су развијена да би се смањило отпуштање токсичних продуката при термичкој деградацији полистирена. Током синтеровања у атмосфери, двостепени режим синтеровања је примењен, који је осигурао дехидратацију глине и брз прелаз ка синтеровању на 1000 °C. Током синтеровања при одсуству кисеоника, температура позако расте до 1000 °C. При томе је процес синтеровања карактерисан одсуством токсичних продуката и карбонизацијом порозне цигле. У зависности од састава смеше и услова синтеровања, могуће је добити постојан зид од керамике са добром термалним и звучно изолаторским својствима. Карбонизована керамика има побољшану чвство услед формирања форстерита. Присуство слободног угљеника у порама утиче на адсорпцију керамике и доприноси појави електричне проводљивости.

**Кључне речи:** црвена глина; стакло; честице полистирена; синтеровање; керамика; својства.

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