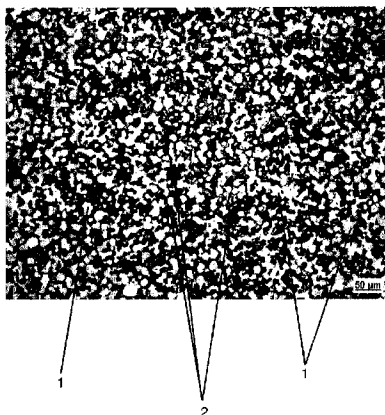




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(54) Titre : PROCÉDE POUR LA FABRICATION D'UNE MAGNÉSIE FRITTEE POREUSE, MELANGE POUR LA FABRICATION D'UN PRODUIT REFRACTAIRE EN CERAMIQUE GROSSIERE AYANT UNE GRANULOMETRIE A PARTIR DE LA MAGNÉSIE FRITTEE, UN TEL PRODUIT AINSI QUE PROCÉDE POUR SA FABRICATION, DISPOSITION D'UN FOUR INDUSTRIEL ET FOUR INDUSTRIEL
 (54) Title: METHOD FOR PRODUCING A POROUS SINTERED MAGNESIA, BATCH FOR PRODUCING A COARSE CERAMIC REFRACTORY PRODUCT HAVING A GRANULAR MATERIAL MADE OF THE SINTERED MAGNESIA, SUCH A PRODUCT AND METHOD FOR ITS PRODUCTION, LINING OF AN INDUSTRIAL FURNACE, AND INDUSTRIAL FURNACE



(57) **Abrégé/Abstract:**

The present invention relates to a method for producing a granular material from sintered magnesia, the sintered magnesia being produced by sintering of pressed articles, in particular pellets, from MgO powder, preferably from caustic MgO powder, and subsequent mechanical comminution of the pressed articles, the sintering being carried out in such a way that the granular material has a grain porosity (total porosity), according to DIN EN 993-1:1195-04 and DIN EN 993-18:1999-01, of from 15 to 38 vol%, preferably 20 to 38 vol%, and to a batch for producing a coarse ceramic, refractory, shaped or unshaped product containing the porous sintered magnesia, to such a product produced from the batch and to a method for its production, to a lining, in particular a working casing and/or a backing, of a large-volume industrial furnace, the lining, in particular the working casing and/or the backing, having at least one such product, as well as to such an industrial furnace.

Abstract

The present invention relates to a method for producing a granular material from sintered magnesia, the sintered magnesia being produced by sintering of pressed articles, in particular pellets, from MgO powder, preferably from caustic MgO powder, and subsequent mechanical comminution of the pressed articles, the sintering being carried out in such a way that the granular material has a grain porosity (total porosity), according to DIN EN 993-1:1195-04 and DIN EN 993-18:1999-01, of from 15 to 38 vol%, preferably 20 to 38 vol%, and to a batch for producing a coarse ceramic, refractory, shaped or unshaped product containing the porous sintered magnesia, to such a product produced from the batch and to a method for its production, to a lining, in particular a working casing and/or a backing, of a large-volume industrial furnace, the lining, in particular the working casing and/or the backing, having at least one such product, as well as to such an industrial furnace.

**METHOD FOR PRODUCING A POROUS SINTERED MAGNESIA, BATCH
FOR PRODUCING A COARSE CERAMIC REFRACTORY PRODUCT
HAVING A GRANULAR MATERIAL MADE OF THE SINTERED MAGNESIA,
SUCH A PRODUCT AND METHOD FOR ITS PRODUCTION, LINING OF AN
INDUSTRIAL FURNACE, AND INDUSTRIAL FURNACE**

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The present invention relates to a method for producing a porous sintered magnesia and to a batch for producing a coarse ceramic, refractory, shaped or unshaped product containing the porous sintered magnesia. The present invention also relates to such a product produced from the batch, and to a method for its production. In addition, the present invention relates to a lining, in particular a working casing and/or a backing, of a large-volume industrial furnace, the lining, in particular the working casing and/or the backing, having at least one such product, and to such an industrial furnace.

15

In the context of the present invention, the term "refractory" is not intended to be limited to the definition according to ISO 836, or DIN 501060, which define a pyrometric cone equivalent of $> 1500^{\circ} \text{C}$. Refractory products in the sense of the present invention have a compression softening point $T_{0.5}$ according to DIN EN ISO 1893: 2009-09 of $T_{0.5} \geq 600^{\circ} \text{C}$, preferably $T_{0.5} \geq 800^{\circ} \text{C}$. Accordingly, refractory, or fire-resistant, grainy materials, or granular materials in the sense of the present invention, are those materials, or granular materials, that are suitable for a refractory product having the above-mentioned compression softening point $T_{0.5}$. The refractory products according to the present invention are used for the protection of aggregate constructions in aggregates in which temperatures of between 600 and 2000°C , in particular between 1000 and 1800°C , predominate.

25

In the sense of the present invention, the term "granular material" or "grainy material" includes a pourable material made up of a large number of small solid grains. If the grains have a grain size $\leq 200 \mu\text{m}$, the granular material is a meal or powder. The grains are produced by mechanical comminution, e.g.

30

breaking and/or grinding. The grain distribution of the granular material is usually adjusted by sieving.

Persons skilled in the art know that refractory materials are based on six
5 refractory base oxides, as well as carbon and refractory carbon compounds,
which are named and classified for example in Gerald Routschka/Hartmut
Wuthnow, Practical Handbook "Feuerfeste Werkstoffe [**Refractory
materials**]," 5th ed., Vulkan-Verlag (hereinafter referred to simply as "Practical
Handbook"), pages 1-7". According to DIN EN ISO 10081:2005-05, a
10 distinction is made between non-basic and basic refractory products, based on
their chemical reaction behavior. The product group of non-basic products
includes the materials of the $\text{SiO}_2\text{-Al}_2\text{O}_3$ series, and other materials that cannot
be classified more precisely according to their chemical reaction behavior,
such as SiC products and carbon products. The materials having a high
15 content of SiO_2 are designated acidic. An essential feature of most basic
products is that the sum of the oxides MgO and CaO predominates. In
addition, chromite, picrochromite, spinel, and forsterite bricks are considered to
be among the basic products, although they are almost neutral. The shaped
basic products include in particular products containing magnesia, in particular
20 magnesia products, magnesia chromite products, magnesia spinel products,
magnesia zirconia products, magnesia pleonaste products, magnesia galaxite
products, magnesia hercynite products, magnesia doloma products (see e.g.
Practical Handbook, page 99, Table 4.26). Basic unshaped products are
products whose aggregates are substantially made up of magnesia, dolomite,
25 chromium magnesia, chromium ore, and spinel (see e.g. Practical Handbook,
page 146).

Typical magnesia raw materials for producing magnesia products are granular
materials, or granulates, of sintered and/or fused magnesia. Sintered
30 magnesia is produced by firing at a temperature of $> 1700\text{ }^\circ\text{C}$, preferably $> 1800\text{ }^\circ\text{C}$,
in order to achieve the highest possible grain bulk density. Fused
magnesia is produced at a temperature $> 2800\text{ }^\circ\text{C}$, in order to likewise achieve

the highest possible grain bulk density and the lowest possible grain porosity. Standard sintered magnesia types have a grain bulk density of $> 3.10 \text{ g/cm}^3$. Values of $> 3.30 - 3.40 \text{ g/cm}^3$ are sought. The corresponding grain porosities (total porosity) are standardly 4-10 vol%. Granular materials of fused
5 magnesia usually have a grain bulk density of $> 3.50 \text{ g/cm}^3$, with a grain porosity (total porosity) $< 2.5 \text{ vol\%}$.

Shaped products according to the present invention are ceramically fired or unfired, in particular pressed, products, preferably produced in a ceramic
10 factory, in particular bricks or plates. The shaped products, in particular the bricks, are used to form the kiln lining or the kiln backing, preferably walled using mortar or without mortar (laid tightly against one another). The unshaped products according to the present invention are products that are produced, mostly by the user, from an unshaped mass, e.g. through casting or injection.
15 Unshaped products are installed in larger sections at the location of use, usually behind molds, and after hardening form the kiln lining or the kiln backing.

The products according to the present invention are preferably used in
20 industrial firing aggregates or melting aggregates, or in other fired industrial aggregates, e.g. in a large-volume industrial furnace in order to form a refractory, fire-sided lining or aggregate inner lining (working casing) thereof. Preferably, they are used as working casings in burning kilns used in non-metal industry, preferably in cement kiln installations, lime shaft kilns or lime
25 rotary kilns, or heating kilns, or kilns for energy production, or in kilns in steel production or in nonferrous metal industry. The products according to the present invention can also be used as insulating backing in one of the named kilns. Refractory products of these types should therefore have low thermal conductivity and a high resistance to infiltration. In addition, they should
30 ensure good thermal resistance at temperatures of use, good chemical resistance, thermal shock resistance, good structural elasticity, appropriate compression softening and low gas permeability, and high heat bending

strength. In addition, the shaped products should have a cold compression strength that is adapted to the intended use, and that in particular should be sufficiently high for their handling during and after their production and after temperature shocks.

5

Refractory products of this type are known from DE 10 2006 040 269 A1 and from DE 10 2013 020 732 A1. In these products, a desired porosity is set via the grain size distribution:

10 From DE 10 2006 040 269 A1, fired coarse ceramic refractory products made of various refractory materials are known that can be used as working casing, and that may well also have a relatively low thermal conductivity due to an open porosity > 10 vol%. These are fine-grained products made from a batch that has 50-90 wt% fine particulate refractory material having a grain size $d_{90} < 100 \mu\text{m}$, the portion of grain size d_{90} between 100-500 μm being limited to $\leq 10 \text{ wt}\%$. This results in a coarse-grained fraction of 10-50 wt% with $d_{90} > 500 \mu\text{m}$, the specific grain selection of the batch being decisive for the microstructure of the fired product and its properties. The open porosity of the products is made up, by more than half, of pores having a diameter $d_{90} < 15$
15 μm , and more than 1/10 of pores having a diameter $d_{90} > 100 \mu\text{m}$. Here, the pore portion between 15 and 100 μm is a maximum of 1/7 of the total open porosity.
20

From DE 10 2013 020 732 A1, a coarse ceramic refractory product made of at least one grainy refractory material is known that has an open porosity
25 between 22 and 45 vol%, in particular between 23 and 29 vol%, and that has a grain structure in which the medium-grained fraction, having grain sizes between 0.1 and 0.5 mm, is from 10 to 55 wt%, in particular 35 to 50 wt%, the rest of the grain structure being a powdered grain fraction having grain sizes
30 up to 0.1 mm and/or a coarse-grained portion having grain sizes larger than 0.5 mm. The refractory product is used in particular to produce a working casing of a large-volume industrial furnace.

US 4,927,611 describes a magnesia clinker having a porosity of > 40 vol%, preferably in the range of 50 to 70 vol%, and a grain bulk density of < 2.0 g/cm³. In addition, more than 90 vol% of the pores have a pore size < 50 μm.

5 The production of the magnesia clinker takes place through granulation of a component that forms magnesium oxide, having a grain size of < 150 μm (100 mesh) and a burnout material in an additional quantity of 10-40 wt%, as well as the addition of 1-15% of a magnesium salt and subsequent firing at 1300 to 1600 °C. The magnesia clinker produced in this way is used in injectable

10 suspensions in order to coat nozzles and distributor troughs.

The use of lightweight basic granular materials based on magnesia spinels is also known from Wen Yan et al., "Effect of Spinel Content of lightweight aggregates on the reaction characteristics of periclase-spinel refractories with cement clinker," in Proc. 128, UNITECR 2015, and from Wen Yan et al., "Effect of Spinel Content on the Reaction of Porous Periclase-Spinel Ceramics and Cement Clinker," in Key Engineering Materials, Vol. 697, pp. 581-585. According to these references, granular materials are produced from MgO and from MgO-spinel mixtures, i.e. MgO or MgO-spinel co-clinker, having a

15 porosity of from 24.8 – 30.0 vol%, and are subsequently mixed with magnesia as a matrix, shaped, and fired at a temperature of 1550° C. These shaped products are characterized by a porosity of approximately 30 vol%. MgO grains have, in their pore size distribution, a maximum at a pore diameter of 50 μm; the average pore diameter of the MgO-spinel co-clinker grains is indicated

20 by values between 11.33 μm and 27.58 μm, and the average pore diameter of the matrix is 50.52 μm. In general, as the spinel content increases the susceptibility to cement clinker attack also increases. The highest resistances are shown by a pure magnesia product and a product having a co-clinker of 75% magnesia and 25% spinel. Other technologically important variables,

25 such as strength, refractoriness, elasticity (modulus of elasticity, shear modulus), resistance to thermal shock, volume stability, etc., are not named. It can therefore be presumed that such bricks cannot be used in a cement rotary

30

kiln due to inadequate technological properties. Notable is the large pore diameter, which suggests the use of burnout materials for the pore formation (organic compounds, hydroxides, carbonates), which are also described by the same author (Wen Yan et al., "Preparation and characterization of porous MgO-Al₂O₃ refractory aggregates using an in-situ decomposition pore-forming technique," Ceram. Int., Jan. 2015, pp. 515-520).

CN 106747594 A discloses the production of granular materials from a mixture of 5-95 wt% caustic MgO meal and 5-95 wt% magnesite meal. These mixtures are mixed with lignosulfonate and pressed to form pressed articles. The pressed articles are dried for 20 to 50 hours, and are subsequently fired at 1450-1700° C in a tunnel kiln or shuttle kiln for 10-20 hours. Granular materials produced for example having 95 wt% caustic MgO meal and 5 wt% magnesite meal have a porosity of 16.5 vol% and a density of 2.97 g/cm³.

15

The object of the present invention is to provide a sintered magnesia having good grain strength for a batch for the production of refractory products having high porosity and low thermal conductivity, and having properties suitable for use in large-volume industrial furnaces, and in particular having a low tendency to infiltration with regard to alkali infiltration.

20

A further object of the present invention is the provision of such a batch, as well as of a shaped or unshaped refractory product produced from the batch, as well as a method for its production.

25

In addition, an object of the present invention is the provision of a refractory lining of a large-volume industrial furnace, in particular a burning kiln of the non-metal industry, preferably a cement kiln installation, a lime shaft kiln or lime rotary kiln, a kiln for producing magnesia or doloma, or heating kiln or a kiln for energy production, or a kiln of the non-ferrous or steel industry, having or being formed from at least one product according to the present invention.

30

The lining can for example be multilayered, and can have a fire-sided or heat-sided working casing, or an aggregate inner-sided cladding and an insulating backing situated behind the cladding.

5

10 In the following, the present invention is explained in exemplary fashion on the basis of a drawing.

Figure 1 shows, as an example, a pore diameter distribution of a granular material according to the present invention made of porous sintered magnesia;

15

Figure 2 shows, as an example, a pore diameter distribution of a shaped brick according to the present invention;

Figure 3 shows a light microscopic image (reflected light) of a sintered magnesia according to the present invention, sintered in an HT kiln at 1530 °C, firing duration 6 h.

20

In the context of the present invention, it has been surprisingly discovered that by sintering of pressed articles, in particular pellets, from MgO meal, preferably caustic MgO meal, at a reduced maximum temperature (instead of the standard temperatures of > 1700 °C), and subsequent mechanical comminution of the pressed articles, a sintered magnesia can be produced that has a grain porosity (total porosity) according to DIN EN 993-1:1995-04 and DIN EN 993-18:2002-11 of 15 to 38 vol%, preferably 20 to 38 vol%.

25

30

The MgO meal can also be made up for example of dead-burned magnesia (DBM) or fused magnesia. However, it is preferably caustic MgO meal.

And, using this granular , porous sintered magnesia, refractory products can be produced having typical mechanical and chemical properties, having higher porosity and therefore lower thermal conductivity compared to the products previously used, but nonetheless having low tendency to infiltration.

5

In particular, in the context of the present invention it has been discovered that, it is possible, without the addition of burnout materials, solely through a reduced maximum firing temperature instead of the standard temperatures > 1700 °C, to produce a granular material made of sintered magnesia from the pressed articles made of MgO meal grains, preferably caustic MgO particles, having, compared to known sintered magnesia and fused magnesia, a significantly lower grain bulk density and significantly higher porosity, in turn resulting in the improved properties of the products produced therefrom.

15 The firing duration and the sintering temperatures, i.e. the temperature curve or temperature regime or temperature profile, of the sintering, or of the sintering process, are also set according to the present invention in such a way that the granular material according to the present invention made of porous sintered magnesia has a grain porosity (total porosity) according to
20 DIN 993-18:2002-11 and DIN 993-1:1995-4 of 15 to 38 vol%, preferably 20 to 38 vol%, and preferably has a grain bulk density according to DIN 993-18:2002-11 of 2.20 to 2.85 g/cm³, preferably 2.20 to 2.75 g/cm³. Thereby, for example, the temperature regime depends on the type of magnesia (its reactivity) and the particle size of the MgO meal.

25

Preferably, the sintering takes place at a maximum temperature ≤ 1600 °C, preferably ≤ 1550 °C, more preferably ≤ 1500 °C, particularly preferably ≤ 1400 °C.

30 That is, the sintering preferably takes place at a maximum temperature of between 1100-1600 °C, preferably between 1200-1600 °C, more preferably between 1200-1550 °C, particularly preferably between 1200-1500 °C.

The firing duration at the maximum temperature for the production of the sintered magnesia according to the present invention is preferably from 0.5 h to 7 h, preferably 2 h to 6 h. The total firing duration preferably corresponds to that of the standard production of sintered magnesia.

The firing preferably takes place in an oxidizing atmosphere, but can also take place in a reducing atmosphere. After the firing, the sintered magnesia is mechanically comminuted, in particular broken, and is classified by sieving.

The used mealy MgO causter or caustic MgO meal is preferably produced in the standard manner from magnesium hydroxide or from magnesium carbonate.

In addition, the MgO meal, preferably the caustic MgO meal, that is used preferably has a particle size distribution having the following values:

d_{90} between 80 and 100 μm and/or d_{50} between 5 and 15 μm and/or d_{10} between 1 and 3 μm . As is known, the d_x value means that x wt% of the particles are smaller than the indicated value. It is determined by laser granulometry according to DIN ISO 13320:2009. For this purpose, the MgO meal is dispersed in ethanol using ultrasound.

In addition, the used MgO meal, preferably the used caustic MgO meal preferably contains at least 88 wt%, preferably at least 95 wt%, MgO, particularly preferably at least 97 wt% MgO, determined using X-ray fluorescence analysis (XRF) according to DIN 12677:2013-02. In addition, the used MgO meal, preferably the used caustic MgO meal, preferably contains a maximum of 4 wt%, preferably a maximum of 2 wt%, CaO, determined using X-ray fluorescence analysis (XRF) according to DIN 12677:2013-02.

The MgO meal, preferably the caustic MgO meal, is in addition pressed in a standard press, preferably a pelleting press or briquetting press or hydraulic press, in such a way that the pressed articles have a bulk density, according to DIN 66133:1993-06, of 1.8 to 2.3 g/cm³, preferably 1.9 to 2.2 g/cm³, and/or a porosity, according to DIN 66133:1993-06, of 32 to 52 vol%, preferably 35 to 45 vol%. The pressed articles are preferably pellets. However, they can also advantageously be briquettes or bricks.

Thereby preferably, exclusively the MgO meal, preferably the caustic MgO meal, is pressed, if applicable with the addition of some water, i.e. without a binder and thus without any burnout materials.

The pressed articles thus consist, with regard to their dry mass, preferably of at least 96 wt%, more preferably of at least 98 wt%, particularly preferably of 100 wt%, of MgO meal, preferably of caustic MgO meal.

In particular, the pressed articles do not contain any magnesite meal.

As explained above, the firing duration and the sintering temperatures are set such that the granular material according to the present invention made of porous sintered magnesia has a grain porosity (total porosity) according to DIN 993-18:2002-11 and DIN 993-1:1995-4 of 15 to 38 vol%, preferably 20 to 38 vol%, and preferably has a grain bulk density according to DIN 993-18:2002-11 of 2.20 to 2.85 g/cm³, preferably 2.20 to 2.75 g/cm³. This also holds for the other properties of the granular material.

In particular, the granular material according to the present invention made of porous sintered magnesia preferably has a small average pore diameter d_{50} of 0.1 to 10 μm , preferably of 2 to 8 μm , determined in accordance with DIN 66133:1993-06. Thereby the pore diameter distribution can be monomodal (see Figure 1).

Figure 3 shows the microstructure of the sintered magnesia according to the present invention. It has a homogenous distribution of magnesia particles 1 and small pores 2. No larger pores are visible. The brighter pores 2 are pores filled with epoxy resin, the somewhat darker pores 2 are unfilled.

5

The granular material according to the present invention made of porous sintered magnesia additionally has a grain compression strength, based on DIN 13055:2016-11 (10 mm instead of 20 mm) of 10 to 30 MPa, preferably 11 to 25 MPa.

10

The granular material made of porous sintered magnesia according to the present invention in addition preferably has the following thermal conductivity values (TC), in accordance with DIN EN 821-2:1997-08:

15 **Table 1: Preferred thermal conductivity values of the sintered magnesia according to the present invention**

TC		preferably
400 °C [W/mK]	3 to 9	4 to 8
800 °C [W/mK]	2 to 7	3 to 6
1200 °C [W/mK]	2 to 7	3 to 6

The granular material according to the present invention is distinguished in particular by the following properties:

Table 2: Properties of porous sintered magnesia according to the present invention and of dense sintered magnesia

	Sintered magnesia according to the present invention	Conventional dense sintered magnesia
Grain bulk density [g/cm ³]	2.20-2.85	3.15-3.46
Grain porosity [vol%]	11-40	4-10
MgO [wt%]	88->99	88->99
Al ₂ O ₃ [wt%]	<1	<1
Fe ₂ O ₃ [wt%]	0.1-8	0.1-8
CaO [wt%]	0.3-8	0.3-8
SiO ₂ [wt%]	0.2-5	0.2-5
TC		
400 °C [W/mK]	5.84 (≤9)	13.29 (>9)
800 °C [W/mK]	3.71 (≤7)	8.33 (>7)
1200 °C [W/mK]	3.41 (≤7)	7.22 (>7)

- 5 As explained above, the sintered magnesia according to the present invention is used in batches according to the present invention for the production of shaped or unshaped refractory products according to the present invention.

10 A batch according to the present invention comprises a dry material mixture containing the sintered magnesia, and binder. That is, the quantity of binder (dry or liquid) is additively added, and relates to the total dry mass of the dry material mixture. If applicable, another liquid additive, also added additively, and also relating to the total dry mass of the dry material mixture, can be contained. Preferably, the batch consists of at least 90 wt%, more preferably
 15 of at least 99 wt%, particularly preferably of 100 wt%, of binder and the dry material mixture, relative to the total mass of the batch.

The dry material mixture preferably comprises the following components, related in each case to the total dry mass of the dry material mixture (the
 20 quantity indications indicate in each case the total sum of the respective components, i.e. for example the total amount of coarse granular material of

sintered magnesia according to the present invention, the total amount of powdered granular material, or of further granular material):

- 5 a) at least one coarse granular material made of the sintered magnesia according to the present invention having a grain size $> 200 \mu\text{m}$, preferably in a quantity of 10 to 90 wt%, more preferably of 20 to 80 wt%
- 10 b) at least one powdered granular material made of magnesia, e.g. of the sintered magnesia according to the present invention, having a grain size $\leq 200 \mu\text{m}$, preferably in a quantity of 90 to 10 wt%, more preferably of 80 to 20 wt%
- 15 c) if applicable, at least one further granular material made of a refractory material, preferably in a total quantity of additional granular material of 0.5 to 40 wt%, preferably of 3 to 30 wt%
- d) if applicable, at least one additive for refractory materials, preferably in a total quantity $< 5 \text{ wt}\%$
- 20 e) if applicable, at least one admixture for refractory materials, preferably in a total quantity of $< 5 \text{ wt}\%$.

The components can be contained in any combination in the dry material mixture.

25

In addition, as already explained, the batch according to the present invention contains, additively to the dry material mixture, at least one liquid or solid binder for refractory materials, preferably in a total quantity of 1 to 9 wt%, preferably 2.5 to 6 wt%, relative to the dry total mass of the dry material mixture.

30

In the case of unshaped products, the liquid binder is preferably packed in a container separate from the dry components of the batch.

5 In addition, the coarse granular material made of the sintered magnesia according to the present invention preferably has a grain size of up to a maximum of 8 mm, more preferably up to a maximum of 6 mm, particularly preferably up to a maximum of 4 mm.

10 The grain distribution of the coarse granular material made of the sintered magnesia according to the present invention and/or of the dry material mixture according to the present invention, is preferably steady, preferably in accordance with a Litzow, Furnas, or Fuller curve, or has a Gaussian distribution.

15 The further granular material is preferably made up of an elastifying raw material, i.e. a raw material that is typically used to lower the modulus of elasticity.

20 Preferably, the further granular material consists of a raw material from the following group:

Magnesium aluminate spinel, bauxite, alumina, hercynite, pleonaste, chromium ore, pleonastic spinel, zirconium oxide, olivine, and/or forsterite.

25 The present invention succeeds quite particularly effectively with a dry material mixture of the following materials:

magnesia

magnesia with magnesium aluminate spinel

30 magnesia with hercynite

magnesia with forsterite

magnesia with pleonaste or pleonastic spinel

magnesia with chromium ore
magnesia with zirconium oxide.

As explained, combinations of various further granular materials are also
5 possible, preferably a combination of a further granular material of hercynite
with a further granular material of magnesium aluminate spinel.

In addition, the further granular material preferably has a maximum grain size
of ≤ 8 mm, more preferably ≤ 6 mm, particularly preferably ≤ 4 mm.

10

The dry binder is a binder suitable for refractory products. These binders are
indicated for example in the Practical Handbook, page 28/point 3.2.

15 Preferably, the liquid binder is a binder from the following group: thermally
curing synthetic resin binder, in particular phenol formaldehyde resin, or
molasses or lignin sulfonate or a sulfur-free binder, in particular a binder based
on dextrose, an organic acid, saccharose, an Al_2O_3 binder, phosphoric acid, a
phosphate binder, water glass, ethyl silicate, or a sulfate, e.g. magnesium
sulfate or aluminum sulfate, or a sol-gel system.

20

The dry additive is an additive suitable for refractory products. These additives
are indicated for example in the Practical Handbook, page 28/point 3.3. They
are used to improve processability or deformability, or to modify the
microstructure of the products and in this way to achieve particular properties.

25

As already explained, the batch according to the present invention is used to
produce refractory shaped or unshaped products according to the present
invention.

30 For the production of shaped products, in particular bricks, a mixture or plastic
mass is produced from the dry material mixture of the batch according to the
present invention, with at least one liquid and/or solid binder and/or water. If

the batch contains a liquid binder, the addition of water is not necessary, but is possible.

5 For the optimal distribution of the binder or binders, and/or of the water, mixing takes place for e.g. 3 to 10 minutes.

The mixture is poured into molds and is pressed so that shaped bodies are formed. The molding pressures are within standard ranges, e.g. 60-180 MPa, preferably 100-150 MPa.

10

Preferably, after pressing a drying is carried out, e.g. at between 60 and 200° C, in particular between 90 and 140° C. The drying preferably takes place until there is a residual moisture between 0.1 and 0.6 wt%, in particular between 0.2 and 0.5 wt%, determined according to DIN 51078:2002-12.

15

Thus, in context of the present invention it has turned out that the production of shaped bodies is possible using standard molding pressures in order to achieve the named porosities with the corresponding mechanical and thermal properties. Apparently, the porosity of the sintered magnesia according to the present invention, used in particular in standard granulations in accordance with the Fuller or Litzow grain distribution of the material mixtures, in the overall granular material mixture ensures that, in particular during pressing, the pore volume according to the present invention can form without the grains having to form a support framework in the microstructure as described in DE 20 25 10 2013 020 732 A1.

The shaped bodies according to the present invention, in particular the bricks, can be used in unfired form or in tempered form or in fired form. Preferably, however, they are used in fired form.

30

The green pressed bricks are tempered in a ceramic burning kiln, e.g. a tunnel kiln, at between 400 and 1000° C, in particular between 500 and 800° C.

For the firing, the preferably dried pressed bricks are ceramically fired in a ceramic burning kiln, e.g. a tunnel kiln, preferably at between 1200 and 1800° C, in particular between 1400 and 1700° C. Preferably, firing is done in oxidizing fashion, but, depending on the material composition, a reducing firing may also be advantageous.

The thermal conductivity, according to the hot-wire (parallel) method according to DIN 993-15:2005-14, of the fired shaped products according to the present invention, in particular the bricks, is preferably 4.0 to 6.0 W/mK, more preferably 4.5 to 5.8 W/mK, at 300° C, 3.0 to 5.0 W/mK, more preferably 3.0 to 4.8 W/mK, at 700° C and 2.0 to 3.5 W/mK, more preferably 2.0 to 3.2 W/mK, at 1000° C.

The fired, shaped products, in particular the bricks, preferably have a high open porosity of 22 to 45 vol%, more preferably 23 to 35 vol%, determined according to DIN EN 993-1:1995-04.

In addition, they preferably have a mean value d_{50} of the pore size distribution (diameter), determined according to DIN 66133:1993-06, of 0.5 to 10 μm , preferably 2 to 8 μm .

In addition, the fired, shaped products, in particular the bricks, preferably have a low bulk density of 1.9 to 2.9 g/cm^3 , in particular 2.0 to 2.8 g/cm^3 , determined according to DIN 993-1:1995-04.

The cold compression strength according to DIN EN 993-5:1998-12 of the fired shaped products according to the present invention, in particular the bricks, is preferably 30 and 100 MPa, in particular 45 and 90 MPa. The cold bending strength according to DIN EN 993-6:1995-04 of the fired shaped products according to the present invention, in particular the bricks, is preferably 2 to 18 MPa, in particular 3 to 10 MPa.

The gas permeability according to DIN EN 993-4:1995-04 of the fired shaped products according to the present invention, in particular the bricks, is preferably 0.2 to 8 nPm, in particular 0.5 to 6 nPm.

5

The resistance to thermal shock, determined according to DIN EN 993-11:2008-03, in air at an elevated testing temperature of 1100° C of the fired shaped products according to the present invention, in particular the bricks, is preferably > 20 quenching cycles, in particular > 30 quenching cycles.

10

For the production of unshaped products, in particular masses, preferably injection masses or vibration masses or casting masses or stoker masses, a mixture is likewise produced from the dry material mixture according to the present invention, with at least one dry and/or liquid binder and/or water. If the batch contains a liquid binder, the addition of water is not necessary, but is possible.

In sum, the present invention provides refractory products that are highly porous but are outstandingly suitable for use as working casings and also as backings, with regard to thermal conductivity and pore size, and thus gas permeability. Particularly advantageous is the low average pore diameter d_{50} of the sintered magnesia according to the present invention, which is preferably 2-8 μm and which is also present in the produced product alongside the average pore diameter d_{50} of the matrix of approximately 4 μm (see Figure 2).

25

The shaped, in particular pressed, or unshaped coarse ceramic refractory products according to the present invention can be used as working casings in a fired industrial furnace aggregate despite their high porosity, because they have the required mechanical, thermomechanical, and thermochemical working casing properties.

30

The use of fine particulate material, approximately 50-90 wt% with $d_{90} < 100$ μm , is not necessary, rather, granulations of up to 8 mm, which are standard in refractory technology, may be used. In this way, the production effort for providing the granular material is reduced, in particular the grinding
5 comminution energy.

In addition, CO_2 emissions are reduced due to the lower firing temperature of the sintered magnesia according to the present invention. According to the present invention, the addition of burnout materials, which is very complex, to
10 integrate the burnout materials into the batch in homogenous fashion, and which also increases environmental impact due to CO_2 emissions, can be omitted.

In addition, the savings of material and weight for a volume to be lined is to be
15 considered a positive factor.

Up to now, the reduction of the thermal conductivity of refractory linings was usually brought about through multilayer casing configurations made of working layers and insulating layers. Particularly in moving aggregates, such
20 as cement rotary kilns, multilayer linings are mechanically very sensitive, or susceptible to breakage. Moreover, their installation is complicated. In order to avoid uncertainty during operation resulting from so-called intermediate layer casings, the installation of working casings not having an insulating layer is therefore not unusual. However, this is associated with higher temperatures,
25 which stress the material of an aggregate cladding, and higher heat losses. A working casing according to the present invention can be used with outstanding results even without an intermediate layer, in particular due to its low thermal conductivity.

30 On the basis of the following examples, the superiority of coarse ceramic products according to the present invention, compared to products according

to the closest existing prior art according to DE 10 2013 020732 A1 and compared to known dense products, is illustrated.

Production of the sintered magnesia according to the present invention

5 **for Examples 1 to 3:**

The production of the granular material made of the porous sintered magnesia was done as follows:

10 A filter cake obtained from a $\text{Mg}(\text{OH})_2$ suspension using a vacuum press, having a solids amount > 50%, was dried in a kiln and subsequently calcinated at 1100°C and comminuted, so that a caustic magnesia was obtained from the $\text{Mg}(\text{OH})_2$, whose typical particle size distribution d_{50} was = $10 \mu\text{m}$.

15 Using a pelleting press, the caustic magnesia was pressed to form almond-shaped pellets having dimensions of $13 \times 20 \times 30 \text{ mm}^3$. These green pellets had a grain bulk density of 2.0 g/cm^3 .

20 These pellets were sintered in a high-temperature laboratory kiln with a temperature profile in which the temperature was increased by 2 K/min until 800°C was reached. After a holding time of 6 h, the temperature was further increased by 2 K/min to 1450°C . The holding time at this temperature was 5 h. Cooling took place continuously through heat dissipation from the high-temperature laboratory kiln to the surrounding environment.

25

Subsequently, the porous sintered magnesia was broken up and classified by sieving.

30 The granular material according to the present invention made of the porous sintered magnesia had a grain bulk density of 2.59 g/cm^3 . The corresponding open porosity was 25.8 vol% (DIN EN 993-18:2002-11; DIN EN 993-1:1195-04).

Example 1:

In Example 1, bricks were produced based on the same materials and the same mineralogical composition (84 wt% magnesia, 16 wt% sintered spinel, magnesia meal made of dense sintered magnesia):

Table 3: Composition of the batches for Example 1

	Bricks a)	Bricks b)	Bricks c)
Sintered magnesia according to the present invention [wt%], 0-4 mm	54		
Dense sintered magnesia [wt%], 0-4 mm		54	10
Dense sintered magnesia [wt%], 0.1-0.5 mm			32
Sintered spinel [wt%], 0-4 mm	16	16	16
Magnesia meal, ≤ 200 μm	30	30	42
Binder lignin sulfonate [wt%, relative to dry mass]	3.7	3.7	6
Compression [MPa]	130	130	40
Firing temperature [°C]	1600	1600	1600

The used raw materials had the following properties:

Table 4: Properties of the sintered magnesia according to the present invention

Sintered magnesia according to the present invention	
Grain bulk density according to DIN 993-1:1995-04, 993-18:2002-11	2.59 g/cm ³
Grain porosity according to DIN 993-1:1995-04, 993-18:2002-11	25.8 vol%

Table 5: Properties of the dense sintered magnesia for bricks b) and c)

Dense sintered magnesia	
Grain bulk density according to DIN 993-1:1995-04, 993-18:2002-11	3.41 g/cm ³
Grain porosity according to DIN 993-1:1995-04, 993-18:2002-11	1 Vol.-%

Table 6: Properties of the sintered spinel for bricks a), b) and c)

Sintered spinel	
Grain bulk density according to DIN 993-1:1995-04, 993-18:2002-11	3.37 g/cm ³
Grain porosity according to DIN 993-1:1995-04, 993-18:2002-11	2 vol%

The production of the bricks a)-c) took place in each case as follows:

The corresponding raw materials according to Table 3, having a grain size
 5 distribution according to Fuller, were mixed dry in a mixer for 3 minutes,
 provided with the liquid binder, and further mixed for 5 minutes. The mixture
 was brought to a hydraulic press and was pressed in a B format for rotary kiln
 bricks, with a molding pressure as shown in Table 3. The bricks were dried in
 a dryer at approximately 130° C and were subsequently fired in oxidizing
 10 fashion at 1600° C in a tunnel kiln for 50 hours. The holding time at the
 maximum temperature was 5 h. The firing shrinkage was determined by
 measuring, the final bulk density was determined by measuring and weighing,
 the porosity was determined according to DIN EN 993-1:1995-04, the cold
 compression strength was determined according to DIN EN 993-5:1998-12,
 15 the cold bending strength was determined according to DIN EN 993-6:1995-
 04, the gas permeability was determined according to DIN EN 993-4:1995-04,
 and the thermal conductivity was determined according to the hot-wire
 (parallel) method DIN 993-15:2005-14. The resistance to thermal shock was
 determined according to DIN EN 993-11:2008-03 in air at an elevated test
 20 temperature of 1100° C:

Table 7: Properties of the fired bricks of Example 1

	Bricks a)	Bricks b)	Bricks c)
Bulk density [g/cm³]	2.68	2.95	2.63
Porosity [vol%]	24.1	16.0	25.2
Cold compression strength [MPa]	88	70	80
Cold bending strength [MPa]	5.98	5.6	6.0
Gas permeability [nPm]	0.85	1.6	1.2
Firing shrinkage [%]	1.18	0.30	0.60
Pore diameter d₅₀ [µm]	3.8	14.2	10.4
TSR [cycles]	> 30	> 30	> 30
TC			
300 °C [W/mK]	5.4	6.7	5.5
700 °C [W/mK]	3.5	5.1	3.6
1000 °C [W/mK]	2.6	4.0	2.8

Compared to the conventional dense bricks according to b), the brick properties change in the case of a) and also of c), where the bricks have a significantly higher porosity and a significantly reduced bulk density, without having a negative influence on the other brick properties. In particular, the gas permeability and the pore diameter are reduced in the bricks according to the present invention.

In the case of a) according to the present invention, in which the granular material is made up of porous magnesia according to the present invention, the reduction of the bulk density and the increase in the open porosity are considerable compared to b).

In addition, the average pore diameter d_{50} is dramatically reduced in comparison with b) and c), so that there is a reduced tendency to infiltration by alkalis and clinker melts. In comparison with b), the cold compression strength and cold bending strength continue to be reliably in the range typical for dense bricks. The resistance to thermal shock is, at > 30 quench cycles, at the same required high level without breakage for all brick types.

In addition, for bricks according to the present invention according to a), the results show significantly reduced thermal conductivity values compared to the dense magnesia spinel bricks b).

Example 2:

25

For Example 2, bricks d), a porous spinel was used instead of the sintered spinel of Example 1:

Table 8: Composition of the batches for Example 2

	Bricks a)	Bricks b)	Bricks d)
Magnesia according to the present invention [wt%], 0-4 mm	54		54
Dense sintered magnesia [wt%], 0-4 mm		54	
Sintered spinel [wt%], 0-4 mm	16	16	
Porous sintered spinel, 0-4 mm			16
Magnesia meal $\leq 200 \mu\text{m}$	30	30	30
Binder lignin sulfonate [wt%, relative to dry mass]	3.7	3.7	3.7
Compression [MPa]	130	130	40
Firing temperature [°C]	1600	1600	1600

The properties of the magnesia according to the present invention for d) correspond to those of Example 1.

5

Table 9: Properties of the porous sintered spinel for bricks d)

Porous sintered spinel	
Grain bulk density according to DIN 993-1:1995-04, 993-18:2002-11	2.66 g/cm³
Grain porosity according to DIN 993-1:1995-04, 993-18:2002-11	25 vol%

The bricks d) were produced and tested analogously to Example 1:

Table 10: Properties of the fired bricks of Example 2

	Bricks a)	Bricks b)	Bricks d)
Bulk density [g/cm³]	2.68	2.95	2.64
Porosity [vol%]	24.1	16.0	25.2
Cold compression strength [MPa]	88	70	85
Cold bending strength [MPa]	5.98	5.6	6.4
Gas permeability [nPm]	0.85	1.6	0.92
Firing shrinkage [%]	1.18	0.30	1.2
Pore diameter d₅₀ [μm]	3.8	14.2	4.2
TSR [cycles]	> 30	> 30	> 30
TC			
300 °C [W/mK]	5.4	6.7	5.2
700 °C [W/mK]	3.5	5.1	3.3
1000 °C [W/mK]	2.6	4.0	2.4

5 Compared to the bricks of Example 1, here the brick properties differ only slightly due to the use of porous magnesia and porous spinel, but a further reduced thermal conductivity can be seen. All other positive mechanical and thermal properties are maintained.

Example 3:

10

In the first Examples 1 and 2, the advantages of the porous sintered magnesia according to the present invention for magnesia spinel bricks were explained. In order to demonstrate the effectiveness of the present invention in products made of other refractory materials, in Example 3 bricks based on sintered magnesia in combination with fused pleonaste (pleonastic fused spinel) were examined. Bricks e) were based on sintered magnesia according to the present invention, and bricks f), provided for comparison, were based on dense sintered magnesia. The production took place as in Example 1, at a firing temperature of 1450° C:

20

Table 11: Composition of the batches for Example 3

	Steine e)	Steine f)
Magnesia according to the present invention [wt%], 0-4 mm	54	
Dense sintered magnesia [wt%], 0-4 mm		54
Fused pleonaste [wt%], 0-4 mm	16	16
Magnesia meal $\leq 200 \mu\text{m}$	30	30
Binder lignin sulfonate [wt%, relative to dry mass]	3.7	3.7
Compression [MPa]	130	130
Firing temperature [$^{\circ}\text{C}$]	1450	1450

Table 12: Properties of the fused pleonaste for bricks e) and f)

Fused pleonaste	
Grain bulk density according to DIN 993-1:1995-04, 993-18:2002-11	3.74 g/cm ³
Grain porosity according to DIN 993-1:1995-04, 993-18:2002-11	2 vol%

- 5 The following table shows the results of Example 3:

Table 13: Properties of the fired bricks of Example 3

	Steine e)	Steine f)
Bulk density [g/cm ³]	2.66	3.00
Porosity [vol%]	24.8	15.7
Cold compression strength [MPa]	98	100
Cold bending strength [MPa]	6.25	6.75
Gas permeability [nPm]	0.98	1.45
Firing shrinkage [%]	1.12	0.20
Pore diameter d_{50} [μm]	4.8	14.6
TSR [cycles]	> 30	> 30
TC		
300 $^{\circ}\text{C}$ [W/mK]	5.3	6.9
700 $^{\circ}\text{C}$ [W/mK]	3.4	5.3
1000 $^{\circ}\text{C}$ [W/mK]	2.5	4.2

- 10 Table 4 shows that the porous sintered magnesia according to the present invention can also be used in magnesia pleonaste bricks, the porosity increases significantly due to the use of the sintered magnesia according to the present invention, and all positive mechanical and thermal properties are maintained.

Claims

1. A method for producing a granular material of sintered magnesia,
wherein
5 the sintered magnesia is produced by
 - a) sintering of pressed articles of MgO meal that consist, relative to their dry mass, of at least 96 wt% of MgO meal and contain no magnesite meal and have a grain size $\leq 200 \mu\text{m}$, and
 - b) subsequent mechanical comminution of the sintered pressed articles,
10 wherein the sintering takes place at a maximum temperature between 1100-1600 °C and wherein the firing duration at the maximum temperature is 0.5 h to 7 h, such that the granular material has a total grain porosity according to DIN EN 993-1:1995-04 and DIN EN 993-18:2002-11 of 15 to 38 vol%, and a grain compression strength, based
15 on DIN 13055-2016-11 for 10 mm instead of 20 mm, of 10 to 30 MPa.
2. The method according to Claim 1,
wherein
the pressed articles are pressed pellets.
20
3. The method according to Claim 1 or 2,
wherein
the pressed articles are pressed articles of caustic MgO meal.
- 25 4. The method according to any one of claims 1 to 3,
wherein
the granular material has a total grain porosity according to DIN EN 993-1:1995-04 and DIN EN 993-18:2002-11 of 20 to 38 vol%.
- 30 5. The method according to any one of claims 1 to 4,
wherein

the sintering takes place at a maximum temperature between 1200-1600° C.

- 5 6. The method according to Claim 5,
wherein
the sintering takes place at a maximum temperature between 1200-1550 °C.
- 10 7. The method according to Claim 6,
wherein
the sintering takes place at a maximum temperature between 1200-1500 °C.
- 15 8. The method according to any one of claims 1 to 7,
wherein
the firing duration at the maximum temperature is 2 h to 6 h.
- 20 9. The method according to any one of claims 1 to 8,
wherein
the granular material has a grain bulk density, according to DIN EN 993-1:1995-04 and DIN EN 993-18:2002:11, of 2.20 to 2.85 g/cm³.
- 25 10. The method according to Claim 9,
wherein
the granular material has a grain bulk density, according to DIN EN 993-1:1995-04 and DIN EN 993-18:2002-11, of 2.20 to 2.75 g/cm³.
- 30 11. The method according to any one of claims 1 to 10,
wherein
the pressed articles have a bulk density according to DIN 66133:1993-06 of 1.8 to 2.3 g/cm³.

12. The method according to Claim 11,
wherein
the pressed articles have a bulk density according to DIN 66133:1993-06 of 1.9 to 2.2 g/cm³.
- 5
13. The method according to any one of claims 1 to 12,
wherein
the pressed articles have a porosity, according to DIN 66133:1993-06,
of 32 to 52 vol%.
- 10
14. The method according to Claim 13,
wherein
the pressed articles have a porosity, according to DIN 66133:1993-06,
of 35 to 45 vol%.
- 15
15. The method according to any one of claims 1 to 14,
wherein
the MgO meal comprises at least 88 wt% MgO, determined by x-ray
fluorescence analysis according to DIN 12677:2013-02.
- 20
16. The method according to Claim 15,
wherein
the MgO meal comprises at least 95 wt% MgO, determined by x-ray
fluorescence analysis according to DIN 12677:2013-02.
- 25
17. The method according to Claim 16,
wherein
the MgO meal comprises at least 97 wt% MgO, determined by x-ray
fluorescence analysis according to DIN 12677:2013-02.
- 30
18. The method according to any one of claims 1 to 17,
wherein

the MgO meal has a particle size distribution having the following value, determined using laser granulometry according to DIN ISO 13320:2009: d_{90} between 80 and 100 μm .

5 19. The method according to any one of claims 1 to 18,
wherein
the MgO meal has a particle size distribution having the following value,
determined using laser granulometry according to DIN ISO 13320:2009:
10 d_{50} between 5 and 15 μm .

20. The method according to any one of claims 1 to 19,
wherein
the MgO meal has a particle size distribution having the following value,
determined using laser granulometry according to DIN ISO 13320:2009:
15 d_{10} between 1 and 3 μm .

21. The method according to one of claims 1 to 20,
wherein
20 the pressed articles contain, relative to their dry mass, 100 wt% of MgO
meal.

22. The method according to any one of claims 1 to 21,
wherein
25 the granular material made of sintered magnesia is produced without the
use of burnout materials.

23. The method according to any one of claims 1 to 22,
wherein
30 the granular material made of sintered magnesia has an average pore
diameter d_{50} of 0.1 to 10 μm , determined according to DIN 66133:1993-
06.

24. The method according to Claim 23,
wherein
the granular material made of sintered magnesia has an average pore
5 diameter d_{50} of 2 to 8 μm , determined according to DIN 66133:1993-06.
25. The method according to any one of claims 1 to 24,
wherein
the granular material made of sintered magnesia has a grain
10 compression strength, based on DIN 13055-2016-11 for 10 mm instead
of 20 mm, of 11 to 25 MPa.
26. The method according to any one of claims 1 to 25,
wherein
15 the granular material made of sintered magnesia has a thermal
conductivity according to DIN EN 821-2:1997-08 of 3 to 9 W/mK at 400
 $^{\circ}\text{C}$ and of 2 to 7 W/mK at 800 $^{\circ}\text{C}$ and of 2 to 7 W/mK at 1200 $^{\circ}\text{C}$.
27. The method according to Claim 26,
20 wherein
the granular material made of sintered magnesia has a thermal
conductivity according to DIN EN 821-2:1997-08 of 4 to 8 W/mK at 400
 $^{\circ}\text{C}$ and of 3 to 6 W/mK at 800 $^{\circ}\text{C}$ and of 3 to 6 W/mK at 1200 $^{\circ}\text{C}$.
- 25 28. Use of the granular material made of sintered magnesia produced
according to the method of any one of claims 1 to 27, the granular
material made of sintered magnesia being mechanically comminuted
and having a total grain porosity according to DIN EN 993-1:1995-04
and DIN EN 993-18:2002-11 of 15 to 38 vol%, and a grain compression
30 strength, based on DIN 13055-2016-11 for 10 mm instead of 20 mm, of
10 to 30 MPa, in a batch for producing a coarse ceramic, refractory,
shaped or unshaped product, the batch comprising a dry material

mixture comprising the granular material and in addition thereto, the batch further comprising at least one liquid or solid binder for refractory materials.

5 29. The use according to Claim 28,
 wherein
 the granular material is used in a batch for producing a product for a
 working casing or a backing of an industrial furnace.

10 30. The use according to Claim 29,
 wherein
 the granular material is used in a batch for producing a product for a
 working casing or a backing of a cement kiln installation, a lime shaft
 kiln, a lime rotary kiln, a magnesite kiln, a dolomite kiln, a heating kiln, a
15 kiln for energy production, a kiln for steel production, or a kiln of the
 nonferrous metal industry.

 31. The use according to any one of claims 28 to 30,
 wherein
20 the granular material is used in a batch comprising
 the dry material mixture comprising the following components:
 a) at least one coarse granular material made of the sintered
 magnesia produced according to the method of any one of claims
 1 to 27 having a grain size $> 200 \mu\text{m}$, and
25 b) at least one powdered granular material made of magnesia,
 having a grain size $\leq 200 \mu\text{m}$,
 and in addition to the dry material mixture, the at least one liquid or solid
 binder for refractory materials.

32. The use according to Claim 31,
wherein
the dry material mixture comprises the coarse granular material made of
the sintered magnesia produced according to the method of any one of
5 claims 1 to 27 in a total quantity of 10 to 90 wt%.
33. The use according to Claim 32,
wherein
the dry material mixture comprises the coarse granular material made of
10 the sintered magnesia produced according to the method of any one of
claims 1 to 27 in a total quantity of 20 to 80 wt%.
34. The use according to any one of Claims 31 to 33,
wherein
15 the at least one powdered granular material made of magnesia consists
of the granular material made of sintered magnesia produced according
to the method of any one of claims 1 to 27.
35. The use according to any one of Claims 31 to 34,
20 wherein
the dry material mixture comprises the at least one powdered granular
material made of magnesia in a total quantity of 90 to 10 wt%.
36. The use according to Claim 35,
25 wherein
the dry material mixture comprises the at least one powdered granular
material made of magnesia in a total quantity of 80 to 20 wt%.
37. The use according to any one of Claims 31 to 36,
30 wherein
the dry material mixture comprises at least one further granular material
made of a refractory material.

38. The use according to Claim 37,
wherein
the dry material mixture comprises the at least one further granular
5 material made of a refractory material in a total quantity of 0.5 to 40 wt%.
39. The use according to Claim 38,
wherein
the dry material mixture comprises the at least one further granular
10 material made of a refractory material in a total quantity of 3 to 30 wt%.
40. The use according to any one of Claims 31 to 39,
wherein
the dry material mixture further comprises at least one additive for
15 refractory materials.
41. The use according to Claim 40,
wherein
the dry material mixture comprises the at least one additive for refractory
20 materials in a total quantity of additive < 5 wt%.
42. The use according to any one of Claims 31 to 41,
wherein
the batch comprises the at least one liquid or solid binder for refractory
25 materials in a total quantity from 1 to 9 wt% relative to the total dry mass
of the dry material mixture.
43. The use according to Claim 42,
wherein
30 the batch comprises the at least one liquid or solid binder for refractory
materials in a total quantity from 2.5 to 6 wt%, relative to the total dry
mass of the dry material mixture.

44. The use according to any one of Claims 31 to 43,
wherein
the granular material is used in a batch containing at least 90 wt% of the
5 binder and the dry material mixture, relative to the total mass of the
batch.
45. The use according to Claim 44,
wherein
10 the granular material is used in a batch consisting of the binder and the
dry material mixture.
46. The use according to any one of Claims 31 to 45,
wherein
15 the dry material mixture comprises ≥ 50 wt% of the coarse granular
material made of the sintered magnesia.
47. The use according to Claim 46,
wherein
20 the dry material mixture comprises ≥ 60 wt% of the coarse granular
material made of the sintered magnesia.
48. The use according to Claim 47,
wherein
25 the dry material mixture comprises ≥ 70 wt% of the coarse granular
material made of the sintered magnesia.
49. The use according to any one of Claims 31 to 48,
wherein
30 the coarse granular material made of the sintered magnesia has a
maximum grain size ≤ 8 mm.

50. The use according to Claim 49,
wherein
the coarse granular material made of the sintered magnesia has a
5 maximum grain size ≤ 6 mm.
51. The use according to Claim 50,
wherein
the coarse granular material made of the sintered magnesia has a
10 maximum grain size ≤ 4 mm.
52. The use according to any one of Claims 31 to 51,
wherein
the grain distribution of the coarse granular material made of the sintered
15 magnesia is continuous.
53. The use according to any one of Claims 37 to 52,
wherein
the at least one further granular material comprises a raw material
20 selected from the group consisting of:

magnesium aluminate spinel, bauxite, alumina, hercynite, pleonaste,
chromium ore, pleonastic spinel, zirconium oxide, olivine, and forsterite.
54. The use according to any one of Claims 37 to 53,
25 wherein
the further granular material has a maximum grain size ≤ 8 mm.
55. The use according to Claim 54,
wherein
30 the further granular material has a maximum grain size ≤ 6 mm.

56. The use according to Claim 55,
wherein
the further granular material has a maximum grain size ≤ 4 mm.
- 5 57. The use according to any one of Claims 37 to 56,
wherein
the grain distribution of the further granular material is continuous.
- 10 58. The use according to any one of Claims 31 to 57,
wherein
the liquid binder is a binder selected from the group consisting of:
thermally curing synthetic resin binder, molasses, lignin sulfonate, a
sulfur-free binder, a sulfate system, and a sol-gel system.
- 15 59. The use according to Claim 58,
wherein
the thermally curing synthetic resin binder is a phenol formaldehyde
resin.
- 20 60. The use according to Claim 58,
wherein
the sulfur-free binder is a binder selected from the group consisting of:
a binder based on dextrose, an organic acid, saccharose, an Al_2O_3
binder, phosphoric acid, a phosphate binder, water glass, and ethyl
25 silicate.
- 30 61. The use according to Claim 58,
wherein
the sulfate system is a binder selected from the group consisting of:
magnesium sulfate and aluminum sulfate.

62. The use of the granular material made of sintered magnesia produced according to the method of any one of Claims 1 to 27 in a coarse ceramic, refractory, shaped or unshaped product.
- 5 63. The use according to Claim 62,
wherein
the granular material is used in a product for a working casing of an industrial furnace.
- 10 64. The use according to Claim 63,
wherein
the granular material is used in a product for a cement kiln installation, a lime shaft kiln, a lime rotary kiln, a magnesite kiln, a dolomite kiln, a heating kiln, a kiln for energy production, a kiln for steel production, or a
15 kiln of the nonferrous metal industry.
65. The use according to any one of claims 62 to 64,
wherein
the shaped product is a green shaped body.
- 20 66. The use according to Claim 65,
wherein
the shaped product is a green pressed shaped body.
- 25 67. The use according to Claim 66,
wherein
the green pressed shaped body is a brick.
- 30 68. The use according to any one of claims 62 to 64,
wherein
the shaped product is a tempered shaped body.

69. The use according to Claim 68,
wherein
the tempered shaped body is a brick.
- 5 70. The use according to any one of claims 62 to 64,
wherein
the shaped product is a fired shaped body.
71. The use according to Claim 70,
10 wherein
the fired shaped body is a brick.
72. The use according to Claim 70 or 71,
wherein
15 the fired shaped body has a thermal conductivity according to the hot-
wire (parallel) method according to DIN 993-15:2005-14 of 4.0 to 6.0
W/mK at 300° C, 3.0 to 5.0 W/mK at 700° C and 2.0 to 3.5 W/mK at
1000° C.
- 20 73. The use according to Claim 72,
wherein
the fired shaped body has a thermal conductivity according to the hot-
wire (parallel) method according to DIN 993-15:2005-14 of 4.5 to 5.8
W/mK at 300° C, 3.0 to 4.8 W/mK at 700° C and 2.0 to 3.2 W/mK at
25 1000° C.
74. The use according to any one of claims 70 to 73,
wherein
the fired shaped body comprises an open porosity of 22 to 45 vol%,
30 determined according to DIN 993-1:1995-4.
75. The use according to Claim 74,

wherein

the fired shaped body comprises an open porosity of 23 to 35 vol%,
determined according to DIN 993-1:1995-4.

5 76. The use according to any one of Claims 70 to 75,

wherein

the fired shaped body has an average value of the pore diameter
distribution d_{50} , determined according to DIN 66133:1993-06, of 0.5 to
10 μm .

10

77. The use according to Claim 76,

wherein

the fired shaped body has an average value of the pore diameter
distribution d_{50} , determined according to DIN 66133:1993-06, of 2 to 10
15 μm .

78. The use according to any one of Claims 70 to 77,

wherein

the fired shaped body has a bulk density of from 1.9 to 2.9 g/cm^3
20 determined according to DIN 993-1:1995-04.

20

79. The use according to Claim 78,

wherein

the fired shaped body has a bulk density of from 2.0 to 2.8 g/cm^3 ,
25 determined according to DIN 993-1:1995-04.

25

80. The use according to any one of Claims 70 to 79,

wherein

the fired shaped body has a cold compression strength according to DIN
30 EN 993-5:1998-12 of 30 to 100 MPa.

30

81. The use according to Claim 80,

wherein

the fired shaped body has a cold compression strength according to DIN EN 993-5:1998-12 of 45 to 90 MPa.

5 82. The use according to any one of Claims 70 to 81,
 wherein
 the fired shaped body has a cold bending strength according to DIN EN 993-6:1995-04 from 2 to 18 MPa.

10 83. The use according to Claim 82,
 wherein
 the fired shaped body has a cold bending strength according to DIN EN 993-6:1995-04 of from 3 to 10 MPa.

15 84. The use according to any one of Claims 70 to 83,
 wherein
 the fired shaped body has a gas permeability according to DIN EN 993-4:1995-04 from 0.2 to 8 nPm.

20 85. The use according to Claim 84,
 wherein
 the fired shaped body has a gas permeability according to DIN EN 993-4:1995-04 from 0.5 to 6 nPm.

25 86. The use according to any one of Claims 70 to 85,
 wherein
 the fired shaped body has a thermal shock resistance, determined according to DIN EN 993-11:2008-03 in air at a test temperature of 1100° C of the fired shaped body, of > 20 quenching cycles.

30 87. The use according to Claim 86,
 wherein

the fired shaped body has a thermal shock resistance, determined according to DIN EN 993-11:2008-03 in air at a test temperature of 1100° C of the fired shaped body, of > 30 quenching cycles.

- 5 88. A method for producing a coarse ceramic, refractory shaped product from a batch comprising:

10 a dry material mixture comprising the granular material made of sintered magnesia produced according to the method of any one of claims 1 to 27, the granular material made of sintered magnesia being mechanically comminuted and having a total grain porosity according to DIN EN 993-1:1995-04 and DIN EN 993-18:2002-11 of 15 to 38 vol%, and a grain compression strength, based on DIN 13055-2016-11 for 10 mm instead of 20 mm, of 10 to 30 MPa, and

15 at least one liquid or solid binder for refractory materials, the method comprising the following steps:

a) mixing the dry material mixture with the at least one liquid or solid binder, or with water and the at least one liquid or solid binder, to form a plastic mass, and

b) shaping of the plastic mass to form a green shaped body.

20

89. The method according to Claim 88, wherein the mass is pressed to form the green shaped body.

- 25 90. The method according to Claim 88 or 89, further comprising drying of the green shaped body.

91. The method according to any one of claims 88 to 90, further comprising tempering or firing of the green shaped body.

30

92. The method according to Claim 91,
wherein
the shaped body is fired at a temperature of 1200 to 1800° C.
- 5 93. The method according to Claim 92,
wherein
the shaped body is fired at a temperature of 1400 to 1700° C.
- 10 94. Use of a refractory product for a lining of a large-volume industrial
furnace,
wherein
the refractory product comprises the granular material made of sintered
magnesia produced according to the method of any one of Claims 1 to
27, the granular material made of sintered magnesia being mechanically
15 comminuted and having a total grain porosity according to DIN EN 993-
1:1995-04 and DIN EN 993-18:2002-11 of 15 to 38 vol%, and a grain
compression strength, based on DIN 13055-2016-11 for 10 mm instead
of 20 mm, of 10 to 30 MPa.
- 20 95. The use according to claim 94,
wherein
the product is a shaped product and the shaped product is a green
shaped body, a tempered shaped body or a fired shaped body.
- 25 96. The use according to Claim 95,
wherein
the shaped product is a brick.
- 30 97. The use according to Claim 95 or 96,
wherein
the fired shaped body has a thermal conductivity according to the hot-
wire (parallel) method according to DIN 993-15:2005-14 of 4.0 to 6.0

W/mK at 300° C, 3.0 to 5.0 W/mK at 700° C and 2.0 to 3.5 W/mK at 1000° C.

- 5 98. The use according to Claim 97,
wherein
the fired shaped body has a thermal conductivity according to the hot-wire (parallel) method according to DIN 993-15:2005-14 of 4.5 to 5.8 W/mK at 300° C, 3.0 to 4.8 W/mK at 700° C and 2.0 to 3.2 W/mK at 1000° C.
- 10 99. The use according to any one of Claims 95 to 98,
wherein
the fired shaped body has an open porosity of 22 to 45 vol%, determined according to DIN 993-1:1995-4.
- 15 100. The use according to Claim 99,
wherein
the fired shaped body has an open porosity of 23 to 35 vol%, determined according to DIN 993-1:1995-4.
- 20 101. The use according to any one of Claims 95 to 100,
wherein
the fired shaped body has an average value of the pore diameter distribution d_{50} , determined according to DIN 66133:1993-06, of 0.5 to
- 25 10 μm .
- 30 102. The use according to Claim 101,
wherein
the fired shaped body has an average value of the pore diameter distribution d_{50} , determined according to DIN 66133:1993-06, of 2 to 10 μm .

103. The use according to any one of Claims 95 to 102,
wherein
the fired shaped body has a bulk density of from 1.9 to 2.9 g/cm³
determined according to DIN 993-1:1995-04.
- 5
104. The use according to Claim 103,
wherein
the fired shaped body has a bulk density of from 2.0 to 2.8 g/cm³,
determined according to DIN 993-1:1995-04.
- 10
105. The use according to any one of Claims 95 to 104,
wherein
the fired shaped body has a cold compression strength according to DIN
EN 993-5:1998-12 of 30 to 100 MPa.
- 15
106. The use according to Claim 105,
wherein
the fired shaped body has a cold compression strength according to DIN
EN 993-5:1998-12 of 45 to 90 MPa.
- 20
107. The use according to any one of Claims 95 to 106,
wherein
the fired shaped body has a cold bending strength according to DIN EN
993-6:1995-04 from 2 to 18 MPa.
- 25
108. The use according to Claim 107,
wherein
the fired shaped body has a cold bending strength according to DIN EN
993-6:1995-04 of from 3 to 10 MPa.
- 30
109. The use according to any one of Claims 95 to 108,
wherein

the fired shaped body has a gas permeability according to DIN EN 993-4:1995-04 from 0.2 to 8 nPm.

- 5 110. The use according to Claim 109,
wherein
the fired shaped body has a gas permeability according to DIN EN 993-4:1995-04 from 0.5 to 6 nPm.
- 10 111. The use according to any one of Claims 95 to 110,
wherein
the fired shaped body has a thermal shock resistance, determined according to DIN EN 993-11:2008-03 in air at a test temperature of 1100° C of the fired shaped body, of > 20 quenching cycles.
- 15 112. The use according to Claim 111,
wherein
the fired shaped body has a thermal shock resistance, determined according to DIN EN 993-11:2008-03 in air at a test temperature of 1100° C of the fired shaped body, of > 30 quenching cycles.
- 20 113. The use according to any one of Claims 94 to 112,
wherein
the refractory product is produced according to the method of any one of Claims 88 to 93.
- 25 114. The use according to any one of Claims 94 to 113,
wherein
the refractory product is used in a lining of a burning kiln of the non-metallic industry, a heating kiln, a kiln for energy production, a kiln for steel production, or a kiln of the nonferrous metal industry.
- 30 115. The use according to Claim 114,

wherein

the refractory product is used in a lining of a cement kiln installation, a lime shaft kiln, a lime rotary kiln, a magnesite kiln, or a dolomite kiln.

5 116. The use according to any one of Claims 94 to 115,

wherein

the lining has a working casing and the refractory product is used in the working casing.

10 117. The use according to Claim 116,

wherein

the refractory product is used in a working casing that is installed in a one-layer or a multilayer masonry structure.

15 118. The use according to any one of Claims 94 to 117,

wherein

the lining has an insulating backing and the refractory product is used in the insulating backing.

20 119. Use of a lining for a large-volume industrial furnace,

wherein

the lining comprises at least one refractory product that comprises the granular material made of sintered magnesia produced according to the method of any one of Claims 1 to 27, the granular material made of
25 sintered magnesia being mechanically comminuted and having a total grain porosity according to DIN EN 993-1:1995-04 and DIN EN 993-18:2002-11 of 15 to 38 vol%, and a grain compression strength, based on DIN 13055-2016-11 for 10 mm instead of 20 mm, of 10 to 30 MPa.

30 120. The use according to Claim 119,

wherein

the lining has a working casing which comprises the at least one refractory product.

- 5 121. The use according to Claim 119 or 120,
wherein
the lining is used for a burning kiln of the non-metallic industry, a heating kiln, a kiln for energy production, a kiln for steel production, or a kiln of the nonferrous metal industry.
- 10 122. The use according to Claim 121,
wherein
the lining is used for a cement kiln installation, a lime shaft kiln, a lime rotary kiln, a magnesite kiln, or a dolomite kiln.

Figure 1:

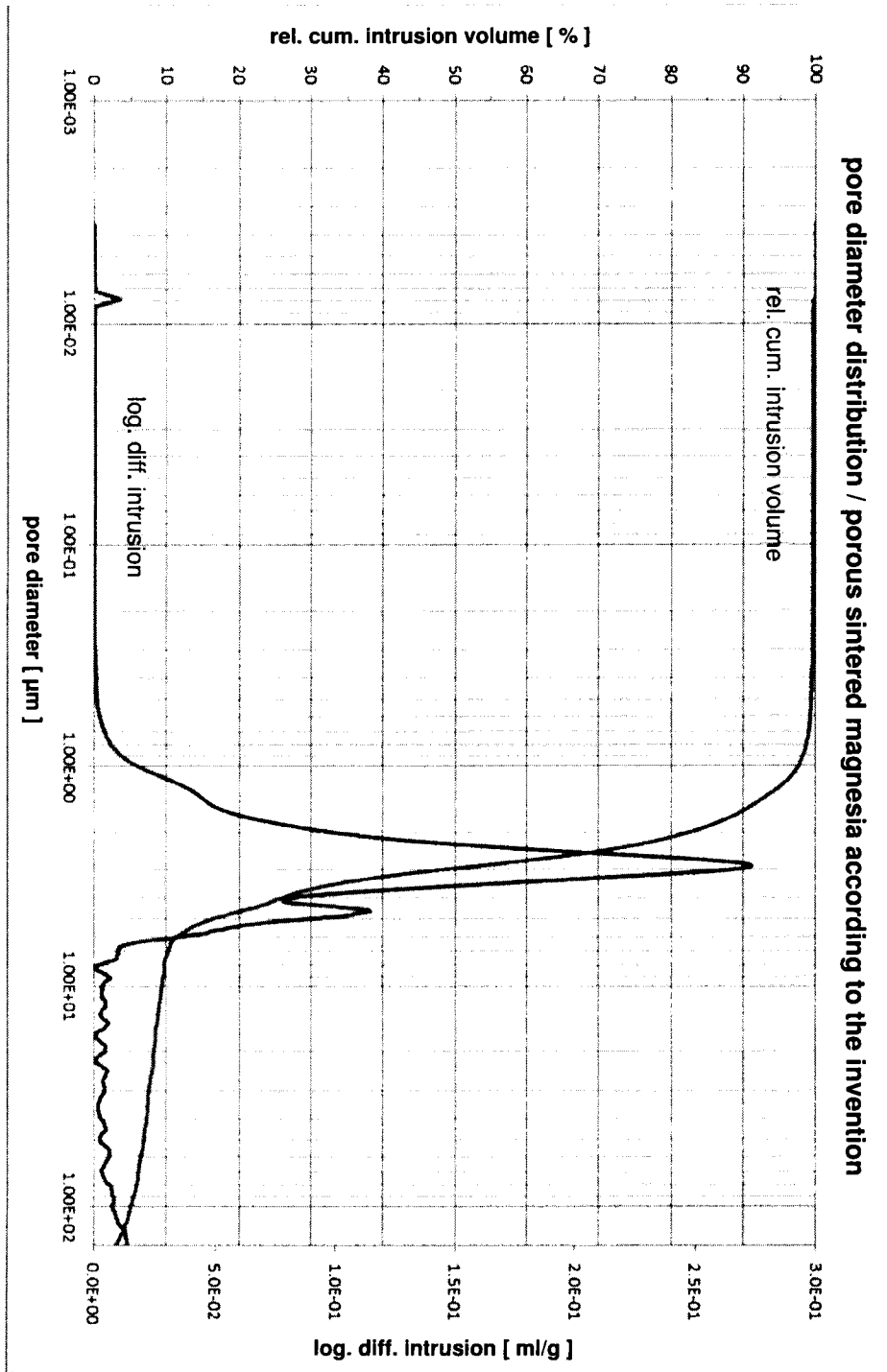


Figure 2:

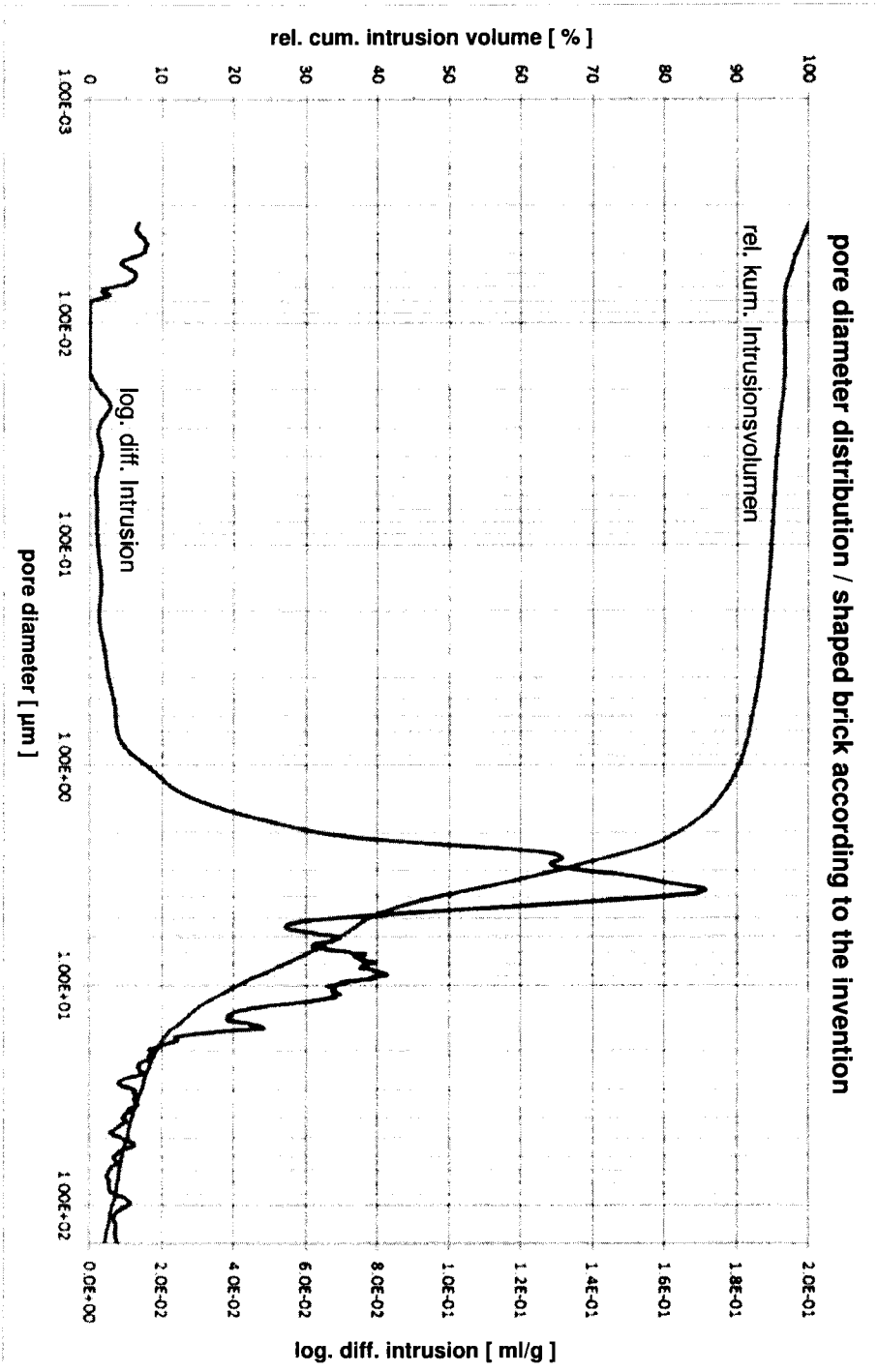
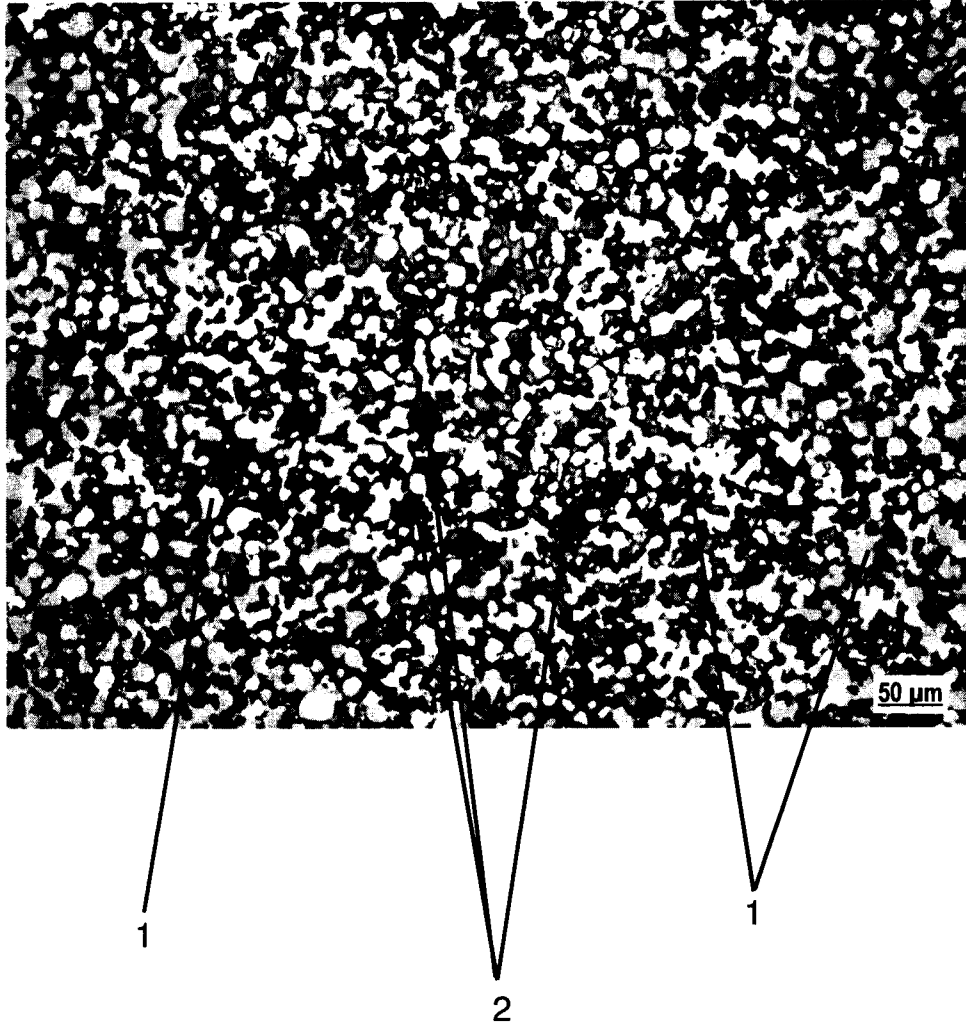
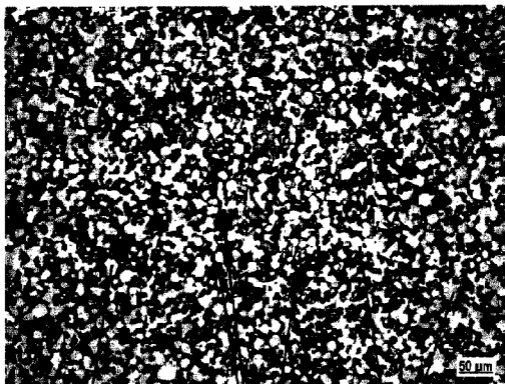


Figure 3:





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