METHOD OF FORMING AN ABRASIVE BODY

INTRODUCTION

[001] Bonded abrasive articles, such as abrasive wheels, can be used for cutting, grinding, or shaping various materials. The industry continues to demand improved bonded abrasive articles having a controlled homogeneous pore structure, low wear, high edge stability and extended life time.

DETAILED DESCRIPTION

[002] The present publication is directed to a method of forming an abrasive body. The method can comprise forming a green body, wherein the green body comprises abrasive particles, a binder, and an aromatic dicarboxylic acid as pore-forming agent; and subjecting the green body to a heat treatment regime to form the abrasive body. The heat treatment regime can include forming a plurality of pores by releasing the aromatic dicarboxylic acid from the green body.

[003] The method of making an abrasive article of the present disclosure may include the following steps: preparing a green body mixture by combining abrasive particles, a binder, and an aromatic dicarboxylic acid; forming a green body from the green body mixture; and subjecting the green body to a heat treatment regime to form the abrasive body comprising a plurality of pores.

[004] Preparing the green body mixture can be conducted by mixing all ingredients of the green body mixture until a homogeneous mixture is obtained. Mixing can be conducted, for example, in a mechanical high frequency mixer or an extruder.

[005] In one aspect, the amount of the aromatic dicarboxylic acid in the green body mixture can be at least 0.5 wt%, or at least 1.0 wt%, or at least 1.5 wt%, or at least 2.0 wt%, or at least 2.5 wt%. In another aspect, the amount of the dicarboxylic acid may be not greater than 5 wt% or not greater than 4 wt%, or not greater than 3 wt%. The amount of the dicarboxylic acid can be a number within any of the minimum and maximum numbers listed above.

[006] In a further aspect, the average particle size (D50) of the aromatic dicarboxylic acid can be at least 10 microns, or at least 20 microns, or at least 30 microns, or at least 50 microns. In another aspect, the average particle size (D50) may be not greater than 150 microns, or not

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greater than 100 microns, or not greater than 75 microns, or not greater than 50 microns. The average particle size of the aromatic dicarboxylic acid can be a number between any of the minimum and maximum numbers noted above.

[0007] In a particular embodiment, the aromatic dicarboxylic acid can include terephthalic acid. It has been surprisingly observed that the inclusion of terephthalic acid as pore forming agent can lead to the forming of abrasive bodies having a very homogeneous pore structure.

[0008] The abrasive particles contained within the green body may not be limited to a specific type of material and can be in non-limiting examples an oxide, a carbide, a nitride, a boride, an oxynitride, an oxyboride, diamond, or any combination thereof. In certain aspects, the material of the abrasive particles can be alumina, zirconia, ceria, or cubic boron nitride. In particular aspects, the alumina material of the abrasive particles can be white fused alumina, pink fused alumina, or brown fused alumina.

[0009] In one aspect, the amount of the abrasive particles in the green body can be at least 50 wt% based on the total weight of the green body, such as at least 55 wt%, at least 60 wt%, at least 65 wt%, at least 70 wt%, at least 75 wt%, at least 80 wt%, or at least 85 wt%. In another aspect, the amount of abrasive particles may be not greater than 90 wt%, or not greater than 88 wt%, or not greater than 85 wt%, or not greater than 80 wt% based on the total weight of the green body.

[0010] In a further aspect, the average particle size (D50) of the abrasive particles can be at least 0.5 microns, or at least 1 micron, or at least 2 microns, or at least 5 microns, or at least 10 microns, or at least 15 microns. In another aspect, the average particle size may be not greater than 100 microns, or not greater than 50 microns, or not greater than 40 microns, or not greater than 30 microns, or not greater than 25 microns, or not greater than 20 microns, or not greater than 18 microns. In a particular aspect the D50 size of the abrasive particles can be from 2 microns to 20 microns.

[0011] The bond material of the body of the abrasive article may have a particular bond chemistry that may facilitate improved manufacturing and performance of the abrasive article of the present disclosure. In one embodiment, the bond material of the body can comprise a vitreous material. In a particular embodiment, the bond material may consist essentially of a vitreous material. As used herein, consisting essentially of a vitreous material means that at least

99 vol% of the bond material are a vitreous material. The vitreous material can form a vitreous phase during melting and may thereby bind the abrasive particles together. Typical materials for forming a vitreous phase can include natural and synthetic minerals, metal oxides, and non-metal oxides. Non-limiting examples of vitreous material can be glass materials including SiO_2 as a majority oxide compound and two or more further oxides, for example, Al_2O_3, Li_2O, Na_2O, B_2O_3, K_2O, BaO, or any combination thereof. In another embodiment, the bond material may not be limited to a vitreous material and may further contain one or more other inorganic materials, for example, a ceramic, a cermet, a metal, a metal alloy, or any combination thereof. Furthermore, the inorganic material can be an amorphous material, a polycrystalline material, a monocrystalline material or any combination thereof.

[0012] In one aspect, the bond material can comprise in addition to the inorganic bond material an organic bond material, hereinafter also called organic binder. During heat treatment, the organic bond material may decompose and can create or assist in addition to the aromatic dicarboxylic acid in forming a desired porosity in the sintered body. The organic bond material can be a natural material, a synthetic material, a resin, an epoxy, a thermoset, a thermoplastic, an elastomer, or any combination thereof. In a certain embodiment, the organic binder can include a polyether, a phenolic resin, an epoxy resin, a polyester resin, a polyurethane, a polyester, a polyimide, a polybenzimidazole, an aromatic polyamide, a modified phenolic resin (such as: epoxy modified and rubber modified resin, or phenolic resin blended with plasticizers), or a carbohydrate (such as a dextrin product, a starch, or microcrystalline cellulose), or animal glue (natural proteins), or any combination thereof.

[0013] In a certain aspect, the organic binder can include a polyethylene glycol (PEG). In a particular aspect, the PEG can have a molecular weight of at least 380 g/mol, or at least 400 g/mol, or at least 600 g/mol, or at least 800 g/mol or at least 1000 g/mol, or at least 1500 g/mol, or at least 2000 g/ mol, or at least 3000 g/mol, or at least 5000 g/mol. In another aspect, the PEG may have a molecular weight not greater than 8000 g/mol, or not greater than 6000 g/mol, or not greater than 4000 g/mol, or not greater than 2000 g/mol, or not greater than 1000 g/mol.

[0014] In one embodiment, the amount of the PEG in the green body (before heating) can be at least 0.07 wt% based on the total weight of the green body, or at least 0.1 wt%, or at least 0.3 wt%, or at least 0.5 wt%, or at least 1.0 wt%, or at least 1.5 wt%, or at least 2.0 wt%, or at least

2.5 wt%. In yet a further aspect, the amount of the PEG may be not greater than 5 wt% based on a total weight of the green body, or not greater than 4 wt%, or not greater than 3 wt%, or not greater than 1 wt%, or not greater than 0.5 wt%, or not greater than 0.2 wt%. The amount of the PEG can be a value within any of the maximum and minimum numbers noted above.

[0015] In a certain embodiment, the weight percent ratio of the aromatic dicarboxylic acid to the PEG can range from 22:1 to 1:1, or from 20:1 to 10:1, or from 20:1 to 15:1, or from 15:1 to 3:1, or from 12:1 to 5:1.

[0016] After combining all ingredients of the green body composition, for example in a mixer, blender, or extruder, the green body composition can be filled into a mold to form the green body (102). A pressure may be applied onto the mold to allow the green body being shaped to a desired dimension.

[0017] The shaped green body may be removed from the mold and subjected to a heat treatment regime to form a ceramic abrasive body (103), also called herein “sintering.” The heat treatment can be conducted at a rate of 30°C to 150°C per hour (about 0.5°C to 2.5°C/minute) up to a maximum temperature. In aspects, the maximum temperature during the heating treatment regime can be at least 900°C, or at least 950°C, or at least 980°C, or at least 1000°C. In other aspects the maximum temperature may be not greater than 1300°C, or not greater than 1200°C, or not greater than 1100°C, or not greater than 1050°C.

[0018] In a particular aspect, the heating to the maximum temperature can be conducted at a rate of at least 0.5°C/minute, or at least 1.0°C/minute, or at least 1.3°C/minute, or at least 1.5°C/minute. In another aspect, the heating can be conducted at a rate not greater than 2.5°C/minute, or not greater than 2.0°C/minute, or not greater than 1.7°C/minute. In a certain aspect, heating may be conducted at a rate between 1.0 °C/minute and 1.7 °C/minute.

[0019] The treatment at the maximum temperature may be continued for at least 0.5 hours, at least 1 hour, at least 2 hours, at least 4 hours, at least 6 hours, or at least 8 hours, followed by cooling down to room temperature.

[0020] In a further aspect, the cooling down to room temperature of the sintered body can be conducted at the same rate as the heating to the maximum temperature, for example, between 1.0 °C/minute and 1.7 °C/minute. In another aspect, the cooling may be conducted by free cooling.

[0021] After the sintering, the obtained abrasive body can have a plurality of interconnected pores formed by the abrasive particles and the bond material.

[0022] In one embodiment, after the applied heat treatment regime, the formed abrasive body can have a porosity of at least 30 vol%, or at least 35 vol%, or at least 40 vol%, or at least 45 vol%, or at least 48 vol%, or at least 50 vol%, or at least 52 vol%, or at least 54 vol%. In another embodiment, the abrasive body may have a porosity of not greater than 70 vol%, or not greater than 65 vol%, or not greater than 60 vol%, or not greater than 58 vol%, or not greater than 55 vol%. The porosity of the abrasive body can be a value between any of the minimum and maximum values noted above. In a particular aspect, the porosity can be between 48 vol% and 58 vol%.

[0023] In a further embodiment, the average pore size (D50) of the abrasive body can be at least 2 microns, or at least 5 microns, or at least 10 microns, or at least 20 microns, or at least 30 microns, or at least microns, or at least 50 microns, at least 100 microns, or at least 150 microns, or at least 200 microns. In another aspect, the D50 pore size may be not greater than 300 microns, or not greater than 250 microns, or not greater than 200 microns, or not greater than 150 microns, or not greater than 100, or not greater than 80 microns, or not greater than 70 microns, or not greater than 60 microns. The average pore size (D50) can be a value between any of the minimum and maximum numbers listed above.

[0024] In a certain embodiment, the average (D50) pore size of the pores of the abrasive body can be between 5 microns and 300 microns, and a D100 value of the pore distribution may not be greater than 500 microns.

[0025] The bonded abrasive article described in embodiments herein can be suitable for various grinding operations including, for example, in superfinishing, internal diameter grinding, creepfeed, cylindrical grinding, surface grinding, or centerless grinding.

[0026] In one embodiment, the total amount of the remaining inorganic bond material in the abrasive body after conducting the heat treatment regime (sintering) can be at least 6 wt% based on the total weight of the abrasive body or at least 8 wt%, or at least 10 wt%, or at least 15 wt%, or at least 20 wt%, or at least 25 wt%. In another embodiment, the amount of the bond material in the abrasive body may be not greater than 50 wt%, or not greater than 40 wt%, or not greater than 30 wt%, or not greater than 25 wt%, or not greater than 20 wt%. The amount of the bond material of the abrasive body may be any value of the minimum and maximum values noted above. In a certain aspect, the bond material in a body can consist essentially of the vitreous bond material. Consisting essentially of the vitreous bond material means herein that the bond material contains not more than 1 wt% based on the total weight of the bond material, a material which is not a vitreous material.

[0027] The amount of the abrasive particles in the abrasive body can be at least 50 wt% based on the total weight of the abrasive body, or at least 60 wt%, or at least 70 wt%, or at least 80 wt%, or at least 85 wt%. In another aspect, the amount of abrasive particles may be not greater than 92 wt%, or not greater than 90 wt%, or not greater than 88 wt%, or not greater than 85 wt%.

[0028] In a further embodiment, the abrasive body of the present disclosure can have a density of at least 1.4 g/cm^3, such as at least 1.5 g/cm^3, or at least 1.60 g/cm^3, or at least 1.7 g/cm^3, or at least 1.7 g/cm^3, or at least 1.75 g/cm^3. In another embodiment, the density of the body may be not greater than 2.0 g/cm^3, or not greater than 1.95 g/cm^3, or not greater than 1.90 g/cm^3, or not greater than 1.80 g/cm^3. The density of the body can be a value between any of the minimum and maximum values noted above.

[0029] The body may have any suitable size and shape and can be incorporated into various types of abrasive articles to form a bonded abrasive article. For example, the body can be attached to a substrate, such as a hub of a wheel to facilitate formation of a bonded abrasive grinding wheel.

EXAMPLES

[0030] In a v-blender were combined alpha alumina abrasive particles with a D50 particle size of 9 microns, terephthalic acid with a D50 particle size of 18 microns, polyethylene glycol having a molecular weight of 400 g/mol, corn syrup, microcrystalline cellulose, animal glue, and dextrin (D124) and mixed for about 15 minutes, until sufficient mixing was achieved by breaking up any aggregates. Thereafter, a vitreous bond material having a particle size of 5 microns was added to the mixture, followed by additional 15 minutes mixing.

[0031] Comparative green body compositions were prepared using fumaric acid as pore forming agent, which is an aliphatic dicarboxylic acid. It was observed that using fumaric acid is inferior to the handling and screening of the green body mixture; the mixture was much more sticky and more difficult to process.

[0032] Table 1 provides a summary of the prepared mixture.

[0033] Table 1

Ingredient	Amount [g]	Amount [wt%]
Alpha alumina abrasive particles	811.2	81.20
Terephthalic acid	20.2	2.02
Corn syrup	27.5	2.75
Microcrystalline cellulose	9.2	0.92
PEG	1.00	0.10
Animal glue	0.90	0.09
Bond material	110.6	11.06
Dextrin (D124)	19.5	1.95

[0034] After the mixing, the obtained mixture was screened by passing it from the v-blender through two screens having a mesh size of #140 and #230 mesh. The mixture which had passed the screens was collected and filled into a mold having the size of 4 inches by 4 inches by 0.5 inches. A pressure of about 80 tons was applied to “close” the mold and to ensure the forming of a dense green body with the desired slab shape (4 x 4 inches with a height of 0.5 inches).

[0035] After forming the green body, the mold was removed and the green body subjected to a firing procedure, also called herein “heat treatment regime”. The heating was conducted in an oven under air with the following heat rate: heating at a rate of 100°C per hour (1.67°C per minute) to a temperature of 980°C, holding the temperature at 980°C for 8 hours, and cooling at a rate of 100°C/hour down to 25°C.

[0036] The formed abrasive body had a density of 1.7 g/cm^3, and was investigated via image analysis. It could be observed that the use of terephthalic acid allowed the forming of abrasive bodies having a very homogeneous pore structure, without the inclusion of any undesired macro-pores greater than 500 microns or cracks.