COATED MAGNESIUM HYDROXIDE PARTICLES PRODUCED BY MILL-DRYING

FIELD OF THE INVENTION

[0001] The present invention relates to novel, coated magnesium hydroxide flame retardants, methods of making them, and their use.

BACKGROUND OF THE INVENTION

[0002] The industrial applicability of magnesium hydroxide has been known for some time, and magnesium hydroxide has been used in diverse applications from use as an antacid in the medical field to use as a flame retardant in industrial applications. Thus, many processes for making magnesium hydroxide exist. For example, in conventional magnesium processes, it is known that magnesium hydroxide can be produced by hydration of magnesium oxide, which can be obtained by spray roasting a magnesium chloride solution, see for example United States Patent number 5,286,285 and European Patent number EP 0427817. It is also known that a Mg source such as iron bitten, seawater or dolomite can be reacted with an alkali source such as lime or sodium hydroxide to form magnesium hydroxide particles, and it is also known that a Mg salt and ammonia can be allowed to react and form magnesium hydroxide crystals.

[0003] In the flame retardant area, magnesium hydroxide is used in synthetic resins such as plastics and in wire and cable applications to impart flame retardant properties. The compounding performance and viscosity of the synthetic resin containing the magnesium hydroxide is a critical attribute that is linked to the magnesium hydroxide. In the synthetic resin industry, the demand for better compounding performance and viscosity has increased for obvious reasons, i.e. higher throughputs during compounding and extrusion, better flow into molds, etc.

[0004] In an effort to increase these attributes and provide better compatibility with resins, the surface of the magnesium hydroxide particles has been coated with a variety of surface active materials including silanes, amino silanes, fatty acids, etc., and the demand for such coated magnesium hydroxides is increasing. As the demand for coated magnesium hydroxide increases, the demand for processes that can produce coated magnesium hydroxide particles also increases.

SUMMARY OF THE INVENTION

[0005] In one embodiment, the present invention relates to coated magnesium hydroxide particles comprising a surface coating agent selected from at least one of i) fatty acids; ii) alkylsilanes; iii) organic titanates; iv) organic zirconates, v) aminosilanes, vi) vinylsilanes,

and vii) siloxane derivatives. The magnesium hydroxide particles are produced by mill drying a filter cake comprising in the range of from about 35 to about 99 wt.% magnesium hydroxide, based on the filter cake, in the presence of a surface coating agent.

[0006] In another embodiment, the present invention relates to a process for producing coated magnesium hydroxide particles comprising mill drying a filter cake comprising in the range of from about 35 to about 99 wt.% magnesium hydroxide, based on the filter cake, in the presence of a surface coating agent, thereby producing coated, mill-dried magnesium hydroxide particles. The surface coating agent can be suitably selected from at least one of i) fatty acids; ii) alkylsilanes; iii) organic titanates; iv) organic zirconates, v) aminosilanes, vi) vinylsilanes, and vii) siloxane derivatives.

[0007] In another embodiment, the present invention relates to a process for producing coated magnesium hydroxide particles comprising:

a) mill drying in a mill-drying unit a filter cake comprising from about 35 to about 99 wt.% magnesium hydroxide, based on the filter cake; and

b) introducing into said mill drying unit while said filter cake is being mill dried, a surface coating agent selected from at least one of i) fatty acids; ii) alkylsilanes; iii) organic titanates; iv) organic zirconates, v) aminosilanes, vi) vinylsilanes, and vii) siloxane derivatives, thereby producing coated, mill-dried magnesium hydroxide particles.

[0008] In yet another embodiment, the present invention relates to a process for producing coated magnesium hydroxide particles comprising:

a) introducing into a mill-drying unit a filter cake comprising from about 35 to about 99 wt.% magnesium hydroxide, based on the filter cake;

b) simultaneously and continuously introducing into said mill drying unit, at a point above or after the introduction of the filter cake, a surface coating agent selected from at least one of i) fatty acids; ii) alkylsilanes; iii) organic titanates; iv) organic zirconates, v) aminosilanes, vi) vinylsilanes, and vii) siloxane derivatives; and

c) mill drying said filter cake in the presence of said surface coating agent until coated, mill-dried magnesium hydroxide particles are produced.

[0009] In the practice of the present invention, the surface coating agent can be introduced into the mill drying unit as a batch or it can be continuously metered into the mill drying unit, or it can be introduced as a batch or continuously metered into the filter cake just prior to the introduction of the filter cake into the mill drying unit.

DETAILED DESCRIPTION OF THE INVENTION

[0010] The present invention involves producing coated, mill-dried magnesium hydroxide particles. These coated, mill-dried magnesium hydroxide particles can be suitably produced by mill drying a filter cake in the presence of a surface coating agent.

Filter Cake

[0011] The filter cake typically comprises in the range of from about 35 to about 99 wt.%, preferably in the range of from about 35 to about 80 wt.%, more preferably in the range of from about 40 to about 70 wt.%, magnesium hydroxide, based on the total weight of the filter cake. The remainder of the filter cake is water, preferably desalted water. In some embodiments, the filter cake may also contain a dispersing agent. Non-limiting examples of dispersing agents include polyacrylates, organic acids, naphtalensulfonate / Formaldehydcondensat, fatty-alcohole-polyglycol-ether, polypropylene-ethylenoxid, polyglycol-ester, polyamine- ethylenoxid, phosphate, polyvinylalcohole.

[0012] The filter cake used in the practice of the present invention can be obtained from any process used to produce magnesium hydroxide particles. In an exemplary embodiment, the filter cake is obtained from a process that comprises adding water to magnesium oxide, preferably obtained from spray roasting a magnesium chloride solution, to form a magnesium oxide water suspension. The suspension typically comprises in the range of from about 1 to about 85 wt.% magnesium oxide, based on the total weight of the suspension. However, the magnesium oxide concentration can be varied to fall within the ranges described above. The water and magnesium oxide suspension is then allowed to react under conditions that include temperatures ranging from about 50°C to about 100°C and constant stirring, thus obtaining a mixture comprising magnesium hydroxide particles and water. This mixture is then filtered to obtain the filter cake used in the practice of the present invention. The filter cake can be directly mill dried, or it can be washed one, or in some embodiments more than one, times with water, preferably de-salted water, and then mill dried according to the present invention.

Surface Coating Agent

[0013] The surface coating agent used herein can be selected from at least one of i) a fatty acid; ii) an alkylsilane; iii) an organic titanate; iv) an organic zirconate, v) an aminosilane, vi) a vinylsilane, and vii) siloxane derivatives, thus forming a mixture. In some preferred embodiments, the surface coating agent is a combination of a fatty acid and a siloxane derivative. In other preferred embodiments, the surface coating agent is an amino silane.

[0014] Siloxane derivatives suitable for use herein can be selected from oligoalkylsiloxanes; polydialkylsiloxanes, for example polydimethylsiloxane or polydiethylsiloxane;

polyalkylarylsiloxanes, for example polyphenylmethylsiloxane; or polydiarylsiloxanes, for example polyphenylsiloxane. These siloxane derivatives can have been functionalized with reactive groups, for example hydroxyl, amino, vinyl, methacryl, carboxyl or glycidyl.

[0015] Alkyl silanes suitable for use herein can be any alkyl silane known in the art to be a surface coating for magnesium hydroxide particles. Preferably, the alkyl silane is one that has at least one alkyl group with at least 3 carbon atoms. Alkyl group, as used herein and unless otherwise indicated, is meant to refer to linear or branched primary, secondary, or tertiary alkyl groups. Non-limiting examples of suitable alkyl groups include methyl, ethyl, propyl, isopropyl, butyl, isobutyl, hexyl, octyl, isooctyl (6-methylheptyl), 2-ethylhexyl, dodecyl, tetradecyl, hexadecyl, octadecyl, and the like.

[0016] Fatty acids suitable for use herein can be selected from saturated fatty acids, unsaturated fatty acids, and fatty acids with additional functional groups such as, for example, amino of hydroxy fatty acids are suitable for use herein. Typically, the fatty acid used herein is one that contains from about 8 to about 30 carbon atoms. Preferably, the fatty acid used herein is a saturated fatty acid with about 10 to about 24 carbon atoms. These can be used both as pure or industrially pure substances and as homologue mixtures, i.e. those obtained in the splitting of natural fats. Fatty acids such as these are readily available commercially.

[0017] Likewise, alkylsilanes and aminosilanes suitable for use herein are also available commercially. For example, alkylsilanes and aminosilanes are available commercially from, for example, Degussa-HÜls AG under the brand name Dynasylan®. Preferred alkylsilanes used herein are described by the formula $R^1Si(OR^2)_3$, where R^1 is a linear or branched alkyl group having from about 3 to about 30 carbon atoms, and R^2 is a linear or branched alkyl group having from about 1 to about 6 carbon atoms. More preferably, alkylsilanes suitable for use herein are those wherein R^1 is a linear or branched alkyl group having from about 8 to about 18 carbon atoms, most preferably 12 to 14 carbon atoms, and R^2 is a linear or branched alkyl group having from about 1 to about 4 carbon atoms

[0018] Organic titanates and organic zirconates suitable for use herein are also known in the art and are readily available commercially. For example, organic titanates and organic zirconates can be readily obtained under the name TYZOR® from Dupont. Preferably, organic titanates used herein are those having the formula $R^3OTi(OR^4)_3$, wherein R^3 is a linear or branched alkyl group having from about 1 to about 14 carbon atoms, and R^4 is a linear or branched alkly group having from about 6 to about 12 carbon atoms or an acyl group having from about 8 to about 30 carbon atoms. In some preferred embodiments, the organic titanates used herein are those wherein R^3 is isopropyl and R^4 is isostearoyl, while in

other preferred embodiments the organic titante is one wherein R^3 and R^4 are the same and are selected from isooctyl and 2-ethlyhexyl.

[0019] Preferably the organic zirconates used herein are those having the formula $R^5OZr(OR^6)_3$, where R^5 is a linear or branched alkly group having from about 1 to about 12 carbon atoms, and R^6 is a linear or branched alkyl group having from about 6 to about 12 carbon atoms or an acyl group having from about 8 to about 30 carbon atoms.

[0020] Typically, the amount of surface coating agent introduced into the mill-drying unit is that amount effective at producing mill-dried, coated magnesium hydroxide particles comprising in the range of from about 0.05 to about 5.0 wt.% of the surface coating agent, based on the weight of the uncoated magnesium hydroxide particles. For example, a 1% coating level as used herein means that 0.1 kg of the surface coating agent is added to the filter cake containing 10 kg of magnesium hydroxide, and, thus 10.1 kg of coated magnesium hydroxide is produced. Thus, producing 1wt.% of a fatty acid coated, mill-dried magnesium hydroxide from a filter cake containing 55wt% magnesium hydroxide would mean that 0.55wt.% of the fatty acid is added to the filter cake. In other words, 0.55 kg of a fatty acid would be added to 100 kg of a filter cake containing 55 kg of uncoated magnesium hydroxide. In preferred embodiments, the amount of surface coating agent added to the filter cake is that amount effective at producing coated, mill-dried magnesium hydroxide particles comprising in the range of from about 0.1 to about 4 wt.%, more preferably in the range of from about 0.2 to about 3.5 wt.%, of the surface coating agent, based on the weight of the uncoated magnesium hydroxide particles in the filter cake.

[0021] Generally, the amount of surface coating agent used herein ranges from about 0.25 to about 3wt.%, based on the weight of the filter cake, preferably in the range of from about 0.3 to about 2.5 wt.%, on the same basis.

[0022] The surface coating agent can be introduced into the mill-drying unit simultaneously with the filter cake or the filter cake can be mill dried for a period of time prior to the introduction of the surface coating agent. In one embodiment, the surface coating agent can be introduced into the mill-drying unit at a point above or after the filter cake is introduced. This is possible because most commercially available mill-drying units have multiple points wherein feed materials can be introduced into the mill-drying unit. Further, the surface coating agent can be introduced as a batch or continuously metered into the mill-drying unit as the filter cake is mill-dried, or it can be introduced as a batch or continuously metered into the filter cake just prior to the introduction of the filter cake into the mill drying unit. Preferably the surface coating agent is continuously metered into the mill-drying unit. In this

embodiment, the feed rate of the surface coating agent will depend on factors such as mill-drying conditions, surface coating agent, etc., and the feed rate of the surface coating agent is readily selectable by one having ordinary skill in the art and knowledge of these variables.

Mill Drying

[0023] "Mill-drying" and "mill-dried" as used herein, it is meant that the filter cake is simultaneously milled and dried in the presence of the surface coating agent in a turbulent hot air-stream in a mill-drying unit. The mill-drying unit comprises a rotor that is firmly mounted on a solid shaft that rotates at a high circumferential speed. The rotational movement in connection with a high air through-put converts the through-flowing hot air into extremely fast air vortices which take up the mixture to be dried, accelerate it, and distribute and dry the mixture to produce coated, mill-dried magnesium hydroxide particles. After having been dried completely, the mill-dried, coated magnesium hydroxide particles are transported via the turbulent air out of the mill and separated from the hot air and vapors by using conventional filter systems. In another embodiment of the present invention, after having been dried completely, the mill-dried, coated magnesium hydroxide particles are transported via the turbulent air through an air classifier which is integrated into the mill, and are then transported via the turbulent air out of the mill and separated from the hot air and vapors by using conventional filter systems.

[0024] The throughput of the hot air used in the mill-drying unit is typically greater than about 3,000 Bm^3/h, preferably greater than about to about 5,000 Bm^3/h, more preferably from about 3,000 Bm^3/h to about 40,000 Bm^3/h, and most preferably from about 5,000 Bm^3/h to about 30,000 Bm^3/h.

[0025] In order to achieve throughputs this high, the rotor of the mill drying unit typically has a circumferential speed of greater than about 40 m/sec, preferably greater than about 60 m/sec, more preferably greater than 70 m/sec, and most preferably in a range of about 70 m/sec to about 140 m/sec. The high rotational speed of the motor and high throughput of hot air results in the hot air stream having a Reynolds number greater than about 3,000.

[0026] The temperature of the hot air used in the mill-drying unit is generally greater than about 150°C, preferably greater than about 270°C. In a more preferred embodiment, the temperature of the hot air stream is in the range of from about 150°C to about 550°C, most preferably in the range of from about 270°C to about 500°C.

Coated Mill-Dried Magnesium Hydroxide Particles

[0027] As stated above, the mill drying of the filter cake in the presence of the surface coating agent produces coated, mill-dried magnesium hydroxide particles. The coated, mill

dried magnesium hydroxide particles can be further characterized as having a d_{50} of less than about 3.5 μm. In one preferred embodiment, the coated, mill dried magnesium hydroxide particles can be further characterized as having a d_{50} in the range of from about 1.2 to about 3.5μm, more preferably in the range of from about 1.45 to about 2.8 μm. In another preferred embodiment, the coated, mill dried magnesium hydroxide particles can be further characterized as having a d_{50} in the range of from 1.25 to about 1.65 μm. In yet another preferred embodiment, the coated, mill dried magnesium hydroxide particles can be further characterized as having a d_{50} in the range of from about 0.5 to about 1.4 μm, more preferably from about 0.8 to about 1.1 μm. In still yet another preferred embodiment, the coated, mill dried magnesium hydroxide particles can be further characterized as having a d_{50} in the range of from about 0.3 to about 1.3 μm, more preferably in the range of from about 0.65 to about 0.95 μm.

[0028] It should be noted that the d_{50} measurements reported herein were measured by laser diffraction according to ISO 9276 using a Malvern Mastersizer S laser diffraction machine. To this purpose, a 0.5% solution with EXTRAN MA02 from Merck/Germany is used and ultrasound is applied. EXTRAN MA02 is an additive to reduce the water surface tension and is used for cleaning of alkali-sensitive items. It contains anionic and non-ionic surfactants, phosphates, and small amounts of other substances. The ultrasound is used to de-agglomerate the particles.

[0029] The coated, mill dried magnesium hydroxide particles according to the present invention can also be characterized as having a BET specific surface area as determined by DIN-66132, in the range of from about 1 to 15 m^2/g. In one preferred embodiment, the coated, mill dried magnesium hydroxide particles can be further characterized by a BET specific surface in the range of from about 1 to about 5 m^2/g, more preferably in the range of from about 2.5 to about 4 m^2/g. In another preferred embodiment, the coated, mill dried magnesium hydroxide particles can be further characterized by a BET specific surface of in the range of from about 3 to about 7 m^2/g, more preferably in the range of from about 4 to about 6 m^2/g. In another preferred embodiment, the coated, mill dried magnesium hydroxide particles can be further characterized by a BET specific surface in the range of from about 6 to about 10 m^2/g, more preferably in the range of from about 7 to about 9 m^2/g. In yet another preferred embodiment, the coated, mill dried magnesium hydroxide particles can be further characterized a BET specific surface area in the range of from about 8 to about 12 m^2/g, more preferably in the range of from about 9 to about 11 m^2/g.

Use of Mill-Dried, Coated Magnesium Hydroxide particles as a Fame Retardant

[0030] The coated, mill-dried magnesium hydroxide particles according to the present invention can be used as a flame retardant in a variety of synthetic resins. Non-limiting examples of thermoplastic resins where the magnesium hydroxide particles find use include polyethylene, polypropylene, ethylene-propylene copolymer, polymers and copolymers of C_2 to C_8 olefins (α-olefin) such as polybutene, poly(4-methylpentene-1) or the like, copolymers of these olefins and diene, ethylene-acrylate copolymer, polystyrene, ABS resin, AAS resin, AS resin, MBS resin, ethylene-vinyl chloride copolymer resin, ethylene-vinyl acetate copolymer resin, ethylene-vinyl chloride-vinyl acetate graft polymer resin, vinylidene chloride, polyvinyl chloride, chlorinated polyethylene, chlorinated polypropylene, vinyl chloride-propylene copolymer, vinyl acetate resin, phenoxy resin, polyacetal, polyamide, polyimide, polycarbonate, polysulfone, polyphenylene oxide, polyphenylene sulfide, polyethylene terephthalate, polybutylene terephthalate, methacrylic resin and the like. Further examples of suitable synthetic resins include thermosetting resins such as epoxy resin, phenol resin, melamine resin, unsaturated polyester resin, alkyd resin and urea resin and natural or synthetic rubbers such as EPDM, butyl rubber, isoprene rubber, SBR, NIR, urethane rubber, polybutadiene rubber, acrylic rubber, silicone rubber, fluoro-elastomer, NBR and chloro-sulfonated polyethylene are also included. Further included are polymeric suspensions (latices).

[0031] Preferably, the synthetic resin is a polypropylene-based resin such as polypropylene homopolymers and ethylene-propylene copolymers; polyethylene-based resins such as high-density polyethylene, low-density polyethylene, straight-chain low-density polyethylene, ultra low-density polyethylene, EVA (ethylene-vinyl acetate resin), EEA (ethylene-ethyl acrylate resin), EMA (ethylene-methyl acrylate copolymer resin), EAA (ethylene-acrylic acid copolymer resin) and ultra high molecular weight polyethylene; and polymers and copolymers of C_2 to C_8 olefins (α-olefin) such as polybutene and poly(4-methylpentene-1), polyamide, polyvinyl chloride and rubbers. In a more preferred embodiment, the synthetic resin is a polyethylene-based resin.

[0032] Thus, in one embodiment, the present invention relates to a flame retarded formulation comprising at least one synthetic resin, in some embodiments only one, and a flame retarding amount of coated, mill-dried magnesium hydroxide particles according to the present invention, and molded and/or extruded article made from the flame retarded formulation.

[0033] By a flame retarding amount of the coated, mill-dried magnesium hydroxide particles, it is generally meant in the range of from about 5 wt% to about 90wt%, based on the weight

of the flame retarded formulation, preferably in the range of from about 20wt% to about 70wt%, on the same basis. In a most preferred embodiment, a flame retarding amount is in the range of from about 30wt% to about 65wt% of the coated, mill-dried magnesium hydroxide particles, on the same basis. Thus, the flame retarded polymer formulation typically comprises in the range of from about 10 to about 95wt.% of the at least one synthetic resin, based on the weight of the flame retarded formulation, preferably in the range of from about 30 to about 40wt.% of the flame retarded formulation, more preferably in the range of from about 35 to about 70wt.% of the at least one synthetic resin, all on the same basis.

[0034] The flame retarded formulation can also contain other additives commonly used in the art. Non-limiting examples of other additives that are suitable for use in the flame retarded polymer formulations of the present invention include extrusion aids such as polyethylene waxes, Si-based extrusion aids, fatty acids; coupling agents such as amino-, vinyl- or alkyl silanes or maleic acid grafted polymers; barium stearate or calcium sterate; organoperoxides; dyes; pigments; fillers; blowing agents; deodorants; thermal stabilizers; antioxidants; antistatic agents; reinforcing agents; metal scavengers or deactivators; impact modifiers; processing aids; mold release aids, lubricants; anti-blocking agents; other flame retardants; UV stabilizers; plasticizers; flow aids; and the like. If desired, nucleating agents such as calcium silicate or indigo can be included in the flame retarded formulations also. The proportions of the other optional additives are conventional and can be varied to suit the needs of any given situation.

[0035] The methods of incorporation and addition of the components of the flame-retarded formulation and the method by which the molding is conducted is not critical to the present invention and can be any known in the art so long as the method selected involves uniform mixing and molding. For example, each of the above components, and optional additives if used, can be mixed using a Buss Ko-kneader, internal mixers, Farrel continuous mixers or twin screw extruders or in some cases also single screw extruders or two roll mills, and then the flame retarded formulation molded in a subsequent processing step. Further, the molded article of the flame-retardant polymer formulation may be used after fabrication for applications such as stretch processing, emboss processing, coating, printing, plating, perforation or cutting. The kneaded mixture can also be inflation-molded, injection-molded, extrusion-molded, blow-molded, press-molded, rotation-molded or calender-molded.

[0036] In the case of an extruded article, any extrusion technique known to be effective with the synthetic resin mixture described above can be used. In one exemplary technique, the

synthetic resin, coated magnesium hydroxide particles, and optional components, if chosen, are compounded in a compounding machine to form a flame-retardant formulation as described above. The flame-retardant formulation is then heated to a molten state in an extruder, and the molten flame-retardant resin formulation is then extruded through a selected die to form an extruded article or to coat for example a metal wire or a glass fiber used for data transmission.

[0037] The above description is directed to several embodiments of the present invention. Those skilled in the art will recognize that other means, which are equally effective, could be devised for carrying out the spirit of this invention. It should also be noted that preferred embodiments of the present invention contemplate that all ranges discussed herein include ranges from any lower amount to any higher amount.

What is Claimed:

1. Coated magnesium hydroxide particles comprising a surface coating agent selected from at least one of i) fatty acids; ii) alkylsilanes; iii) organic titanates; iv) organic zirconates, v) aminosilanes, vi) vinylsilanes, and vii) siloxane derivatives, wherein said magnesium hydroxide particles are produced by mill drying a filter cake comprising from about 35 to about 99 wt.% magnesium hydroxide, based on the filter cake, in the presence of the surface coating agent.
2. The coated magnesium hydroxide particles according to claim 1 wherein said surface coating agent is present in an amount ranging from about 0.05 to about 5 wt.%, based on the total weight of the uncoated magnesium hydroxide particles in the filter cake.
3. The coated magnesium hydroxide particles according to claim 1 wherein said alkyl silanes are selected from those alkyl silanes wherein at least one alkyl group of said alkyl silane has at least 3 carbon atoms.
4. The coated magnesium hydroxide particles according to claim 1 wherein said fatty acids are selected from saturated fatty acids, unsaturated fatty acids, and fatty acids with additional functional groups.
5. The coated magnesium hydroxide particles according to claim 4 wherein said fatty acids contain from about 8 to about 30 carbon atoms.
6. The coated magnesium hydroxide particles according to claim 1 wherein said siloxane derivatives are selected from oligoalkylsiloxanes; polydialkylsiloxanes, for example polydimethylsiloxane or polydiethylsiloxane; polyalkylarylsiloxanes, for example polyphenylmethylsiloxane; or polydiarylsiloxanes, for example polyphenylsiloxane, said siloxane derivatives optionally functionalized with reactive groups.
7. The coated magnesium hydroxide particles according to claim 1 wherein said alkylsilanes are described by the formula $R^1Si(OR^2)_3$, where R^1 is a linear or branched alkyl group having from about 3 to about 30 carbon atoms, and R^2 is a linear or branched alkyl group having from about 1 to about 6 carbon atoms.
8. The coated magnesium hydroxide particles according to claim 1 wherein said organic titanates are those having the formula $R^3OTi(OR^4)_3$, wherein R^3 is a linear or branched alkyl group having from about 1 to about 14 carbon atoms, and R^4 is a linear or branched alkyl group having from about 6 to about 12 carbon atoms or an acyl group having from about 8 to about 30 carbon atoms.
9. The coated magnesium hydroxide particles according to claim 1 wherein said organic zirconates are those having the formula $R^5OZr(OR^6)_3$, where R^5 is a linear or branched

alkyl group having from about 1 to about 12 carbon atoms, and R^6 is a linear or branched alkyl group having from about 6 to about 12 carbon atoms or an acyl group having from about 8 to about 30 carbon atoms.

10. The coated magnesium hydroxide particles according to claim 1 wherein said surface coating agent is a combination of a fatty acid and a siloxane derivative.
11. The coated magnesium hydroxide particles according to claim 1 wherein said surface coating agent is a silane.
12. The coated magnesium hydroxide particles according to claim 4 wherein said surface coating agent is a combination of a fatty acid and a siloxane derivative.
13. The coated magnesium hydroxide particles according to claim 1 wherein said coated magnesium hydroxide particles are characterized by a d_{50} of less than about 3.5 μm, as determined by laser diffraction according to ISO 9276; and a BET specific surface area of from about 1 to about 15 m^2/g, as determined by DIN-66132.
14. The coated magnesium hydroxide particles according to claim 1 wherein said filter cake comprises from about 35 to about 80 wt.% magnesium hydroxide, based on the filter cake.
15. The coated magnesium hydroxide particles according to claim 1 wherein said filter cake further comprises a dispersing agent.
16. A process comprising:
    a) mill drying a filter cake comprising in the range from about 35 to about 99 wt.% magnesium hydroxide, based on the total weight of the filter cake, in the presence of a surface coating agent selected from at least one of i) fatty acids; ii) alkylsilanes; iii) organic titanates; iv) organic zirconates, v) aminosilanes, vi) vinylsilanes, and vii) siloxane derivatives thereby producing coated, mill-dried magnesium hydroxide particles.
17. The process according to claim 16 wherein the mill drying is effected by passing the filter cake through a mill drier operated under conditions including a throughput of a hot air stream greater than about 3000 Bm^3/h, a rotor circumferential speed of greater than about 40 m/sec, wherein said hot air stream has a temperature of greater than about 150°C and a Reynolds number greater than about 3000.
18. The process according to claim 16 wherein the mill drying is effected by passing the filter cake through a mill drier operated under conditions including a throughput of a hot air stream greater than about 3000 Bm^3/h to about 40000 Bm^3/h, a rotor circumferential

speed of greater than about 70 m/sec, wherein said hot air stream has a temperature of from about 150°C to about 550°C and a Reynolds number greater than about 3000.

19. The process according to claim 16 wherein said process is continuous or batch.
20. The process according to claim 16 wherein said filter cake is mill-dried in the presence of an amount of surface coating agent effective at producing coated, mill-dried magnesium hydroxide particles having in the range of from about 0.05 to about 5 wt.%, based on the uncoated magnesium hydroxide particles, of said surface coating agent.
21. The process according to claim 19 wherein said surface coating agent is a combination of a fatty acid and a siloxane derivative.
22. The process according to claim 19 wherein said surface coating agent is a silane.
23. The process according to claim 16 wherein the surface coating agent is i) introduced into the mill drier as a batch, ii) continuously metered into the mill drier, iii) introduced as a batch into the filter cake just prior to the introduction of the filter cake into the mill drier or, iv) continuously metered into the filter cake just prior to the introduction of the filter cake into the mill drier.
24. The process according to claim 16 wherein said filter cake further comprises a dispersing agent.
25. A process for producing coated magnesium hydroxide particles comprising:
    a) introducing into a mill-drying unit a filter cake comprising from about 35 to about 99 wt.% magnesium hydroxide, based on the filter cake;
    b) simultaneously introducing into said mill drying unit, at a point above or after the introduction of the filter cake, a surface coating agent selected from at least one of i) fatty acids; ii) alkylsilanes; iii) organic titanates; iv) organic zirconates, v) aminosilanes, vi) vinylsilanes, and vii) siloxane derivatives; and
    c) mill drying said filter cake in the presence of said surface coating agent until coated, mill-dried magnesium hydroxide particles are produced.
26. The process according to claim 25 wherein said surface coating agent is i) continuously metered into said mill drying unit, or ii) introduced into said mill drying unit batch-wise.
27. The process according to claim 25 wherein the mill drying is effected by passing the filter cake through said mill drying unit, which is operated under conditions including a throughput of a hot air stream greater than about 3000 Bm^3/h, a rotor circumferential speed of greater than about 40 m/sec, wherein said hot air stream has a temperature of greater than about 150°C and a Reynolds number greater than about 3000.

28. The process according to claim 26 wherein the mill drying is effected by passing the filter cake through said mill drying unit, which is operated under conditions including a throughput of a hot air stream greater than about 3000 Bm^3/h to about 7000 Bm^3/h, a rotor circumferential speed of greater than about 70 m/sec, wherein said hot air stream has a temperature of from about 150°C to about 450°C and a Reynolds number greater than about 3000.
29. The process according to claim 26 wherein said filter cake is mill-dried in the presence of an amount of surface coating agent effective at producing coated, mill-dried magnesium hydroxide particles having in the range of from about 0.05 to about 5 wt.%, based on the uncoated magnesium hydroxide particles in the filter cake, of said surface coating agent.
30. The process according to claim 26 wherein said surface coating agent is a combination of a fatty acid and a siloxane derivative.
31. The process according to claim 26 wherein said surface coating agent is a silane.
32. The process according to claim 26 wherein the coated, mill-dried magnesium hydroxide particles are characterized as having i) a d_{50} in the range of from about 1.2 to about 3.5μm and a BET specific surface in the range of from about 1 to about 5 m^2/g; ii) a d_{50} in the range of from 1.25 to about 1.65 μm and a BET specific surface in the range of from about 3 to about 7 m^2/g; iii) a d_{50} in the range of from about 0.5 to about 1.4 μm, and a BET specific surface in the range of from about 6 to about 10 m^2/g; or iv) a d_{50} in the range of from about 0.3 to about 1.3 μm and a BET specific surface area in the range of from about 8 to about 12 m^2/g.
33. The process according to claim 25 wherein said filter cake further comprises a dispersing agent.
34. A process for producing magnesium hydroxide particles comprising:
    a) filtering a solution comprising from about 1 to about 99 wt.% magnesium hydroxide, based on the solution, to form a filter cake comprising from about 30 to about 80 wt.% magnesium hydroxide, based on the filter cake;
    b) optionally washing said filter cake one or more times with water;
    c) optionally dehydrating said filter cake under elevated temperatures;
    d) mill drying in a mill drying unit said filter cake in the presence of said surface coating agent until coated, mill-dried magnesium hydroxide particles are produced, wherein said surface coating agent is selected from at least one of i) fatty acids; ii) alkylsilanes; iii) organic titanates; iv) organic zirconates, v) aminosilanes, vi) vinylsilanes, and vii) siloxane derivatives.

35. The process according to claim 34 where said surface coating agent is simultaneously introduced into the mill drying unit, at a point above or after the introduction of the filter cake.
36. The process according to claim 35 wherein said surface coating agent is i) continuously metered into said mill drying unit, or ii) introduced into said mill drying unit batch-wise.
37. The process according to claim 34 wherein said mill drying unit is operated under conditions including a throughput of a hot air stream greater than about 3000 Bm^3/h, a rotor circumferential speed of greater than about 40 m/sec, wherein said hot air stream has a temperature of greater than about 150°C and a Reynolds number greater than about 3000.
38. The process according to claim 34 wherein said mill drying unit is operated under conditions including a throughput of a hot air stream greater than about 5000 Bm^3/h to about 7000 Bm^3/h, a rotor circumferential speed of greater than about 70 m/sec to about 140 m/sec, wherein said hot air stream has a temperature of from about 270°C to about 450°C and a Reynolds number greater than about 3000.
39. The process according claim 34 wherein said filter cake is mill-dried in the presence of an amount of surface coating agent effective at producing coated, mill-dried magnesium hydroxide particles having in the range of from about 0.05 to about 5 wt.%, based on the uncoated magnesium hydroxide particles in the filter cake, of said surface coating agent.
40. The process according to claim 34 wherein the coated, mill-dried magnesium hydroxide particles are characterized by a d_{50} of less than about 3.5 μm, as determined by laser diffraction according to ISO 9276; and a BET specific surface area of from about 1 to about 15 m^2/g, as determined by DIN-66132.
41. The process according to claim 34 wherein the coated, mill-dried magnesium hydroxide particles are characterized as having i) a d_{50} in the range of from about 1.2 to about 3.5μm and a BET specific surface in the range of from about 1 to about 5 m^2/g; ii) a d_{50} in the range of from 1.25 to about 1.65 μm and a BET specific surface in the range of from about 3 to about 7 m^2/g; iii) a d_{50} in the range of from about 0.5 to about 1.4 μm, and a BET specific surface in the range of from about 6 to about 10 m^2/g; or iv) a d_{50} in the range of from about 0.3 to about 1.3 μm and a BET specific surface area in the range of from about 8 to about 12 m^2/g.
42. The process according to claim 34 wherein said filter cake further comprises a dispersing agent.
43. The use of a mill drying unit in producing coated magnesium hydroxide particles.

44. A flame retarded formulation comprising a synthetic resin and coated, mill-dried magnesium hydroxide particles, wherein said coated, mill dried magnesium hydroxide particles are produced by mill drying in a mill drying unit a filter cake comprising in the range from about 35 to about 99 wt.% magnesium hydroxide, based on the total weight of the filter cake, in the presence of a surface coating agent.
45. The flame retarded formulation according to claim 44 wherein said flame retarded formulation comprises in the range of from about 15 to about 80wt.% of said coated, mill dried magnesium hydroxide particles and in the range of from about 20 to about 85 wt.% of said synthetic resin, all based on the total weight of the flame retarded polymer formulation.
46. The flame retarded formulation according to claim 44 wherein surface coating agent is selected from at least one of i) fatty acids; ii) alkylsilanes; iii) organic titanates; iv) organic zirconates, v) aminosilanes, vi) vinylsilanes, and vii) siloxane derivatives.
47. The flame retarded formulation according to claim 44wherein said filter cake further comprises a dispersing agent.
48. The flame retarded formulation according to claim 44 wherein said flame retarded formulation further comprises at least one of i) extrusion aids; ii) fatty acids; iii) coupling agents; iv) barium stearate; v) calcium sterate; vi) organoperoxides; viii) dyes; ix) pigments; x) fillers; xi) blowing agents; xii) deodorants; xiii) thermal stabilizers; xiv) antioxidants; xv) antistatic agents; xvi) reinforcing agents; xvii) metal scavengers or deactivators; xviii) impact modifiers; xix) processing aids; xx) mold release aids, xxi) lubricants; xxii) anti-blocking agents; xxiii) other flame retardants; xxiv) UV stabilizers; xxv) plasticizers; xxvi) flow aids; xxv) nucleating agents; and xxvi) the like.
49. A molded or extruded article made from the flame retarded formulation according to claim 44.
50. A molded or extruded article made from the flame retarded formulation according to claim 48.