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PREPARATION OF DEHYDROXYLATED SUPPORTS

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This case is a continuation-in-part of U.S. Patent Application Serial No. 08/258,396 filed on June 13, 1994.

Background of the Invention

5 In the field of oxide-supported catalysts, in general, and especially for olefin polymerization catalysts, it is often desired to remove surface hydroxyl groups from the oxide support particles before and/or during manufacture of the supported catalyst.

10 In the past, various thermal and/or chemical treatments have been used in an effort to achieve dehydroxylation of the oxide particles.

15 Thermal treatments (i.e. calcining) are advantageous from the point that they do not add undesirable chemicals to the support and that they are relatively simple inexpensive processes. Unfortunately, thermal treatments are often ineffective for achieving a high degree of dehydroxylation. Further, for many porous oxide supports (e.g., silica gel), thermal treatments often result in an undesirable loss of pore volume, shrinkage of the pores
20 and/or loss of surface area.

25 A variety of chemical treatments have been attempted. Many types of chemicals have been used such as organo aluminum compounds, magnesium chloride/dehydrating agent combinations, organosilanes, halosilanes, silazanes, etc. These various chemical processes are often expensive and may result in the addition of undesired or complicating constituents to the oxide support.

30 Thus, there remains a need for improved techniques for dehydroxylation and improved dehydroxylated supports.

Summary of the Invention

The invention provides dehydroxylated oxide supports having unique and simplified surface chemical composition. The invention further provides improved methods for forming dehydroxylated oxide supports.

In one aspect, the invention encompasses porous dehydroxylated oxide particles wherein said silica comprises less than 10 millimoles (mmol) surface hydroxyl groups per gram of oxide and wherein said silica comprises alkoxy and/or aryloxy groups on its surface. Preferably, the oxide particles are silica-containing particles more preferably silica gels.

In another aspect, the invention encompasses a method of removing hydroxyl groups from the surface of an oxide particle, the method comprising:

- (a) contacting the hydroxyl-containing oxide with a carbonate selected from the group consisting of dialkylcarbonates, diarylcarbonates and mixtures thereof and a base to form a mixture,
- (b) heating the mixture whereby the hydroxyl-containing oxide and carbonate react to eliminate at least a portion of the hydroxyl groups and to form alkoxy or aryloxy groups on the surface of the oxide,
- (c) recovering the dehydroxylated oxide formed in step (b).

Preferably, the reaction is carried out in a non-aqueous environment. If desired, the dehydroxylated support may be further treated to form a desired chemical configuration on the oxide surface and/or to place a desired catalyst on the support.

These and other aspects of the invention will be described in further detail below.

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Detailed Description of the Invention

The invention broadly encompasses dehydroxylated oxide particles characterized by very low surface hydroxyl content and by the presence of alkoxy and/or aryloxy groups on the particle surface. If desired, the alkoxy and/or aryloxy groups may be further reacted with other chemicals.

The oxide particles of the invention may be virtually any refractory metal or silicon oxide. Preferably, the oxide composition is one conventionally used as a catalyst support material. It is also preferred that the oxide particles be porous. Preferred oxides are silica, alumina, aluminum phosphate, silica alumina, titania, silica titania, magnesia, silica magnesia and mixtures thereof. The oxide particles are preferably amorphous particles such as amorphous precipitates or amorphous gels. Amorphous silicas and supports based on amorphous silica are most preferred.

The hydroxyl content of the oxide particles may be measured by any known suitable technique. Preferably, a spectral analysis method such as DRIFTS is used. The hydroxyl content of the dehydroxylated product may vary depending on the initial hydroxyl content, the desired degree of dehydroxylation, etc. Preferably, the hydroxyl content is less than 10 mmol per gram of oxide, more preferably less than 1 mmol/g. Most preferably, the oxide is completely free of hydroxyl groups on its surface.

The degree of porosity in the dehydroxylated oxide may be any level that is achievable in the starting hydroxyl-containing oxide. Preferably, the dehydroxylated oxide particles have a pore volume of at least 0.3 cc/g. More preferably, the pore volume exceeds

1 cc/g. Similarly, the surface area of the dehydroxylated oxide particles can be any level that is achievable in the starting hydroxyl-containing oxide. Preferably, the dehydroxylated oxide particles have a surface area of about 50-1000 m²/g.

The alkoxy and/or aryloxy groups on the oxide particle surface are believed to be substituted for at least some of the hydroxyl groups on the surface of the oxide particles. The net effect of the substitution is to replace the hydrogen of the hydroxyl group with an alkyl or aryl group (i.e., -OH being replaced by -OR where R is an alkyl or aryl group). Preferred alkyl groups are selected from the group consisting of methyl, ethyl, propyl and mixtures thereof. In principle, other alkyls may also be used. A preferred aryl group is phenyl, however other substituted aryl groups may also be employed. The total amount of alkyl (alkoxy) and/or aryl (aryloxy) groups on the oxide surface is dependent on the number of hydroxyl groups present on the oxide to be treated. The amount of alkoxy or aryloxy groups is typically about 10 mmol/g or less (but greater than zero), more typically about (0.1-3 mmol/g).

The invention further encompasses methods for forming dehydroxylated oxide particles. The methods of the invention generally encompass a step where hydroxyl-containing oxide particles are reacted with a dialkylcarbonate or diarylcarbonate in the presence of a base whereby at least a portion of the hydroxyl groups are removed or eliminated and alkoxy or aryloxy groups are formed on the oxide particle surface.

The methods preferably involve formation of an initial mixture containing the oxide particles (to be dehydroxylated), the dialkylcarbonate or diarylcarbonate,

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and a base. The initial mixture preferably also contains a solvent (preferably non-aqueous) however, neat mixtures of the oxide particles, carbonate and base may be used. The ingredients forming the initial mixture may be combined in virtually any desired sequence.

The oxide particles to be treated may be any hydroxyl-containing oxide. Preferably, the oxide particles are selected from those described above regarding the product of the invention. The particles may contain any level of hydroxyl content. While the particles may contain some free water, it is preferred that any free water be removed before the initial mixture is formed. (e.g., by solvent exchange or heating to less than 800°C.) The oxide particles are preferably porous. The porosity of the particles is preferably dictated by the intended end use of the particles. Preferably, the porosity of the particles to be dehydroxylated is such that the resulting oxide particles would be suitable for use as polyolefin catalyst supports.

The dialkylcarbonate may be any such carbonate capable of performing the dehydroxylating function. Preferably, the dialkylcarbonate comprises alkyl groups selected from the group consisting of methyl, ethyl, propyl and mixtures thereof, however higher alkyls may be used. Preferably, the alkyl groups in the dialkylcarbonate consist essentially of C₁-C₃ alkyls (dimethylcarbonate being most preferred). The diarylcarbonate may be any such carbonate capable of performing the dehydroxylating functions. Preferred diarylcarbonate is diphenylcarbonate. The amount of dialkylcarbonate and/or diarylcarbonate used may be varied depending on factors such as the hydroxyl content of the initial oxide particles, the desired degree of

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dehydroxylation, the reaction conditions, etc. .
Preferably, about 1-15 mmol of dialkylcarbonate and/or
diarylcarbonate are used per mole of hydroxyl groups
contained in the oxide particles.

5 The dehydroxylation reaction is preferably conducted
in the presence of a base which is believed to catalyze
the dehydroxylation. The base is preferably one which
can be easily removed after the reaction has taken place.
In any event, it is preferred that the base be selected
10 to provide minimal or no deleterious effect on the
resulting properties of the dehydroxylated oxide
particles. Mineral bases such as alkali metal hydroxides
may be employed, however preferred bases are amine-
containing bases such as triethylamine (TEA)
15 tributylamine (TBA), ammonia, n-butyllithium,
dimethylamine (DBA), anilines and mixtures thereof. The
amount of base used may be varied depending on the
desired rate of reaction. The amount of base added is
preferably about 0.1-10 mmol per gram of oxide particles
20 more preferably about 1-5 mmol per gram.

The initial mixture preferably contains a solvent to
facilitate mixing, etc. The solvent is preferably a
non-aqueous solvent. Organic solvents such as hexane,
tetrahydrofuran, toluene, ether and heptane are generally
25 preferred. The amount of solvent used is not critical,
but amounts in excess of that needed to form a pourable
slurry are generally unnecessary.

Once the initial mixture is formed, it is then
reacted to cause the dehydroxylation. If desired, the
30 mixture may be heated to about 30-150°C to facilitate the
reaction. The solvent is preferably refluxed during the
heating using any conventional refluxing technique. The
reaction is preferably conducted in a substantially dry

atmosphere. Inert gas atmospheres such as dry argon are preferred. The required reaction time may vary depending on the composition of the mixture, the temperature used, the desired degree of dehydroxylation, etc. Typical
5 reaction times are about 1-24 hours.

While the dehydroxylation can generally be completed in a single reaction step, it is possible to repeat the dehydroxylation reaction step by recovering the oxide particles and forming a new reaction mixture in the same
10 manner as for the formation of the initial mixture.

Once the desired dehydroxylation has been accomplished, the dehydroxylated particles may be recovered from the mixture. Preferably, recovery can be accomplished by simply evaporating the solvent and other
15 reactants. In some instances, it may be desirable to wash the dehydroxylated oxide with a solvent to further move any residual reactants, etc. Preferably, however, the reactants are selected such that they are all removable by volatilization. Preferably, the removal is
20 conducted under at least a partial vacuum. If desired, techniques such as spray drying may be employed.

The dehydroxylated product will typically be in the form of a free flowing powder having the alkoxy and/or aryloxy surface groups corresponding to the
25 alkylcarbonate and/or arylcarbonate used in the reacting step. The recovered product may be further treated as desired to place a catalyst or other constituents on its surface.

The invention is further illustrated by the
30 following examples. It should be understood that the invention is not limited to the specific details of the examples.

Example 1

A round bottom flask was loaded with 30 g silica gel (Grace Davison 948) which had been calcined at 400°C for two hours. 250 ml of hexane and 34 mmol of tributylamine were added to the flask, and the mixture was stirred for two hours at room temperature to form a slurry. 360 mmol of dimethyl carbonate was then added to the slurry. The slurry was then allowed to react at room temperature (25°C) for about 24 hours. The reacted slurry was then dried under vacuum and the treated silica was examined by infrared (IR) spectroscopy. The IR analysis indicated that substantially all the silanol (hydroxyl) groups present on the untreated silica had been removed and that methoxy groups were present on the surface of the treated silica. No traces of amine on the treated silica.

Example 2

The procedure of Example 1 was repeated except that 68 mmol of tributylamine were used, and 360 mmol diethyl carbonate were used instead of the dimethyl carbonate. The IR analysis of the treated silica indicated that substantially all the silanol groups present on the untreated silica had been removed and that ethoxy groups were present on the surface of the treated silica. No traces of amine on the treated silica.

Example 3

The procedure of Example 1 was repeated except that 34 mmol of n-butyllithium were used instead of the tributylamine. The IR analysis of the treated silica indicated that substantially all the silanol groups present on the untreated silica had been removed and that

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methoxy groups were present on the surface of the treated silica.



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WHAT IS CLAIMED IS:

1. 1. Porous dehydroxylated oxide particles wherein said oxide comprises less than 10 millimoles of surface hydroxyl groups per gram of said oxide and wherein said oxide comprises groups selected from the group consisting of alkoxy groups, aryloxy groups and mixtures thereof on its surface.

2. 2. The dehydroxylated oxide of claim 1 wherein said oxide is selected from the group consisting of silica, alumina, silica alumina, aluminum phosphate, titania, silica-titania, magnesia, silica magnesia, and mixtures thereof.

3. 3. The dehydroxylated oxide of claim 2 wherein said oxide comprises silica.

4. 4. The dehydroxylated silica of claim 3 wherein said silica has a surface area of about 50-1000 m²/g and a pore volume of at least 0.3 cc/g.

5. 5. The dehydroxylated silica of claim 3 wherein said silica is a silica gel.

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1 6. A method of removing hydroxyl groups from the
surface of an oxide particle, said method comprising:

- 3 (a) contacting said hydroxyl-containing oxide with
a carbonate selected from the group consisting
5 of dialkylcarbonates, diarylcarbonates, and
mixtures thereof and a base to form a mixture,
7 (b) heating said mixture whereby said hydroxyl-
containing oxide and carbonate react to
9 eliminate at least a portion of said hydroxyl
groups and to form alkoxy and/or aryloxy groups
11 on the surface of said oxide,
13 (c) recovering the dehydroxylated oxide formed in
step (b).

1 7. The method of claim 6 wherein step (a)
comprises impregnating said hydroxyl-containing oxide
3 with a solution of said carbonate and base in a solvent.

1 8. The method of claim 7 wherein said solvent is
non-aqueous.

1 9. The method of claim 6 wherein said carbonate is
selected from the group consisting of dimethylcarbonate,
3 diethylcarbonate, methylethylcarbonate, diphenylcarbonate
and mixtures thereof.

1 10. The method of claim 6 wherein said base is
selected from the group consisting of alkali metal
3 hydroxides, tertiary amines, anilines, n-butyllithium and
mixtures thereof.

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1 11. The method of claim 8 wherein said solvent is
selected from the group consisting of hexane, heptane,
3 toluene, ether, tetrahydrofuran, and mixtures thereof.

1 12. The method of claim 6 wherein the mixture is
heated to about 30-150°C in step (b).

1 13. The method of claim 7 wherein step (c)
comprises removing said solvent by evaporation.

1 14. The method of claim 7 wherein said
dehydroxylated oxide is washed with a solvent between
3 steps (b) and (c).

1 15. The method of claim 12 wherein said heating is
performed in an inert atmosphere.

1 16. The method of claim 7 wherein said solvent is
refluxed during heating step (b).

1 17. The method of claim 6 wherein said hydroxyl-
containing oxide is selected from the group consisting of
3 silica, alumina, silica alumina, alumina phosphate,
titania, silica-titania, magnesia, silica magnesia and
5 mixtures thereof.

1 18. The method of claim 6 wherein said hydroxyl-
containing oxide is treated prior to step (a) to remove
3 any free water contained therein.

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Abstract of the Invention

5 Dehydroxylated oxide (e.g. silica) particles are obtained by reacting oxide particles, having surface hydroxyl groups, with a dialkylcarbonate or diarylcarbonate. The resulting products have surface alkoxy or aryloxy groups and significantly reduced hydroxyl content. The treated oxide particles are especially suitable for use as catalyst supports, and especially as polyolefin catalyst supports.

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PREPARATION OF DEHYDROXYLATED SUPPORTSAbstract of the Invention

Dehydroxylated oxide (e.g. silica) particles are obtained by reacting oxide particles, having surface hydroxyl groups, with a dialkylcarbonate or diarylcarbonate. The resulting products have surface alkoxy or aryloxy groups and significantly reduced hydroxyl content. The treated oxide particles are especially suitable for use as catalyst supports, and especially as polyolefin catalyst supports.

Detailed Description of the Invention

The invention broadly encompasses dehydroxylated oxide particles characterized by very low surface hydroxyl content and by the presence of alkoxy and/or aryloxy groups on the particle surface. If desired, the alkoxy and/or aryloxy groups may be further reacted with other chemicals.

The oxide particles of the invention may be virtually any refractory metal or silicon oxide. Preferably, the oxide composition is one conventionally used as a catalyst support material. It is also preferred that the oxide particles be porous. Preferred oxides are silica, alumina, aluminum phosphate, silica alumina, titania, silica titania, silica titania alumina, magnesia, silica magnesia and mixtures thereof. The oxide particles are preferably amorphous particles such as amorphous precipitates or amorphous gels. Amorphous silicas and supports based on amorphous silica are most preferred.

The hydroxyl content of the oxide particles may be measured by any known suitable technique. Preferably, a spectral analysis method such as DRIFTS is used. The hydroxyl content of the dehydroxylated product may vary depending on the initial hydroxyl content, the desired degree of dehydroxylation, etc. Preferably, the hydroxyl content is less than 10 mmol per gram of oxide, more preferably less than 1 mmol/g. Most preferably, the oxide is completely free of hydroxyl groups on its surface.

The degree of porosity in the dehydroxylated oxide may be any level that is achievable in the starting hydroxyl-containing oxide. Preferably, the dehydroxylated oxide particles have a pore volume of at least 0.3 cc/g. More preferably, the pore volume exceeds

and a base. The initial mixture preferably also contains a solvent (preferably non-aqueous) however, neat mixtures of the oxide particles, carbonate and base may be used. The ingredients forming the initial mixture may be
5 combined in virtually any desired sequence.

The oxide particles to be treated may be any hydroxyl-containing oxide. Preferably, the oxide particles are selected from those described above regarding the product of the invention. The particles may
10 contain any level of hydroxyl content. While the particle may contain some free water, it is preferred that any free water be removed before the initial mixture is formed. (e.g., by solvent exchange or heating to less than 800°C.) The oxide particles are preferably porous. The porosity
15 of the particles is preferably dictated by the intended end use of the particles. Preferably, the porosity of the particles to be dehydroxylated is such that the resulting oxide particles would be suitable for use as polyolefin catalyst supports.

20 The dialkylcarbonate may be any such carbonate capable of performing the dehydroxylating function. Preferably, the dialkylcarbonate comprises alkyl groups selected from the group consisting of methyl, ethyl, propyl and mixtures thereof, however higher alkyls may be
25 used. Preferably, the alkyl groups in the dialkyl-carbonate consist essential of C₁-C₄ alkyls, e.g., dimethyl carbonate, diethylcarbonate, methylethyl carbonate, diphenyl carbonate and mixtures thereof.

(dimethylcarbonate being most preferred). The
30 diarylcarbonate may be any such carbonate capable of performing the dehydroxylating functions. Preferred diarylcarbonate is diphenylcarbonate. The amount of dialkylcarbonate and/or diarylcarbonate used may be varied depending on factors such as the hydroxyl content of the
35 initial oxide particles, the desired degree of

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dehydroxylation, the reaction conditions, etc.

Preferably, about 1-15 mmol of dialkylcarbonate and/or diarylcarbonate are used per mole of hydroxyl groups contained in the oxide particles.

- 5 The dehydroxylation reaction is preferably conducted in the presence of a base which is believed to catalyze the dehydroxylation. The base is preferably one which can be easily removed after the reaction has taken place. In any event, it is preferred that the base be selected to
- 10 provide minimal or no deleterious effect on the resulting properties of the dehydroxylated oxide particles. Mineral bases such as alkali metal hydroxides may be employed, however preferred bases are amine-containing bases such as triethylamine (TEA) tributylamine (TBA), ammonia, n-
- 15 butyllithium, dimethylamine (DMA), anilines, tertiaryamines and mixtures thereof. The amount of base used may be varied depending on the desired rate of reaction. The amount of base added is preferably about 0.1-10 mmol per gram of oxide particles more preferably
- 20 about 1-5 mmol per gram.

- The initial mixture preferably contains a solvent to facilitate mixing, etc. The solvent is preferably a non-aqueous solvent. Organic solvents such as hexane tetrahydrofuran, toluene, ether and heptane and mixtures
- 25 thereof are generally preferred. The amount of solvent used is not critical, but amounts in excess of that needed to form a pourable slurry are generally unnecessary.

- Once the initial mixture is formed, it is then reacted to cause the dehydroxylation. If desired, the
- 30 mixture may be heated to about 30-150°C to facilitate the reaction. The solvent is preferably refluxed during the heating using any conventional refluxing technique. The reaction is preferably conducted in a substantially dry



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WHAT IS CLAIMED IS:

1. Porous dehydroxylated oxide particles wherein said oxide comprises less than 10 millimoles of surface hydroxyl groups per gram of said oxide and wherein said oxide comprises groups selected from the group consisting of alkoxy groups, aryloxy groups and mixtures thereof on its surface.

2. The dehydroxylated oxide of claim 1 wherein said oxide is selected from the group consisting of silica, alumina, silica alumina, aluminum phosphate, titania, silica titania, silica titania alumina, magnesia, silica magnesia, and mixtures thereof.

3. The dehydroxylated oxide of claim 2 wherein said oxide comprises silica.

4. The dehydroxylated silica of claim 3 wherein said silica has a surface area of about 50-1000 m²/g and a pore volume of at least 0.3 cc/g.

5. The dehydroxylated silica of claim 3 wherein said silica is a silica gel.



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6. A method of removing hydroxyl groups from the surface of an oxide particle, said method comprising the steps of :

(a) contacting said hydroxyl-containing oxide with a carbonate selected from the group consisting of dialkylcarbonates, diarylcarbonates and mixtures thereof and a base to form a mixture, whereby said hydroxyl-containing oxide and said carbonate react to eliminate at least a portion of said hydroxyl groups and to form alkoxy and/or aryloxy groups on the surface of said oxide, and

(b) recovering the dehydroxylated oxide formed in step (a).

7. The method of claim 6, the method further comprising contacting said hydroxyl-containing oxide with a solution of said carbonate and said base in solvent.

8. The method of claim 7, the method further comprising a solution of said carbonate and said base in a non-aqueous solvent.

9. The method of claim 8, the method further comprising selecting said carbonate from the group consisting of dimethylcarbonate, diethylcarbonate, methylethylcarbonate, diphenylcarbonate and mixtures thereof.

10. The method of claim 6 the method further comprising selecting said base from the group consisting of alkali metal hydroxides, tertiary amines, anilines, n-butyllithium and mixtures thereof.

11. The method of claim 8, the method further comprising selecting said solvent from the group consisting of hexane, heptane, toluene, ether, tetrahydrofuran, and mixtures thereof.

12. The method of claim 7, the method further comprising heating said mixture from step (a).

13. The method of claim 12, the method further comprising heating said mixture from step (a) to about 30-150°C.



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14. The method of claim 7, the method further comprising the step of removing said solvent by evaporation in step (b)
15. The method of claim 12, the method further comprising washing said dehydroxylated oxide with a solvent after heating.
16. The method of claim 13, the method further comprising heating said mixture in an inert atmosphere.
17. The method of claim 12, the method further comprising refluxing the solvent during heating.
18. The method of claim 6 wherein said hydroxyl-containing oxide is selected from the group consisting of silica, alumina, silica alumina, aluminum phosphate, titania, silica-titania, silica titania alumina, magnesia, silica magnesia and mixtures thereof
19. The method of claim 6, the method further comprising treating said hydroxyl-containing oxide prior to step (a) to remove any free water contained therein.