

TITANIUM IMPREGNATED SILICA-CHROMIUM CATALYSTS

This invention relates to silica supported chromium catalysts containing titanium.

Supported chromium oxide catalysts have been used for many years in the polymerization of olefins to solid polymers. One widely used method of producing such catalysts involves precipitating a silica hydrogel, impregnating the hydrogel with an aqueous solution of a chromium compound and drying. Such procedure gives a silica which inherently has sufficient strength to resist severe shrinkage of the pores during simple drying techniques such as oven drying, tray drying, spray drying or drying under a heat lamp. Such catalyst is simple and inexpensive to produce and gives outstanding results in solution polymerization of olefins to give normally solid polymer.

There is an economic advantage in some instances to producing olefin polymers in a slurry as opposed to a solution system. However, certain control operations which are easily carried out in the solution process are considerably more difficult in the particle-form or slurry process. For instance in the solution process, control of the molecular weight can be effected by changing the temperature, with lower molecular weight (higher melt flow) being obtained at the higher temperature. However, in the slurry process, this technique is inherently limited since any effort to increase the melt flow to any appreciable extent by increasing the temperature causes the polymer to go into solution and thus destroys the slurry process.

It is known that titanium affects the polymerization activity of silica supported chromium catalysts in a way that is of special importance in slurry polymerizations. However, when titanium is

coprecipitated with the silica, it produces a hydrogel which does not have sufficient strength to resist serious collapse of the pores during simple drying such as spray drying. Accordingly, in order to take full advantage of the improvement which can be imparted to the melt index capability through the use of titanium in accordance with the prior art, the titanium had to be coprecipitated with the silica and the resulting hydrogel (cogel) dried by a more expensive azeotrope distillation or washing with a liquid oxygen-containing water soluble organic compound.

5 This invention seeks to provide a titanium-containing silica supported chromium catalyst which can be dried in a conventional manner and yet which exhibits the characteristics associated with azeotrope dried titanium-silica coprecipitated catalysts.

10 More generally, it provides a catalyst suitable for use in slurry polymerization systems; and an improved olefin polymerization process. Broadly speaking the improved silica-supported, titanium- and chromium-containing olefin polymerization catalyst provided in accordance with this invention is produced by forming a silica hydrogel, converting the hydrogel to a xerogel, incorporating a chromium-containing compound into the silica gel before or after conversion of the hydrogel to said xerogel, and activating the chromium impregnated xerogel to form said catalyst, wherein said titanium is introduced into the catalyst by treating the silica hydrogel or the xerogel, before or after the incorporation
20 therein of said chromium-containing compound, but before calcination thereof, with an aqueous solution of a hydrolysis resistant titanium compound.

25 There are two techniques for carrying out the process of this invention. In accordance with the first technique, a silica xerogel is aqueously impregnated with a titanium compound which is resistant to hydrolysis, before or after impregnation with the chromium compound, but prior to calcination.

30 In accordance with the second technique, the titanium-containing compound resistant to hydrolysis is incorporated into the hydrogel prior to conversion to the xerogel; in this technique the hydrogel preferably also contains a pore preserving agent.

35 The invention will be further described with reference to the accompanying drawings in which:

FIGURE 1 is a plot of melt index versus reoxidation temperature for reduced and reoxidized activated Catalyst A as defined hereinafter which had been aqueously impregnated with 3 weight percent titanium as Tyzor TE, the polymerization temperature being indicated on the graph (Tyzor TE, is a product of E. I. duPont de Nemours & Co., Inc., Wilmington, DE); FIGURE 2 is a plot of melt index versus air activation temperature for catalyst prepared by aqueously impregnating 952 silica gel with 1 weight percent chromium as chromium (III) acetate ($\text{Cr}(\text{OAc})_3$) and the indicated percentage titanium with Tyzor TE, using a polymerization temperature of 107°C (952 silica, is a product of Davison Chemical Co.); FIGURE 3 is a plot of melt index versus weight percent titanium for catalyst prepared by aqueously impregnating 952 silica gel with 0.8 weight percent chromium as $\text{Cr}(\text{OAc})_3$ and with the indicated weight percentage titanium as Tyzor TE, the catalyst being air activated at the indicated temperatures (polymerization temperature 107°C); FIGURE 4 is a plot of melt index versus reoxidation temperature for reduced and reactivated catalysts prepared by aqueously impregnating 952 silica gel with 0.8 weight percent chromium as $\text{Cr}(\text{OAc})_3$ and with the indicated percentage titanium as Tyzor TE (polymerization temperature 104°C , except as indicated where the temperature was 107°C); and FIGURE 5 is a plot of melt index versus weight percent titanium for reduced and reoxidized activated catalysts prepared by aqueously impregnating 952 silica gel with 0.8 weight percent chromium as $\text{Cr}(\text{OAc})_3$ and with the indicated percentage titanium as Tyzor TE, the catalysts being CO reduced at 871°C and reoxidized to 538°C (polymerization temperature 104°C).

Description of the Preferred Techniques

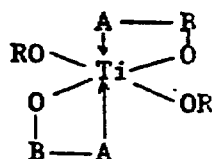
Technique I

In this technique, a dried silica hydrogel (xerogel) is impregnated with an aqueous solution of a hydrolysis resistant titanium compound. In this embodiment, the xerogel can be formed by drying a titanium free hydrogel by conventional means. For instance, an alkali metal silicate can be added to an acid to produce a hydrogel which is washed to remove alkali metal ions, impregnated with an aqueous solution of a chromium compound and thereafter dried in a conventional manner such as spray drying. The silica hydrogel can be prepared in a conventional manner, for instance, by contacting an aqueous acid solution with an aqueous solution of an alkali metal silicate as disclosed in US 3,900,457. Preferably, the alkali metal silicate is added to the acid.

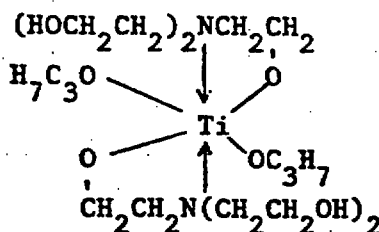
Other conventional drying techniques such as air oven drying, tray drying, vacuum oven drying or drying under a heat lamp or other radiant heat source can be used. Conventional drying temperatures of room temperature to 425°C or higher can be used to thus remove free water and produce a xerogel. With spray drying the incoming air can be up to 425°C although the catalyst does not get that hot.

Thereafter, the resulting xerogel is impregnated with an aqueous solution of a hydrolysis resistant titanium compound. A hydrolysis resistant, water soluble titanium compound is required since otherwise titanium precipitates out independently of the silica. When titanium compounds outside the scope of the hydrolysis resistant titanium compounds of this embodiment of this invention are used, polymers made with the resulting catalyst do not exhibit the superior stress crack resistance shown by polymers made for the use of the catalyst of this embodiment of this invention.

The hydrolysis resistant titanium compounds are preferably selected from titanium chelates, particularly alkanolamine titanates, e.g., triethanolamine titanate. The titanium chelates are known compounds and can be expressed by the general formula:

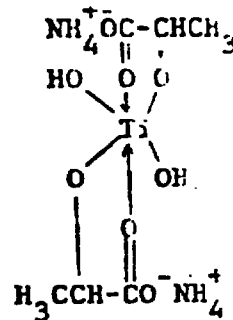


where R is an alkyl group containing from 1 to about 4 carbon atoms, A is a functional group containing O or N or is OH, and B is a divalent hydrocarbon chain of 2 or 3 carbon atoms which can have one or more alkyl groups of 1 to about 4 carbon atoms. An example of a specific compound is triethanolamine titanate chelate. Triethanolamine titanium chelate has the formula



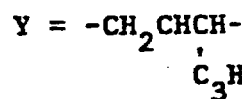
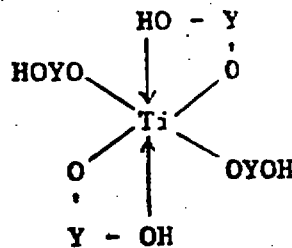
This is available from DuPont under the designation Tyzor TE.

Lactic acid titanium complexes such as lactic acid titanium chelates and tetraethylene glycol titanium complexes such as tetraethylene glycol titanium chelates are also suitable. A specific example of a lactic acid titanium complexes is:



This is available from DuPont under the designation Tyzor LA.

An example of the tetraoctylene glycol titanium complexes is:



This is available from DuPont under the designation Tyzor OG.

It must be emphasized that the invention is applicable only to the hydrolysis resistant compounds of the general formula. The three classes of titanium chelates set out hereinabove are hydrolysis resistant. One class, the titanium acetyl acetonates are not and hence cannot be used in this invention. A simple test can be used to determine if a compound is suitable for use in this invention, namely to mix the compound with water. If a precipitate forms, it is not suitable and if no precipitate forms, it is suitable.

The resulting titanium impregnated xerogel can then be activated without further processing especially if only enough solution is used to just fill the pores. Alternatively, the water can be removed by evaporation at room temperature or an elevated temperature of about 100 to 250°C or higher prior to the activation.

The activation can be carried out in a conventional manner by calcining at an elevated temperature, generally from about 400°C to 1100°C in a dry atmosphere containing oxygen, generally in air. Alternatively, the catalyst can be activated in accordance with the reduction/reoxidation procedures disclosed in US 4,151,122. Use of this activation technique further

enhances the capability to produce high melt index polymers exhibiting superior stress crack resistance.

The final titanium concentration will be such as to give 0.1 to 10 preferably 3-7 weight percent titanium based on the weight of the activated catalyst.

Technique 2

In this technique, a hydrolysis resistant titanium compound as described in technique 1 is incorporated into a hydrogel which is then dried. Conventional techniques as described hereinabove, such as spray drying, oven drying, tray drying, or drying under a heat lamp or other radiant heat source can be used. In this embodiment, it is preferred that the hydrogel further contain a pore preserving agent as described hereinbelow although this is not essential. The resulting titanium-containing xerogel is then activated by calcining as described hereinabove. While the hydrolysis resistant titanium compound can be coprecipitated with the hydrogel, it is preferably added to the hydrogel neat or as a solution in an organic solvent such as isopropanol which is miscible with water. This is because it is normally stored in this form. Alternatively just before using, the hydrolysis resistant titanium compound could be dissolved in water.

The final titanium compound concentration will be such as to give about 0.1 to 10, preferably 2 to 10, more preferably 2-6 percent titanium based on the weight of the activated catalyst.

After the activation step in all of the embodiments, at least a portion of the chromium compound is in the hexavalent state.

In all embodiments, the chromium component of the catalyst can be coprecipitated with the silica or added by means of an anhydrous solution to the xerogel but preferably the chromium is introduced by means of incorporating an aqueous solution of a water soluble chromium compound with the hydrogel. This is preferably done after the hydrogel is washed with water to remove alkali metal ions. The water soluble chromium compound can be selected from among chromium acetate, chromic nitrate, chromic sulfate, chromous sulfate, chromium trioxide, ammonium chromate, and other soluble chromium compounds. Chromium acetate and CrO_3 are preferred.

In all of the embodiments, the amount of chromium compound employed in making the catalyst is sufficient to provide from about 0.001 to about 10 weight percent, preferably 0.1 to 5 weight percent chromium in the final catalyst based on the weight of the activated catalyst.

The silica pore structure preserving agents, when used, can be selected from among organic silicon compounds, e.g., triarylsilanol, described in US patent 4,190,457; oxygen-containing organic compounds selected from polyhydric alcohols, mono and dialkyl ethers of ethylene glycol and poly(alkylene)glycol optionally in combination with a normally liquid hydrocarbon, e.g. n-heptane or kerosene, or a surfactant, such oxygenated compounds and combinations being disclosed in US 4169926. Surfactants, e.g. anionic, cationic and non-ionic surfactants are also suitable themselves as pore preserving agents with non-ionics being particularly preferred.

The pore preserving agents can also include certain inorganic and organic acids used at a specific level of pH. Specifically the hydrogel is contacted with an inorganic or organic acid in an amount sufficient to impart to the mixture a pH ranging generally from about 0 to about 3.5, more specifically from about 0 to 3. About 2.2 or below is presently preferred.

Inorganic acids employable in this invention are those which are water soluble, sufficiently ionized to produce the pH level required in the hydrogels, and do not have a deleterious effect on the silica or in the end use application. For the production of ethylene polymerization catalysts, specific but nonlimiting acids can be selected from among hydrochloric acid, hydrobromic acid, hydriodic acid, nitric acid, sulfamic acid, sulfuric acid, orthophosphoric acid and iodic acid.

Organic acids generally employable in this invention are those which exhibit the same requirements as the inorganic acids. Specific but nonlimiting examples include acetic acid, formic acid, tartaric acid, citric acid, maleic acid, malic acid, malonic acid, succinic acid, gluconic acid, diglycolic acid, ascorbic acid, cyclopentane tetracarboxylic acid, and benzenesulfonic acid.

In general, those organic acids meeting the requirements of water solubility, stability, acid strength, nondeleterious action as described before also have pK values of about 4.76 or less as disclosed in Lange's Handbook of Chemistry, 11th Edition (1973), Tables 5-7, 5-8. In other words their acid strength is equal to or greater than that of acetic acid.

Acids such as sulfuric acid and hydrochloric acid are generally preferred, however, because of their ready availability, relatively low cost, great acid strength, and efficacy in the process.

The pore preserving agent can be incorporated in one of the ingredients used to make the silica hydrogel, however, it is preferably incorporated into the hydrogel after the washing step since this avoids loss of the agent during the washing step.

When the pore preserving agent is an oxygen-containing organic compound, the weight ratio of oxygen-containing organic compound to hydrogel employed in making the catalyst can range from about 5:1 to about 0.5:1.

When both an oxygen-containing organic compound and a normally liquid hydrocarbon are employed with the hydrogel, the weight ratio of hydrocarbon to organic compound can vary from about 20:1 to about 0.5:1.

When employing one or more surfactants with the hydrocarbon/oxygen-containing organic compound, generally about 0.1 to about 5 weight percent surfactant is used based on the weight of hydrocarbon/oxygen-containing organic compound.

When a surfactant or an organic silicon compound of said US patent 4,190,457 is employed as the silica pore structure preserving agent, the weight ratio of hydrogel to surfactant or organic silicon compound can range from about 20:1 to about 500:1, preferably from about 40:1 to about 100:1.

Sufficient treating time is allotted to obtain contact of the various added components with the hydrogel or dried gel. Generally, times ranging from about 30 seconds to about 10 hours, preferably 15 minutes to 120 minutes are adequate. The treated hydrogel is then dried as described above to remove the liquids and the composite is then activated at an elevated temperature.

Specific examples of preferred pore preserving agents are a polysiloxane-polyoxyalkylene copolymer, a polyethoxylated sorbitol monolaurate, and a polyethoxylated t-octylphenol.

The catalyst of this invention resembles coprecipitated silica-titania catalyst in pore volume, in chromium content, and in the titanium content although the process for making the catalyst is substantially simplified and substantially less expensive.

The catalyst of this invention can be used to polymerize at least one mono-1-olefin containing 2 to 8 carbon atoms per molecule. The

invention is of particular applicability in producing ethylene homopolymers and copolymers from mixtures of ethylene and one or more comonomers selected from 1-olefins containing 3 to 8 carbon atoms per molecule. Exemplary comonomers include aliphatic 1-olefins such as propylene, 1-butene, 1-hexene, and higher 1-olefins and conjugated or nonconjugated diolefins, such as 1,3-butadiene, isoprene, piperylene, 2,3-dimethyl-1,3-butadiene, 1,4-pentadiene, 1,7-hexadiene, and mixtures thereof. Ethylene copolymers preferably constitute at least about 90, more preferably 95 to 99 mole percent polymerized ethylene units. Ethylene, propylene, 1-butene, and 1-hexene are especially preferred.

The polymers can be prepared from the catalyst of this invention by solution polymerization, slurry polymerization, and gas phase polymerization technique using conventional equipment and contacting processes. However, the catalyst of this invention is particularly suitable in slurry polymerizations for the production of high melt index polymers in the absence of molecular weight modifiers, such as hydrogen. The slurry process is generally carried out in an inert diluent such as a paraffin, aromatic or cycloparaffin hydrocarbon. For predominantly ethylene polymers, a temperature of about 66 to 110°C is employed. Hydrogen or other molecular weight modifiers can be used, of course, if desired. Also conventional cocatalysts and adjuvants and activators can be utilized, if desired.

Example I

A. Catalyst Preparation: Aqueously titanated catalysts were prepared in two ways.

1. Aqueous Titanation of Catalyst A

Catalyst A was made by spray drying a silica hydrogel having 20 weight percent solids and containing an aqueous solution of chromium acetate sufficient to give 1 weight percent chromium in the final dried catalyst, said catalyst containing about 0.1 weight percent alumina. To 122 grams of Catalyst A was added 44 g Tyzor TE (DuPont's triethanolamine titanium chelate, 8.3 percent Ti in 150 ml of demineralized water). The resulting dry-appearing catalyst was bottled and labeled reference no. 1-4 for Table I and 1-23 for Table II (when activated, it contained 3 percent Ti, 1 percent Cr by weight).

2. Co-impregnation of Davison 952 Silica Gel with Aqueous Chromium (III) Acetate and Tyzor TE

Aqueous solutions containing the appropriate amounts of chromium acetate and Tyzor TE were prepared at the indicated temperature and diluted with demineralized water to volumes which would be nearly absorbed by the pore structure of weighed amounts of grade 952 silica gel. The solutions were placed in a large evaporating dish and the pre-weighed silica gel then added, resulting in deep green slurries which were then dried until free flowing by heating the evaporating dish on a large heating mantle. Catalysts prepared in this manner were blue-green in color, and when activated ranged from 0-6 percent Ti, and were about 0.8 percent Cr by weight.

Titanated Catalyst A Preparations

Table	Ref. ¹ No.	Wt. Cr (OAc) ₃ (g)	Tyzor TE ² (ml)	Temp. °C	Total Vol. Water (ml)	Wt. Silica gel (g)	Wt. ³ % Cr	Wt. ³ % Ti	Wt. ⁴ % Ti
III	1-3	5.51	0	R.T.	600	144	0.87	0	0
IV	1-4								
III	4-6	5.90	18.7	22	516	155	0.86	1.07	1
IV	5-8								
III	7-9	5.70	54.0	23	500	150	0.84	2.95	3
IV	9-11								
III	10-12	7.27	114	19	633	190	0.84	4.46	5
IV	12-15								
III	13-15	5.74	126	22	500	150	0.82	6.26	7
IV	16-18								

1. Catalyst for the indicated runs in the indicated Table III or Table IV.
2. Spec: Gravity = 1.06, 8.3% Ti by weight.
3. Determined by analysis.
4. Calculated values.

B. Catalyst Activations: Air activated catalysts were heated for five hours under fluidizing conditions (42 std. l./hr.) at temperatures ranging from 704° to 816°C. Reduction/reoxidation activated-catalysts were heated to 871°C in an atmosphere of 5% CO in N₂ under fluidizing conditions, held at this temperature for 4 hours, then reduced to the indicated reoxidation temperatures in N₂, and air oxidized for 2 hours.

C. Polymerization Reactions: Polymerizations were run in a two liter stirred, stainless steel autoclave reactor at 3.89 MPa ethylene using isobutane as a diluent. Reactions were run to 5,000 g/g productivity at temperatures ranging from 99° to 110°C. MI potentials were determined from polymer fluff at 190°C.

D. Results

1. Aqueous Titanation of Catalyst A

Table I contains data comparing the invention Catalyst A to the untitanated Catalyst A under standard air activation conditions. Both catalysts showed the usual increase in MI potential with both increased activation temperature, and increased polymerization temperature. The titanated catalyst however had considerably higher MI potentials under all conditions tested. Shear response was also higher in all cases for polymers prepared from the titanated catalysts. Titanation did not appear to affect activity under these activation and polymerization conditions.

Table I

Air Activated Catalyst A Aqueously Impregnated With 3% Ti as Tyzor TE

Reference Number	Wt. % Ti	Activation Temp., C	Polymerization Temp., C	MI ¹	HLMI MI	Induction Time (min)	Run Time (min.)	Productivity (g/g)	Color
5	3	704	107	0.43 (0.43)	75	14	77	4920	Orange
2	3	704	110	1.07 (1.12)	51	30	87	4800	Orange
3	3	816	107	0.74 (0.76)	67	39	72	4830	Green
4	3	816	110	1.55 (1.50)	49	23	83	5180	Green
5	0	704	107	0.25 (0.25)	77	33	67	5030	Yellow/Tan
6	0	704	110	0.67 (0.67)	52	31	83	5010	Yellow/Tan
7	0	816	107	0.48 (0.49)	68	30	57	4950	Green
8	0	816	110	1.15 (1.19)	50	33	64	4820	Green

¹Corr. to 5000 g/g prod.

Values in parentheses are uncorrected.

Table I (Continued)

Air Activated Catalyst A Aqueously Impregnated With 3% Ti as Tyzor TE

Reference Number	Pore Volume cm ³ /g	Surface Area m ² /g	Weight % Cr(VI)
1	1.51	290	1.04
2	1.51	290	1.04
3	1.45	263	0.58
4	1.45	263	0.58
5	1.77	308	1.07
6	1.77	308	1.07
7	1.71	282	0.77
8	1.71	282	0.77

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The titanated catalyst responded very well to reduction/reoxidation activation. Table II contains data describing results obtained from a variety of activation and polymerization conditions. All catalysts were CO reduced at 87°C for 4 hours, and reoxidized at temperatures ranging from 482 to 816°C. Polymerization reactions were run without hydrogen to 5,000 g/g productivity at temperatures ranging from 99 to 107°C. Under these experimental conditions, polymers were produced which ranged in melt index from 8.8 to 0.1. The maximum melt index potential was achieved when reoxidation occurred at 538°C. The MI potential of the reduction/ reoxidation activated catalyst dropped off sharply with increased reoxidation temperature (FIGURE 1).

All polymers produced by the titanated catalyst had unusually broad molecular weight distributions (indicated by high HLMI/MI ratio when compared to polymers made from Catalyst A.

Catalyst activity was somewhat improved by the presence of titanium. Catalyst samples reoxidized at 649°C and above had very short induction periods, and reaction times 1 to 5,000 g/g productivity, comparable to or shorter than those of the air activated catalyst A samples.

2. Aqueous Titanation of 952 Silica Gel

Table II

Reduction/Reoxidation Activated Catalyst A Aqueously
Impregnated with 3% Ti as Tyzor TE

Reference Number	Reoxidation Temp., C	Polymerization Temp., C	MI ¹	HMI MI	Induction Time (min)	Run Time (min.)	Productivity (g/g)	Color
1	482	99	1.42 (1.37)	98	10	79	5190	Green
2	482	102	2.41 (2.27)	88	10	89	5300	
3	482	104.5	4.74 (5.02)	68	10	130	4730	
4	482	107	6.71 (7.09)	58	10	123	4770	
5	538	99	2.76 (2.46)	92	39	140	5610	Green/Tan
6	538	102	3.4 (3.63)	82	10	80	5390	
7	538	104.5	5.8 (5.70)	65	10	120	5290	
8	538	107	8.8 (8.39)	61	70	120	5230	
9	593	102	0.74 (0.67)	102	49	89	5350	Green/Tan
10	593	104.5	0.87 (0.81)	104	10	106	5350	
11	593	107	1.62 (1.54)	79	21	90	5250	
12	649	102	0.79 (0.74)	96	0	50	5370	Green/Tan
13	649	104.5	1.29 (1.21)	87	0	55	5350	
14	649	107	1.53 (1.62)	83	10	70	4730	
15	704	102	0.23 (0.22)	131	0	70	5300	Yellow/Tan
16	704	104.5	0.31 (0.31)	100	3	90	5020	
17	704	107	0.76 (0.75)	73	15	60	5090	
18	760	102	0.12 (0.13)	153	10	65	4730	Yellow/Tan
19	760	104.5	0.23 (0.23)	131	10	49	4970	
20	760	107	0.59 (0.62)	75	10	58	4800	
21	816	102	0.12 (0.14)	135	14	74	4470	Green
22	816	104	0.26 (0.26)	110	10	75	5030	
23	816	107	0.57 (0.59)	77	10	59	4810	

¹Corrected to 5000 g/g productivity, values in parentheses are uncorrected.

²Values in parentheses are believed to be invalid and have not been redetermined.

Table II (Continued)

Reduction/Reoxidation Activated Catalyst A Aqueously
Impregnated with 3% Ti as Tyzor TE

Reference Number	Pore Volume cm ³ /g	Surface Area m ² /g	Wt. % ² Cr(VI)
1	1.42	255	0.30
2			
3			
4			
5	1.46	268	(0.07)
6			
7			
8			
9	1.44	282	(0.05)
10			
11			
12	1.19	280	0.63
13			
14			
15	1.45	282	0.83
16			
17	1.43	283	0.76
18			
19			
20			
21	1.43	265	0.65

¹Corrected to 5000 g/g productivity, values in parentheses are uncorrected.

²Values in parentheses are believed to be invalid and have not been redetermined.

Table III contains data illustrating the effects of titanium levels on MI potentials of air activated catalysts. FIGURE 2 shows that for a given Ti level, MI potentials generally increased with increased activation temperature. It appeared that about 2 percent, preferably 3 percent or more titanium was necessary to achieve substantial MI potential improvements. Titanium levels of 3 to 5 percent resulted in the highest MI potentials at all activation temperatures. FIGURE 3 shows that at lower activation temperatures the maximum MI potential is obtained at higher titanium levels. A catalyst containing 5.5 percent Ti activated at 649°C (1200°F) was superior in MI potential to the control catalyst activated at 760°C (1400°F).

Table III

Air Activated 952 Catalyst Aqueously Impregnated With $\text{Cr}(\text{OAc})_3$ and Tyzor TE

Reference Number	Wt. % Ti	Activation Temp. C	MI ¹	HMI MI	Induction Time (min)	Run Time (min.)	Productivity (g/g)	Color		Pore Volume cm ³ /g	Surface Area m ² /g	Wt. % Cr(VI)
1	0	649	0.14 (0.14)	81	48	83	4880	Orange	Orange	1.66	303	0.83
2	0	760	0.34 (0.32)	78	38	57	5380	Orange	Orange	1.61	322	0.81
3	0	871	0.45 (0.45)	89	20	47	5000	Tan	Tan	1.51	285	0.69
4	1.07	649	0.19 (0.18)	71	62	93	5150	Orange	Orange	1.54	271	0.76
5	1.07	760	0.30 (0.29)	78	34	63	5210	Orange	Orange	1.50	297	0.73
6	1.07	871	0.36 (0.33)	101	25	56	5390	Tan/Green	Tan/Green	1.41	262	0.59
7	2.95	649	0.27 (0.26)	74	62	125	5310	Orange	Orange	1.51	282	0.78
8	2.95	760	0.62 (0.58)	73	35	70	5420	Orange	Orange	1.47	300	0.70
9	2.95	871	0.73 (0.71)	74	41	75	5140	Tan/Yellow	Tan/Yellow	1.33	244	0.61
10	4.46	649	0.38 (0.38)	74	10	69	5040	Orange	Orange	1.43	298	0.73
11	4.46	760	0.63 (0.71)	74	10	71	4440	Orange	Orange	1.39	281	0.71
12	4.46	871	0.61 (0.56)	89	10	63	5460	Orange/Yellow	Orange/Yellow	1.27	243	0.61
13	6.26	649	0.26 (0.28)	78	12	91	4670	Orange	Orange	1.39	298	0.64
14	6.26	760	0.48 (0.50)	77	10	71	4740	Orange	Orange	1.37	286	0.60
15	6.26	871	0.66 (0.67)	83	15	66	4950	Orange	Orange	1.22	250	0.53

¹Corrected to 5000 g/g productivity, run at 107°C.

Values in parentheses are uncorrected.

The results of several reduction/reoxidation activations are in Table IV. In FIGURE 4, MI potentials are plotted as a function of reoxidation temperature for catalysts containing 0.0 to 6.5 percent Ti by weight. Again maximum MI potentials were achieved at 538°C reoxidation temperature, however, it did not appear that the MI potential dropped off as sharply with increased reoxidation temperature compared to the titanated finished Type A catalyst (compare FIGURES 1 and 4). FIGURE 5 more clearly shows the effect of titanium content on melt index. Increased titanium content dramatically increased MI potentials, MI's as high as 12 were obtained with a 6.5 percent Ti catalyst run at 104°C without hydrogen. All polymers made from the reduction/reoxidation activated catalysts had higher than usual shear response.

Table IV

Reduction/Reoxidation Activated Catalyst A Aqueously
Impregnated with Cr(OAc)₃ and Tyzor TE

5	Reference Number	Wt. % Ti	Reoxidation Temp. C	MI ²	HLMI MI	Induction Time (min)	Run Time (min.)	Productivity (g/g)	Color	Pore Volume cm ³ /g	Surface Area m ² /g	Wt. % Cr(VI)
	1	0	538	0.94 (0.93)	67	25	60	5010	Light Brown	1.61	302	0.34
	2	0	593	0.33 (0.33)	95	23	70	5050	Tan	-	-	-
	3	0	649	0.37 (0.37)	106	10	50	5040	Tan	-	-	-
10	4	0	704	0.22 (0.21)	118	13	54	5290	Tan	-	-	-
	5	1.07	538	1.6 (2.0)	65	12	58	4280	Tan	1.52	290	0.39
	6	1.07	593	0.75 (0.75)	86	11	55	5030	Tan	-	-	-
	7	1.07	649	0.56 (0.51)	103	10	46	5430	Tan/Orange	1.46	293	-
15	8	1.07	704	0.30 (0.29)	114	10	38	5210	Light Orange	1.38	296	-
	9	2.95	538	3.77 (4.27)	63	10	76	4410	Green/tan	1.43	280	0.25
	10	2.95	593	2.63 (2.59)	79	10	70	5070	Yellow/tan	1.42	285	-
	11	2.95	649	1.42 (1.26)	86	10	53	5640	Yellow	1.43	284	-
	12	4.46	538	5.6 (5.16)	68	10	120	5210	Green	1.31	273	0.20
	13	4.46	593	5.27 (5.18)	62	22	94	5080	Yellow/tan	-	-	-
20	14	4.46	649	1.88 (1.66)	97	10	54	5660	Green/tan	-	-	-
	15	4.46	704	1.96 (2.10)	87	13	87	4660	Yellow	-	-	-
	16	6.26	538	12.0 (15.3)	51	49	162	3920	Green/yellow	1.27	286	0.19
	17	6.26	593	7.35 (6.7)	63	10	135	5480	Yellow/green	-	-	-
25	18	6.26	649	2.34 (2.35)	82	70	153	5200	Yellow	1.26	273	-

¹ Determined by analysis.

² Corrected to 5000 g/g productivity. Reactor Temp. 104°C.

Values underlined were run at 107°C.

Values in parentheses are uncorrected.

Example II

A series of catalysts was prepared from a commercially obtained silica hydrogel containing 20 weight percent solids in the manner described below. In each instance, 100 ml of the hydrogel was admixed with sufficient aqueous chromium trioxide solution to provide 1 weight percent chromium based on the dry composite, a titanium compound, when employed, and 3 volume percent of a liquid surfactant based on the hydrogel, when used. Each mixture was then dried overnight, about 16 hours, in an air oven maintained at 130°C. The dry products of runs 1-5 were individually activated by calcination in a 46 mm diameter quartz tube under fluidizing conditions with dry air at 760°C for 5 hours. Each recovered sample was stored in a stoppered bottle in a dry atmosphere until ready for further use. The liquid surfactant (except for run 7) was a commercially available organosilicone-based nonionic material sold as L-5340 by the Union Carbide Corp., 270 Park Ave., New York, NY. The surfactant is believed to be a polysiloxane-polyoxyalkylene copolymer.

The nature of each catalyst is further shown below:

Catalyst 1; control, silica containing sufficient chromium compound to give 1 weight percent chromium in the final calcined catalyst with no surfactant or titanium being employed.

Catalyst 2; invention, silica made by adding triethanolamine titanate added to the hydrogel in an amount sufficient to give 1 weight percent titanium in the final calcined catalyst based on the weight of the dry composite with 3 percent surfactant as a pore preserving agent being employed. No reaction with the water was noted with the titanium compound.

Catalyst 3, invention, silica containing sufficient chromium compound to give 1 weight percent chromium, 3 volume percent surfactant added to the hydrogel, and titanium as triethanolamine titanate added to the hydrogel in an amount sufficient to give 4 weight percent titanium in the final catalyst based on the weight of the final calcined catalyst. No reaction of the titanium compound with the water was noted.

Catalyst 4, invention; silica containing sufficient chromium compound to give 1 weight percent chromium in the final catalyst, 3 volume percent surfactant added to the hydrogel, and triethanolamine titanate added to the hydrogel in an amount sufficient to give 6 weight percent titanium in the final catalyst based on the weight of the final

calcined catalyst. No reaction with the water was noted with the titanium compound.

Catalyst 5, control; silica containing sufficient chromium compound to give 1 weight percent chromium in the final calcined catalyst, no surfactant used, titanium tetraisopropoxide added to the hydrogel in an amount sufficient to give 4 weight percent titanium based on the weight of the final calcined catalyst. The titanium compound reacted (hydrolyzed) immediately with the water, precipitating titanium dioxide on the silica and container walls.

Catalyst 6, control; silica containing 0.8 weight percent chromium, based on the final calcined catalyst which was produced by impregnating commercially available silica (Davison 952 silica) with an aqueous solution of chromium (III) acetate and drying.

Catalyst 7, invention: To 715 g of a commercially available silica hydrogel containing 28 weight percent solids was added 300 ml of an aqueous solution containing 7.6 g of chromium III acetate, 96 ml of a commercially available nonionic surfactant, a polyethoxylated sorbitol monolaurate, sold by ICI United States Inc., Atlas Chemicals Div., Wilmington, Del., under the trademark Tween 20. The resulting slurry was dried overnight in a vacuum oven. The final calcined catalyst was calculated to contain about 0.8 weight percent Cr and about 4 weight percent Ti.

Catalysts 6 and 7 were individually activated in a fluidized bed by following the procedure detailed below: (a) Heat in 5/95 volume percent CO/nitrogen to 871°C and hold at that temperature for 4 hours. (b) Reduce temperature to 538°C in an atmosphere of 100 percent nitrogen. (c) Replace the nitrogen with dry air and hold in dry air at 538°C for 2 hours, then recover and store in a dry atmosphere until ready for use.

A sample of each activated catalyst was employed in ethylene particle form polymerization at 107°C, unless specified otherwise, using isobutane as diluent as known in the art. A normal reactor pressure of 550 psia (3.9 MPa) was used. Each run was conducted sufficiently long to produce about 5000 g polymer per g catalyst. Each product was recovered at the end of the run by flashing off diluent and ethylene and removing the polymer which was dried and weighed to determine the actual yield. The melt index (MI) and high load melt index (HLMI) was determined for each resin sample in accordance with ASTM Procedure D 1238-65T, Condition E and F, respectively. From the melt index values, the HLMI/MI ratios

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were calculated to obtain a measure of the molecular weight distribution of the polymer. Each MI value was corrected to a common productivity level of 5000 g polymer per g catalyst so that a valid comparison of the values could be made as is known in the art. The catalyst weights
5 employed and results obtained are given in Table V.

Table V

Ethylene Polymerization, 107°C, 3.9 MPa
Aqueous Titaniation Of Hydrogel

Run No.	Catalyst		Polymer Yield g	Productivity g polymer/g cat.	Melt Index	Percent		Remarks
	Wt. g	Wt. % Ti				Calculated Melt Index Improvement	HLMI MI	
1	0.0460	0	248	5390	0.34	(a)	90	control
2	.0740	2	356	4810	0.39	(b)	79	invention
3	.0920	4	405	4400	0.62	(b)	72	invention
4	.0715	6	352	4920	0.63	(b)	78	invention
5	.0930	4(c)	dead	-	-	-	-	control
6(d)	.0365	0	183	5010	0.94	-	67	control
7(d)	.0479	4	240	5010	5.8	(e)	65	invention

(a) A dash signifies no entry is needed.

(b) Based on melt index of control run 1 for runs 2-4.

(c) Based on prior experience, had this catalyst been active; the melt index of the polymer obtained therewith would be expected to be similar to that of control run 1.

(d) Reactor temperature was 104°C.

(e) Based on melt index of control run 6 for run 7.

The results presented in Table V in invention runs 2-4 show that triethanolamine titanate can be added to a silica hydrogel containing a water soluble chromium compound plus a nonionic surfactant, the mixture can be dried in an air oven and the product can be conventionally activated with dry air or sequentially in CO/N₂, then dry air, at an elevated temperature to produce active ethylene polymerization catalysts having enhanced melt index capability compared to control catalysts. The results suggest that a titanium level, calculated as the metal, of about 4 weight percent is sufficient to improve the melt index capability of silica-chromium oxide catalyst as exemplified in control run 1 by at least about 80 percent. A higher titanium level affords little improvement in melt index capability, a lower level, specifically 2 weight percent titanium, gives a catalyst having about a 15 percent improvement in melt index capability.

The poor results of control run 5 utilizing a catalyst containing titanium derived from a water sensitive titanium compound (titanium tetraisopropoxide) shows that titanation of silica hydrogels requires a hydrolysis-resistant titanium compound if an active polymerization catalyst is desired. Otherwise, the precipitated titania forms a mixture with the silica that at best is no better than silica alone as a component of the silica-chromium oxide catalyst.

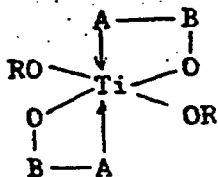
The fractional melt index polymers produced with invention catalysts 2-4 as prepared in this example are expected to be of value in blow molding, extrusion, etc. since the articles would have good environmental stress cracking resistance. Copolymerizing a minor amount of 1-butene or 1-hexene with the ethylene, e.g., about 10 mole percent, in the presence of the catalysts would yield fractional melt index copolymers having even better stress cracking resistance than the homopolymers.

Invention catalyst 7 demonstrates that relatively high melt index ethylene polymers can be produced when the catalyst is activated sequentially in a carbon monoxide ambient then an air ambient. About a five-fold increase (517 percent) in melt index capability over control catalyst 6 is shown. The results also demonstrate in run 7 that the nonionic surfactant employed is equivalent to the silicone based surfactant employed in runs 2-4, in producing active catalysts.



CLAIMS

1. A process for the preparation of silica-supported titanium-and chromium-containing olefin polymerisation catalysis, which comprises forming a silica hydrogel, converting the hydrogel to a xerogel, incorporating a chromium-containing compound into the silica gel before or after conversion of the hydrogel to said xerogel, and activating the chromium impregnated xerogel to form said catalyst, wherein said titanium is introduced into the catalyst by treating the silica hydrogel or the xerogel, before or after the incorporation therein of said chromium-containing compound, but before calcination thereof, with an aqueous solution of a hydrolysis resistant titanium compound.
2. A process according to claim 1, which comprises precipitating a silica hydrogel by adding an alkali metal silicate to an acid, washing the hydrogel, impregnating the washed hydrogel with an aqueous solution of a chromium compound comprising CrO_3 , or which is convertible to CrO_3 upon calcination, spray drying the chromium-containing hydrogel to form a chromium-containing xerogel and activating the chromium-containing xerogel to form the catalyst, the titanium compound being incorporated therein by treating either the chromium-containing hydrogel or the chromium-containing xerogel prior to activation with an aqueous solution of said hydrolysis resistant titanium compound.
3. A process according to claim 2 wherein the chromium compound is incorporated into the catalyst by treating the washed hydrogel with an aqueous solution of CrO_3 or chromium acetate.
4. A process according to claim 1, 2 or 3, wherein said hydrolysis resistant titanium compound is a titanium chelate having the formula





where R is an alkyl group containing from 1 to 4 carbon atoms, A is a functional group containing O or N, or is OH, and B is a divalent hydrocarbon chain of 2 or 3 carbon atoms which can have one or more alkyl groups of from 1 to 4 carbon atoms.

5. A method according to claim 4 where said hydrolysis resistant titanium compound is lactic acid titanium chelate, tetraoctylene glycol titanium chelate or triethanolamine titanate.
6. A process according to any one of claims 1 to 5 wherein the chromium- and titanium-containing xerogel is activated by reduction and reoxidation.
7. A process according to any one of claims 1 to 6 wherein the chromium- and titanium-containing xerogel is activated by heating in air at a temperature in the range 400 to 1100°C.
8. A process according to any one of claims 1 to 7 wherein the chromium-containing compound is added in an amount sufficient to provide from 0.5 to 4% chromium based on the final weight of the activated catalyst.
9. A process according to any one of claims 1 to 8 wherein the titanium compound is added in an amount sufficient to provide 2 - 6% titanium based on the final weight of the activated catalyst.
10. Process according to claim 2 or any one of claims 3 to 9 as dependent thereon wherein the titanium compound is incorporated into the hydrogel prior to conversion to said xerogel and wherein said hydrogel contains in addition a pore preserving agent selected from organic silicon compounds, oxygen-containing organic compounds, acids, and surfactants.
11. A process according to claim 10 wherein said pore preserving agent is added to the hydrogel after washing but before impregnation of the hydrogel with the titanium compound.
12. A process according to claim 10 or 11 wherein said pore preserving agent is a polysiloxane-polyoxyalkylene copolymer, a polyethoxylated sorbitol monolaurate or a polyethoxylated t-octylphenol.
13. A polymerisation process which comprises contacting at least one mono-1-olefin having 2 to 8 carbon atoms per molecule under polymerisation conditions with a catalyst prepared by a process claimed in any one of the preceding claims.

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14. A process according to claim 13 wherein said olefin comprises ethylene, propylene, 1-butene or 1-hexene.
15. A process according to claim 14 wherein said olefin is predominantly ethylene.
16. A process according to claim 15 wherein said polymerisation is carried out at a temperature in the range 66 to 110°C.
17. A process according to claims 13, 14, 15 or 16, wherein the process is carried out under slurry conditions.

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