CONVENTION

AUSTRALIA

Patents Act

628654

APPLICATION FOR A STANDARD PATENT

Idemitsu Kosan Co., Ltd.
1-1, Marunouchi 3-chome, Chiyoda-ku, Tokyo, JAPAN

hereby applies for the grant of a standard patent for an invention entitled:

PROCESS FOR PRODUCING STYRENE POLYMERS

which is described in the accompanying complete specification.

Details of basic application(s):-
256371/1989 JAPAN 29 September 1989

Address for Service:

PHILLIPS ORMONDE & FITZPATRICK
Patent and Trade Mark Attorneys
367 Collins Street
Melbourne 3000 AUSTRALIA

DATED this TWENTY FOURTH day of SEPTEMBER 1990

PHILLIPS ORMONDE & FITZPATRICK
Attorneys for:
Idemitsu Kosan Co., Ltd.

By:

David B Fitzpatrick

Our Ref : 190916
POF Code: 93170/47107

M 021397 240990

6010

AUSTRALIA

Patents Act

DECLARATION FOR A PATENT APPLICATION

▼ INSTRUCTIONS
(a) Insert "Convention" if applicable
(b) Insert FULL name(s) of applicant(s)

In support of the (a) convention application made by (b)

IDEMITSU KOSAN CO., LTD.

(c) Insert "of addition" if applicable
(d) Insert TITLE of invention

(hereinafter called "applicant~~(s)~~ for a patent (c) for an invention entitled (d)

PROCESS FOR PRODUCING STYRENE POLUMERS

(e) Insert FULL name(s) AND address(es) of declarant(s) (See headnote*)

I/~~We~~ (e) Kazuto Tominaga, Manager of Patent Department of Idemitsu Kosan Co., Ltd.: 1-1, Marunouchi 3-chome, Chiyoda-ku, Tokyo, Japan

do solemnly and sincerely declare as follows:

1. ~~I am/We are the applicant(s)~~.
   (or, in the case of an application by a body corporate)
1. I am/~~We are~~ authorized to make this declaration on behalf of the applicant~~(s)~~.
2. ~~I am/We are the actual inventor(s) of the invention~~.
   (or, where the applicant(s) is/are not the actual inventor(s))
2. (f) Masahiko Kuramoto: 216, Imazuasayama, Ichihara-shi, Chiba-ken, Japan

(f) Insert FULL name(s) AND address(es) of actual inventor(s)

(g) Recite how applicant(s) derive(s) title from actual inventor(s) (See headnote**)

is/~~are~~ the actual inventor~~(s)~~ of the invention and the facts upon which the applicant~~(s)~~ is/~~are~~ entitled to make the application are as follows:

(g) The applicant is the assignee of the invention from the said actual inventor.

(Note: Paragraphs 3 and 4 apply only to Convention applications)

(h) Insert country, filing date, and basic applicant(s) for the/or EACH basic application

3. The basic application~~(s)~~ for patent or similar protection on which the application is based is/~~are~~ identified by **country, filing date, and basic applicant~~(s)~~** as follows:

(h) Japan
29 September 1989
Idemitsu Kosan Co., Ltd.

4. The basic application~~(s)~~ referred to in paragraph 3 hereof was/~~were~~ the first application~~(s)~~ made in a Convention country in respect of the invention the subject of the application.

(k) Insert PLACE of signing

(l) Insert DATE of signing

(m) Signature(s) of declarant(s) Idemitsu Kosan Co., Ltd.

Note: No legalization or other witness required

Declared at (k) Tokyo, Japan

Dated (l) 30 July, 1990

(m) [signature]

Kazuto Tominaga/ Manager of Patent Department

To: The Commissioner of Patents

P18/7/78

PHILLIPS ORMONDE & FITZPATRICK
Patent and Trade Mark Attorneys
367 Collins Street
Melbourne, Australia

(12) PATENT ABRIDGMENT (11) Document No. AU-B-63123/90
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 628654

(54) Title
PROCESS FOR PRODUCING STYRENE POLYMERS

International Patent Classification(s)
(51)[5] **C08F 012/08** **C08F 004/642**

(21) Application No. : **63123/90** (22) Application Date : **24.09.90**

(30) Priority Data

(31) Number	(32) Date	(33) Country
1-256371	**29.09.89**	**JP JAPAN**

(43) Publication Date : **11.04.91**

(44) Publication Date of Accepted Application : **17.09.92**

(71) Applicant(s)
IDEMITSU KOSAN CO., LTD.

(72) Inventor(s)
MASAHIKO KURAMOTO

(74) Attorney or Agent
PHILLIPS ORMONDE & FITZPATRICK , 367 Collins Street, MELBOURNE VIC 3000

(57) Claim

1. A process for producing styrene polymers having a syndiotactic configuration with a wide molecular weight distribution and a proportion of racemic diad of at least 75%, which process comprises polymerizing styrene monomers in the presence of a catalyst comprising (a) not less than two kinds of titanium compounds such that each titanium compound is present in an amount of not less than 1 molar percent of component (a); and (b) alkylaluminoxane.

5. The process according to any one of claims 1 to 4 wherein, of not less than two kinds of titanium compounds, at least one titanium compound is titanium compound represented by the general formula:

$$TiRXYZ \qquad \ldots (III)$$

wherein, R represents a cyclopentadienyl group, a substituted cyclopentadienyl group or an idenyl group, X, Y and Z independently represent a hydrogen, an alkyl group having 1 to 12 carbon atoms, an alkoxyl group having 1 to 12 carbon atoms, an aryl group having 6 to 20 carbon atoms, an aryloxy group having 6 to 20 carbon atoms, an arylalkyl group having 6 to 20 carbon atoms or a halogen.

.../2

combinations of pentamethylcyclopentadienyltitanium trimethoxide and cyclopentadienyltitanium trimethoxide; pentamethylcyclopentadienyltitanium trimethoxide and cyclopentadienyltitanium triisopropoxide; pentamethylcyclopentadienyltitanium triisoproposixe and cyclopentadienyltitanium trimethoxide; pentamethylcyclopentadienyltitanium triphenoxide and cyclopentadienyltitanium triphenoxide; pentamethylcyclopentadienyltitanium trimethoxide and 1,3-dimethylcyclopentadienyltitanium trimethoxide; pentamethylcyclopentadienyltitanium trimethoxide and 1,3,4-trimethylcyclopentadienyltitanium trimethoxide; pentamethylcyclopentadienyltitanium trichloride and cyclopentadienyltitanium trichloride; or pentamethylcyclopentadienyltrimethyltitanium and cyclopentadienyltrimethyltitanium.

AUSTRALIA

Patents Act

628654

COMPLETE SPECIFICATION
(ORIGINAL)

Class Int. Class

Application Number:
Lodged:

Complete Specification Lodged:
Accepted:
Published:

Priority

Related Art:

Applicant(s):

Idemitsu Kosan Co., Ltd.
1-1, Marunouchi 3-chome, Chiyoda-ku, Tokyo, JAPAN

Address for Service is:

PHILLIPS ORMONDE & FITZPATRICK
Patent and Trade Mark Attorneys
367 Collins Street
Melbourne 3000 AUSTRALIA

Complete Specification for the invention entitled:

PROCESS FOR PRODUCING STYRENE POLYMERS

Our Ref : 190916
POF Code: 93170/47107

The following statement is a full description of this invention, including the best method of performing it known to applicant(s):

6006

PROCESS FOR PRODUCING STYRENE POLYMERS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a process for producing styrene polymers, more particulary to a process for producing styrene polymers having a high degree of syndiotactic configuration with a wide molecular weight distribution, by a polymerization reaction using specific catalysts in a comparatively simple step.

2. Description of the Related Arts

Styrene polymers have heretofore been widely used as materials of various moldings. Especially, styrene polymers having a syndiotactic configuration are excellent in physical properties such as heat resistance and water resistance, so utilizations of said polymers have attracted attention.

As the process for producing such styrene polymers having a syndiotactic configuration, a process for polymerizing with the use of catalysts containing titanium compound and alkylaluminoxane as main components (Japanese Patent Application Laid-Open No. 187708/1987) has been found. However, though the styrene polymer having a syndiotactic configuration produced according to said process have a high syndiotacticity, its molecular weight distribution was narrow such as weight average molecular weight (Mw)/number average molecular weight (Mn) = 1.5 to 3.0. As for styrene polymers having a narrow molecular weight distribution thus obtained, there has been no problem in injection molding, but there

have been problems such as draw down or a large neck-in, in hollow molding, and sheet and film molding.

The present inventors have studied earnestly to produce styrene polymers which are suitable for hollow molding, sheet and film molding, and have a wide molecular weight distribution and a high syndiotacticity. As the result, it has been found that the object can be attained by polymerization reaction with the use of catalysts containing not less than two kinds of titanium compounds and alkylaluminoxane. The present invention has been accomplished according to these knowledges.

SUMMARY OF THE INVENTION

The present invention is to provide a process for producing styrene polymers having a high degree of syndiotactic configuration with a wide molecular weight distribution, which process comprises using a catalyst of (a) not less than two kinds of titanium compounds and (b) alkylaluminoxane, in a process for producing styrene polymers by polymerizing styrene monomer.

PREFERRED EMBODIMENTS OF THE INVENTION

The styrene monomers to be used as materials of the present invention are not critical and various ones can be used depending on the properties and applications required for polymers to be produced. Specifically, styrene; alkylstyrenes such as p-methylstyrene, m-methylstyrene, o-methylstyrene, 2,4-dimethylstyrene, 2,5-dimethylstyrene, 3,4-dimethylstyrene, 3,5-dimethylstyrene, p-ethylstyrene, m-ethylstyrene; p-tert-butylstyrene, and p-phenylstyrene;

halogenated styrenes such as p-chlorostyrene, m-chlorostyrene, o-chlorostyrene, p-bromostyrene, m-bromostyrene, o-bromostyrene, p-fluorostyrene, m-fluorostyrene, o-fluorostyrene, and o-methyl-p-fluorostyrene; alkoxystyrenes such as p-methoxystyrene, m-methoxystyrene, o-methoxystyrene, p-ethoxystyrene, m-ethoxystyrene, and o-ethoxystyrene; carboxymethylstyrenes such as p-carboxymethylstyrene, m-carboxymethylstyrene, and o-carboxymethylstyrene; alkyletherstyrenes such as p-vinylbenzylpropylether; polycyclic vinyl compounds such as vinylnaphthalene, vinylantracene, vinylbiphenyl can be mentioned.

They may be used singly or in the state of forming a copolymer using two or more kinds. In addition, in producing styrene copolymers, if necessary, with the above styrene monomers, olefin monomers such as ethylene, propylene, 1-butene, 1-hexene, 1-octene; diene monomers such as butadiene, isoprene; cyclic diene monomers; polar vinyl monomers such as methyl methacrylate, maleic anhydride and acrylonitrile can be used.

In the process of the present invention, both (a) not less than two kinds of titanium compounds and (b) alkylaluminoxane are used as catalyst.

Therein as (a) not less than two kinds of titanium compounds (hereinafter referred to as component (a)), two or more kinds of various compounds containing titanium may be selected and used appropriately without specified limitation.

For example, at least two compounds selected from the

group consisting of titanium compounds and titanium chelate compounds represented by the general formula:

$$TiR^1_aR^2_bR^3_cR^4_{4-(a+b+c)} \quad \ldots (I)$$

or

$$TiR^1_dR^2_eR^3_{3-(d+e)} \quad \ldots (II)$$

(wherein R^1, R^2, R^3 and R^4 are each a hydrogen atom, an alkyl group having 1 to 20 carbon atoms, an alkoxyl group having 1 to 20 carbon atoms, an aryl group having 6 to 20 carbon atoms, an alkylaryl group and arylalkyl group, an acyloxy group having 1 to 20 carbon atoms, a cyclopentadienyl group, a substituted cycropentadienyl group, an indenyl group or a halogen atom; a, b and c are each an integer of 0 to 4; and d and e are each an integer of 0 to 3) may be used in combination.

R^1, R^2, R^3 and R^4 in the general formula (I) or (II) are each a hydrogen atom, alkyl group having 1 to 20 carbon atoms (preferably ~~specifically~~, a methyl group, an ethyl group, a propyl group, a butyl group, an amyl group, an isoamyl group, an isobutyl group, an octyl group, 2-ethylhexyl group and the like), an alkoxyl group having 1 to 20 carbon atoms (preferably ~~specifically~~, a methoxyl group, an ethoxyl group, a propoxyl group, a butoxyl group, an amyloxy group, a hexyloxy group, a phenoxyl group, 2-ethylhexyloxy group and the like), an aryl group having 6 to 20 carbon atoms, an alkylaryl group and an arylalkyl group, group (preferably ~~specifically~~, a phenyl group, a tolyl group, a xylyl group, a benzyl group and the like), an acyloxy group having 1 to 20 carbon atoms (preferably ~~specifically~~, a heptadecylcarbonyloxy group and the like), a cyclopentadienyl

group, a substituted cyclopentadienyl group (~~specifically~~ preferably, a methylcyclopentadienyl group, 1,2-dimethylcyclopentadienyl group, pentamethylcyclopentadienyl group and the like), an indenyl group or a halogen atom (chlorine, bromine, iodine and fluorine). There R^1, R^2, R^3 and R^4 may be identical or different.

More preferred titanium compounds include titanium compound represented by the general formula:

$$TiRXYZ \qquad \ldots (III)$$

wherein, R represents a cyclopentadienyl group, a substituted cyclopentadienyl group or an indenyl group, X, Y and Z independently represent a hydrogen, an alkyl group having 1 to 12 carbon atoms, an alkoxyl group having 1 to 12 carbon atoms, an aryl group having 6 to 20 carbon atoms, an aryloxy group having 6 to 20 carbon atoms, an arylalkyl group having 6 to 20 carbon atoms or a halogen. Of not less than two kinds of titanium compounds to be used, at least one kind selected from the above is preferably used. Further, not less than two kinds are preferably selected from these compounds.

The substituted cyclopentadienyl group represented by R in the above formula is, for example, a cyclopentadienyl group substituted by at least one of an alkyl group having 1 to 6 carbon atoms, more ~~specifically~~ preferably, methylcyclopentadienyl group, 1,2-dimethylcyclopentadienyl group, 1,3-dimethylcyclopentadienyl group, 1,2,4-trimethylcyclopentadienyl group, pentamethylcyclopentadienyl group, and the like.

In addition, X, Y and Z independently represent a hydrogen, an alkyl group having 1 to 12 carbon atoms (preferably, a methyl group, an ethyl group, a propyl group, n-butyl group, an isobutyl group, an amyl group, an isoamyl group, an octyl group, 2-ethylhexyl group and the like), an alkoxyl group having 1 to 12 carbon atoms (preferably, a methoxyl group, an ethoxyl group, a propoxyl group, a butoxyl group, an amyloxy group, hexyloxy group, an octyloxy group, 2-ethylhexyloxy group and the like), an aryl group having 6 to 20 carbon atoms (preferably, a phenyl group, naphthyl group and the like), an aryloxy group having 6 to 20 carbon atoms (preferably, a phenoxyl group and the like), an arylalkyl group having 6 to 20 carbon atoms (preferably, a benzyl group) or a halogen (preferably, chlorine, bromine, iodine or fluorine).

Specific examples of titanium compounds represented by the general formula (III) include

cyclopentadienyltrimethyltitanium,

cyclopentadienyltriethyltitanium,

cyclopentadienyltripropyltitanium,

cyclopentadienyltributyltitanium,

methylcyclopentadienyltrimethyltitanium,

1,2-dimethylcyclopentadienyltrimethyltitanium,

1,2,4-trimethylcyclopentadienyltrimethyltitanium,

pentamethylcyclopentadienyltrimethyltitanium,

pentamethylcyclopentadienyltriethyltitanium,

pentamethylcyclopentadienyltripropyltitanium,

pentamethylcyclopentadienyltributyltitanium,

cyclopentadienylmethyltitanium dichloride,
cyclopentadienylethyltitanium dichloride,
pentamethylcyclopentadienylmethyltitanium dichloride,
pentamethylcyclopentadienylethyltitanium dichloride,
cyclopentadienyldimethyltitanium monochloride,
cyclopentadienyldiethyltitanium monochloride,
cyclopentadienyltitanium trimethoxide,
cyclopentadienyltitanium triethoxide,
cyclopentadienyltitanium tripropoxide,
cyclopentadienyltitanium triphenoxide,
1,3-dimethylcylclopentadienyltitanium trimethoxide,
1,3,4-trimethylcylclopentadienyltitanium trimethoxide,
pentamethylcyclopentadienyltitanium trimethoxide,
pentamethylcyclopentadienyltitanium triethoxide,
pentamethylcyclopentadienyltitanium tripropoxide,
pentamethylcyclopentadienyltitanium tributoxide,
pentamethylcyclopentadienyltitanium triphenoxide,
cyclopentadienyltitanium trichloride,
pentamethylcyclopentadienyltitanium trichloride,
cyclopentadienylmethoxytitanium dichloride,
cyclopentadienyldimethoxytitanium chloride,
pentamethylcyclopentadienylmethoxytitanium dichloride,
cyclopentadienyltribenzyltitanium,
pentamethylcyclopentadienylmethyldiethoxytitanium,
indenyltitanium trichloride, indenyltitanium trimethoxide,
indenyltitanium triethoxide, indenyltrimethyltitanium,
indenyltribenzyltitanium, and the like.

Of these titanium compounds, a compound containing no

halogen atoms is preferred and a titanium compound having at least one unsaturated π electron type ligand is particularly preferred.

As component (a) of the catalyst of the present invention, not less than two kinds of titanium compounds as described above are used in combination.

In combining not less than two kinds, titanium compounds suitable for producing high-molecular polymers, and titanium compounds suitable for producing low-molecular polymers are preferably used in combination.

Various combination may be applied, for example, titanium compounds suitable for producing high-molecular polymers include a cyclopentadienyl group, in which R in the general formula (III) is substituted by 5 alkyl groups having 1 to 6 carbon atoms, ~~specifically~~ preferably pentalkylcyclopentadienyl group such as pentamethylcyclopentadienyl. On the other hand, titanium compounds suitable for producing include cyclopentadienyl group in which R in the general formula (III) is unsubstituted cyclopentadienyl group or cyclopentadienyl group substituted by 1 to 4 alkyl groups having 1 to 6 carbon atoms. Specifically, combinations of

pentamethylcyclopentadienyltitanium trimethoxide and cyclopentadienyltitanium trimethoxide;

pentamethylcyclopentadienyltitanium trimethoxide and cyclopentadienyltitanium triisopropoxide;

pentamethylcyclopentadienyltitanium triisopropoxide and cyclopentadienyltitanium trimethoxide;

pentamethylcyclopentadienyltitanium triphenoxide and

cyclopentadienyltitanium triphenoxide; pentamethylcyclopentadienyltitanium trimethoxide and 1,3-dimethylcyclopentadienyltitanium trimethoxide; pentamethylcyclopentadienyltitanium trimethoxide and 1,3,4-trimethylcyclopentadienyltitanium trimethoxide; pentamethylcyclopentadienyltitanium trichloride and cyclopentadienyltitanium trichloride; or pentamethylcyclopentadienyltrimethyltitanium and cyclopentadienyltrimethyltitanium can be mentioned.

Further, a compound represented by the general formula (I) may be used with a compound represented by the general formula (III), provided that the compound represented by the general formula (III) is not also of general formula (I). For example, combinations of cyclopentadienyltitanium trichloride and tetraethoxytitanium; pentamethylcyclopentadienyltitanium trichloride and tetraethoxytitanium; pentamethylcyclopentadienyltitanium trimethoxide and tetraethoxytitanium; cyclopentadienyltitanium trichloride and tetrabenzyltitanium; or cyclopentadienyltitanium triethoxide and tetraethoxytitanium can be mentioned.

By varying these combinations, molecular weight or molecular weight distribution of the resulting styrene polymers can be controlled in the desired range.

As described above, in the present invention, combinations of the titanium compounds are various and not critical. However, those which react each other to be a kind of titanium compound when mixed with other titanium compounds are not preferably generally, though they can be used as

catalysts for polymerization by controlling the condition so that such reaction is not completed.

In addition, the proportion of not less than two kinds of titanium compounds is not critical and may be determined depending on the desired molecular weight and molecular weight distribution.

As catalyst of the present invention, (b) alkylaluminoxane (hereinafter referred to as component (b)) is used with component (a). There, alkylaluminoxane is a condensation product ~~(contact product)~~ of condensing agent (for example, water) and various alkylaluminum compounds.

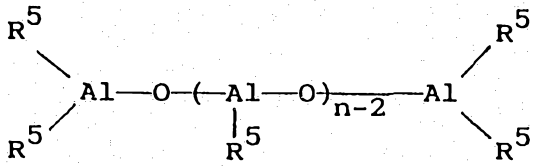
As alkylaluminum compounds used to obtain alkylaluminoxane, the compound represented by the general formula:

$$AlR^5_3 \qquad \ldots (IV)$$

(wherein, R^5 is an alkyl group having 1 to 8 carbon atoms), specifically, trimethylaluminum, triethylaluminum, triisobutylaluminum and the like can be mentioned, and trimethylaluminum is most preferable.

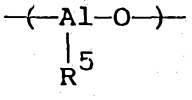
A typical example of the condensing agent to be reacted with the above alkylaluminum compound is water. In addition, and compounds can be used as long as they undergo a condensation reaction with alkylaluminum compounds.

As alkylaluminoxane as component (b), chain alkylaluminoxane represented by the following general formula:



...(V)

(wherein n represents an integer of 2 to 50 and R^5 is defined as above) or cyclic alkylaluminoxane (degree of polymerization 2 to 52) having a recurring unit represented by the following general formula:



... (V')

In general, the ~~contact~~ condensation product of the alkylaluminum compound (e.g., trialkylaluminum) and water contains aforementioned chain alkylaluminoxane and cyclic alkylaluminoxane, unreacted alkylaluminum compound (e.g., trialkylaluminum), various mixtures of condensates and further a molecule resulting from complex association ~~in a complicated manner~~ of the above mixture, the type of which varies depending on contacting conditions of alkylaluminum compound are water.

Suitable examples of the above alkylaluminoxane are those in which the area of the high magnetic field component in the methyl proton signal region due to the aluminum-methyl group ($Al-CH_3$) bond as observed by the proton nuclear magnetic resonance method is not more than 50%. That is, in a proton nuclear magnetic resonance (^1H-NMR) spectral analysis of the above contact product in toluene solvent at room temperature, the methyl proton signal due to $Al-CH_3$ is observed in the region of 1.0 to -0.5 ppm (tetramethylsilane (TMS) standard). Since the proton signal of TMS (0 ppm) is

in the region of the methyl proton signal due to Al-CH_3, the methyl proton signal due to Al-CH_3 is measured with 2.35 ppm methyl proton signal of TMS standard. The methyl proton signal is divided into two components: the high magnetic field component in the -0.1 to -0.5 ppm region and the other magnetic field component in the 1.0 to -0.1 ppm region. In alkylaluminoxane preferably used as component (b), the area of the high magnetic field component is not more than 50%, preferably 45 to 5% of the total signal area.

The reaction of the alkylaluminum compound and water is not critical and can be carried out according to the well known methods. For example, (1) a method in which alkylaluminum compound is dissolved in an organic solvent and then contacted with water, (2) a method in which alkylaluminum compound is first added at the time of polymerization and then water is added, and (3) a method in which alkylaluminum compound is reacted with the water of crystallization contained metal salts and the like, or water absorbed in inorganic or organic materials are mentioned.

In the present invention, the catalyst composed of component (a) and (b) may be used, and if desired, in addition to the above catalyst, other catalytic components can be added. As other catalytic components, organic aluminum compound can be mentioned and specifically those represented by the general formula:

$$AlR^6_3 \qquad \ldots (VI)$$

wherein, R^6 is a hydrogen atom or an alkyl group having 1 to 10 carbon atoms. In the formula, an alkyl group having 1 to

10 carbon atoms represented by R^6 includes a methyl group, an ethyl group, a propyl group, an isopropyl group, a butyl group, an isobutyl group, t-butyl group, a pentyl group, a hexyl group, a pentyl group, an octyl group and the like. R^6 may be identical or different.

As such organic aluminum compounds, specifically triisobutylaluminum, and diisobutylaluminum monohydride are suitable.

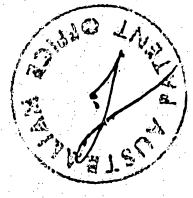
In the present invention, the ratio of amount of component (a) and (b) varies depending on the kind thereof, the kind of styrene monomer, reaction condition, molecular weight or molecular weight distribution of the desired styrene polymer, and can not be decided definitely, but usually a ratio of titanium contained in component (a) and aluminum contained in component (b), i.e. aluminum/titanium (molar ratio), is 1 to 10^6, preferably 10 to 10^5. However, when other organic aluminum compound is used as described above, it is preferably added that the total amount of aluminum contained in it and aluminum of component (b) should be in the above range.

The molar ratio of one titanium compound contained in component (a) and the other titanium compound contained in component (a) is 1 : 99, preferably 10 : 90.

~~In the present invention, the mixing method of~~ catalysts is not critical, for example, the method in which not less than two kinds of titanium compounds of component (a) are previously mixed and then contacted with component ~~(b), and if desired, with organic aluminum compound, and the~~

Where component (a) comprises more than 2 titanium compounds, each titanium compound is present in an amount of at least 1, preferably 10, molar percent of component (a).

In the present invention, the mixing method of catalysts is not critical, for example, the method in which not less than two kinds of titanium compounds of component (a) are previously mixed and then contacted with component (b), and if desired, with organic aluminum compound, and the



method in which component (b), and if desired, organic aluminum compound is contacted with each of not less than two kinds of titanium compounds of component (a) and then mixed, can be applied. The mixing of the catalytic components is usually carried out at the temperature of 0 to 100°C.

In the present invention, polymerization or copolymerization of the beforementioned styrene monomer may be carried out in the presence of the above catalyst. As polymerization method, conventional method, for example, bulk polymerization, solution polymerization using solvents such as an aliphatic hydrocarbon such as pentane, hexane and heptane; an alicyclic hydrocarbon such as cyclohexane, or an aromatic hydrocarbon such as benzene, toluene and xylene, or slurry polymerization and the like can be applied. Any methods may be applied, but bulk polymerization is especially excellent in productivity. In addition, batch polymerization and continuous polymerization may be applied.

In the above polymerization, reaction temperature is not particularly limited, but is usually 0 to 100°C, preferably 20 to 80°C. In batch polymerization, reaction time is 10 minutes to 20 hours, preferably 0.5 to 5 hours.

The amount of catalyst used to the styrene monomer as material is not particularly limited, but preferably 0.001 to 1 mole per one liter of the styrene monomer. A ratio of alkylaluminoxane and the transition metal compound, in terms of the ratio of aluminum and titanium, i.e. aluminum/titanium (molar ratio), is 1 to 10^6, and preferably 10 to 10^4.

After polymerization, if necessary, the resulting

polymer is subjected to post-treatment, a styrene polymer having a high purity can be obtained in high yield.

Styrene polymers thus obtained are those having syndiotactic configuration, especially high syndiotacticity. The styrene-based polymer having a syndiotactic configuration means that the polymer has a stereostructure with a configuration that is syndiotactic, i.e., the stereostructure in which phenyl groups or substituted phenyl groups as side chains are located alternately at opposite directions relative to the main chain consisting of carbon-carbon bonds. The tacticity is quantitatively determined by the nuclear magnetic resonance method using carbon isotope (^{13}C-NMR method). The tacticity as determined by the ^{13}C-NMR method can be indicated in terms of proportions of structural units continuously connected to each other, i.e., a diad in which two structural units are connected to each other, a triad in which three structural units are connected to each other, or pentad in which five structural units are connected to each other. Styrene-based polymers having syndiotactic configuration of the present invention include such a syndiotacticity that the proportion of racemic diad is at least 75% and preferably at least 85%, or the proportion of racemic pentad is at least 30% and preferably at least 50%.

Further, styrene polymers obtained in the present invention have a wide molecular weight distribution, that is, weight average molecular weight (Mw)/number average molecular weight (Mn) such as in the range of 3 to 100, preferably 4 to 50, and are styrene polymers having a syndiotactic

configuration with a wide molecular weight distribution as compared with conventional styrene polymers.

The number average molecular weight of styrene polymer produced by the process of the present invention is not critical and usually 1,000 to 5,000,000 preferably 5,000 to 4,000,000.

As described above, according to the process of the present invention, styrene polymers having syndiotactic configuration of especially high tacticity with a wide molecular weight distribution can be produced by a simple process. Such styrene polymers are excellent in physical properties such as heat resistance because of high syndiotacticity, have a wide molecular weight distribution and can be used suitably for hollow molding, sheet and film molding.

Accordingly, styrene polymers obtained in the process of the present invention are effectively used as materials of various moldings including hollow molding, sheet molding, film molding and the like as well as injection molding.

The present invention will be described in greater detail by referring to the following Examples and Comparative Examples.

Example 1

Into a 500 ml glass container with a stirrer, 200 ml of styrene was placed, heated to 70°C, and then 4 mmol of methylaluminoxane was added as aluminum atom, and then a mixed solution of 0.005 mmol of cyclopentadienyltitanium trimethoxide and 0.05 mmol of pentamethylcyclopentadienyl-

titanium trimethoxide was added, and polymerization was carried out at 70°C for 30 minutes. Then, the reaction was stopped with methanol, and the mixture was deashed with hydrochloric acid-methanol and was washed with methanol, dried to obtain 6.15 g of polymer. The weight average molecular weight (Mw) of the polymer was 870,000, Mw/Mn was 24.60.

Examples 2 to 5 and Comparative Example 1

The same procedure was repeated as in Example 1 except that catalytic component and reaction condition in Example 1 were changed to as shown in Table 1.

Table 1

No.	Catalytic Component (mmol)*1					Polymerization Condition		Polymer Formed		
	$CpTi(OR)_3$		$Cp^*Ti(OCH_3)_3$	MAO	TIBA	Temperature (°C)	Time (min.)	Yield (g)	Mw	Mw/Mn
Example 1	0.005	($R:CH_3$)	0.005	4	—	70	30	6.15	870,000	24.60
Example 2	0.0075	($R:CH_3$)	0.025	4	—	70	30	2.28	363,000	21.83
Example 3	0.01	($R:CH_3$)	0.01	4	—	70	30	11.26	595,000	12.07
Example 4	0.01	($R:i\text{-}C_3H_7$)	0.01	4	—	70	30	19.00	952,000	12.12
Example 5	0.01	($R:CH_3$)	0.01	2	2	70	30	7.07	453,000	18.85
Comparative Example 1	—	—	0.01	4	—	70	30	15.28	1,069,000	2.41

*1 ..... shown in millimoles of titanium or aluminum contained.

$CpTi(OR)_3$ ..... Cyclopentadienyltitanium trialkoxide

$Cp^*Ti(OCH_3)_3$ ... Pentamethylcyclopentadienyltitanium trimethoxide

MAO ..... Methylaluminoxane

TIBA ..... Triisobutylaluminum

Example 6

Into a 500 ml glass container with a stirrer, 200 ml of styrene was placed, and heated to 70°C, then a mixed solution of 2 mmol of methylaluminoxane as aluminum atom and 0.01 mmol of cyclopentadienyltitanium trimethoxide and a mixed solution of 2 mmol of methylaluminoxane as aluminum atom and 0.01 mmol of pentamethylcyclopentadienyltitanium trimethoxide were added, and polymerization was carried out at 70°C for 2 hours. Then, the reaction was stopped with methanol, the mixture was deashed with hydrochloric acid-methanol and was washed with methanol, dried to obtain 11.06 g of polymer. The weight average molecular weight (Mw) was 957,000, Mw/Mn was 5.62.

Example 7

Into a 500 ml glass container with a stirrer, 100 ml of toluene was placed, and heated to 50°C, then 7.5 mmol of methylaluminoxane was added as aluminum atom, and then 0.0125 mm of a mixed solution (1:1) of cyclopentadienyltitanium trichloride and tetraethoxytitanium was added, and polymerization was carried out at 50°C for 1 hour. Then, the reaction was stopped with methanol, and the mixture was deashed with hydrochloric acid-methanol, washed with methanol, and dried to obtain 0.42 g of polymer. The weight average molecular weight (Mw) was 96,500, Mw/Mn was 5.14.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A process for producing styrene polymers having a syndiotactic configuration with a wide molecular weight distribution and a proportion of racemic diad of at least 75%, which process comprises polymerizing styrene monomers in the presence of a catalyst comprising (a) not less than two kinds of titanium compounds such that each titanium compound is present in an amount of not less than 1 molar percent of component (a); and (b) alkylaluminoxane.

2. The process according to claim 1 wherein each titanium compound in component (a) is present in an amount of at least 10 molar percent of component (a).

3. The process according to either claim 1 or 2, wherein weight average molecular weight/number average molecular weight of styrene polymer is in the range of 3 to 100.

4. The process according to any one of claims 1 to 3 wherein, of not less than two kinds of titanium compounds, at least one titanium compound is that having one unsaturated π electron type ligand.

5. The process according to any one of claims 1 to 4 wherein, of not less than two kinds of titanium compounds, at least one titanium compound is titanium compound represented by the general formula:

$$TiRXYZ \qquad \ldots (III)$$

wherein, R represents a cyclopentadienyl group, a substituted

cyclopentadienyl group or an idenyl group, X, Y and Z independently represent a hydrogen, an alkyl group having 1 to 12 carbon atoms, an alkoxyl group having 1 to 12 carbon atoms, an aryl group having 6 to 20 carbon atoms, an aryloxy group having 6 to 20 carbon atoms, an arylalkyl group having 6 to 20 carbon atoms or a halogen.

6. The process according to any one of claims 1 to 5, wherein (a) not less than two kinds of titanium compounds are combinations of pentamethylcyclopentadienyltitanium trimethoxide and cyclopentadienyltitanium trimethoxide; pentamethylcyclopentadienyltitanium trimethoxide and cyclopentadienyltitanium triisopropoxide; pentamethylcyclopentadienyltitanium triisoproposixe and cyclopentadienyltitanium trimethoxide; pentamethylcyclopentadienyltitanium triphenoxide and cyclopentadienyltitanium triphenoxide; pentamethylcyclopentadienyltitanium trimethoxide and 1,3-dimethylcyclopentadienyltitanium trimethoxide; pentamethylcyclopentadienyltitanium trimethoxide and 1,3,4-trimethylcyclopentadienyltitanium trimethoxide; pentamethylcyclopentadienyltitanium trichloride and cyclopentadienyltitanium trichloride; or pentamethylcyclopentadienyltrimethyltitanium and cyclopentadienyltrimethyltitanium.

7. The process according to any one of claims 1 to 5, wherein (a) not less than two kinds of titanium compounds are combinations of cyclopentadienyltitanium trichloride and tetraethoxytitanium; pentamethylcyclopentadienyltitanium

trichloride and tetraethoxytitanium; pentamethylcyclopentadienyltitanium trimethoxide and tetraethoxytitanium; cyclopentadienyltitanium trichloride and tetrabenzyltitanium; or cyclopentadienyltitanium triethoxide and tetraethoxytitanium.

8. A process for producing styrene polymers substantially as hereinbefore described with reference to any one of Examples 1 to 7.

DATED: 17 July 1992
PHILLIPS ORMONDE & FITZPATRICK
Patent Attorneys For:
IDEMITSU KOSAN CO LTD

David B Fitzpatrick

(3181h)