

## DESCRIPTION

### HOLE TRANSPORTING MATERIALS

#### Field of the Invention

The present invention relates to hole  
5 transporting materials which are excellent in film-forming  
property, flexibility, optoelectronic function and the  
like.

The hole transporting materials of the present  
invention are useful as an organic hole transporting  
10 material which can be used for electrophotographic  
photoreceptors, organic electroluminescent devices, thin  
film transistors, rectifying devices and the like.

#### Background Art

Generally a material with a hole drift mobility  
15 such as a low molecular pigment has been dispersed in a  
binder resin to produce a hole transporting material useful  
for an electrophotographic photoreceptor or the like.  
However, this procedure entails problems such as  
degradation of properties arising due to precipitation  
20 and/or crystallization of a pigment.

Since organic electroluminescent devices require  
a high hole drift mobility, a pigment or the like is formed  
into a film by a vacuum deposition method without use of a

binder resin. However, this procedure necessitates a large-scale vacuum device and entails a low productivity. Further the procedure suffers a problem of property degradation owing to crystallization of a pigment.

5                Researches are under way to discover hole transporting polymer materials which are free of the foregoing drawbacks, namely which are capable of mitigating the property degradation and are easy to form into a film. Polysilanes, because of their hole drift mobility, have  
10 attracted attention as a promising candidate and have been investigated.

              However, while conventional polysilanes such as methylphenylpolysilane exhibit an excellent hole drift mobility (as high as  $10^{-4} \text{ cm}^2/\text{V}\cdot\text{s}$ ), these polysilanes have  
15 a high ionization potential which poses a problem. In constructing a useful device structure, a hole can not be properly injected from a charge generation layer or an electrode (such as ITO electrode) to a polysilane layer. The polysilanes which have a high hole drift mobility at  
20 room temperature have been limited to those with aryl group such as phenyl group at the side chain. The polysilanes having phenyl group or the like entail problems of showing a poor film-forming property due to their rigidity in forming a thin film and creating cracks for their low  
25 flexibility, failing to show a good hole drift mobility.

In view of the foregoing problems, the manufacture of electrophotographic photoreceptors, organic electroluminescent devices and the like from polysilanes has not become commercially practical.

5                    Brief Description of the Drawings

FIG. 1 is an IR chart of the dichlorosilane prepared in Example 1;

FIG. 2 is a  $^1\text{H}$ -NMR chart of the dichlorosilane prepared in Example 1;

10                  FIG. 3 is a  $^1\text{H}$ -NMR chart of the polysilane prepared in Example 1; and

FIG. 4 is a  $^{29}\text{Si}$ -NMR chart of the polysilane prepared in Example 1.

Disclosure of the Invention

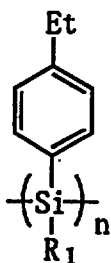
15                  A primary object of the present invention is to provide polysilane-type hole transporting materials useful for electrophotographic photoreceptors, organic electroluminescent devices or the like.

                  The present inventors conducted extensive  
20                  research in view of the foregoing prior art problems and found the following. When ethyl group is introduced into the p-position of phenyl group in a polysilane having phenyl group at the side chain, the main chain of silicon is given a controlled skeleton structure due to the  
25                  cohesion of side chains between each other, whereby a low

ionization potential is involved, resulting in enhanced optoelectronic function such as proper injection of holes from a charge generation layer or an electrode. At the same time, the flexibility of ethyl group serves to improve the film-forming property, flexibility and other properties of the polysilane. Based on these findings, the inventors succeeded in substantially obviating or markedly alleviating the problems of conventional hole transporting materials.

According to the present invention, there are provided the following hole transporting materials:

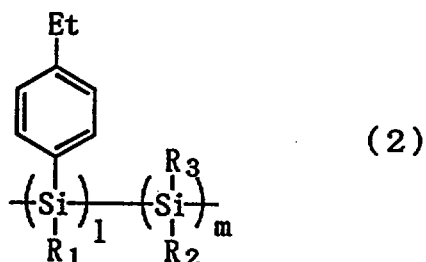
1. a hole transporting material which has a structure represented by the following formula (1) and which is excellent in film-forming property and hole transporting characteristic



(1)

wherein  $\text{R}_1$  is hydrogen atom and alkyl group,  $\text{R}_1$  may be the same or at least two of them may be different from each other and  $n$  is in the range of 10 to 20000 (hereinafter referred to as "first invention"); and

2. a hole transporting material which has a structure represented by the following formula (2) and which is excellent in film-forming property and hole transporting characteristic



5 wherein  $R_1$  is hydrogen atom and alkyl group,  $R_2$  and  $R_3$  are hydrogen atom, alkyl group, aryl group, alkoxy group, amino group and silyl group,  $R_1$ ,  $R_2$  and  $R_3$  may be the same or at least two of them may be different from each other,  $l$  is a positive number,  $m$  is zero or a positive number, and  $l+m$  is  
10 in the range of 10 to 20000 (hereinafter referred to as "second invention").

The first invention and the second invention will be described below in more detail.

The hole transporting material of the first  
15 invention is the polysilane represented by the formula (1). In the formula (1),  $R_1$  is hydrogen atom and alkyl group having 1 to 10 carbon atoms, and the carbon atom adjacent to a silicon atom is the primary or secondary carbon atom.  $R_1$  is more preferably alkyl group having 1 to 6 carbon

atoms, and most preferably methyl group. The symbol  $n$  is in the range of 10 to 20000, more preferably 15 to 5000, most preferably 20 to 1000.

The polysilane of the formula (1) can be prepared from the corresponding silane monomer as the raw material, for example, by the following methods. Specific examples of the methods include (a) a method wherein a dichlorosilane is subjected to dechlorination condensation polymerization in the presence of an alkali metal ("Kipping Method", J. Am. Chem. Soc., 103 (1981) 7352), (b) a method wherein a dichlorosilane is subjected to dechlorination condensation polymerization due to electrochemical reduction (J. Chem. Soc., Chem. Commun., 897 (1992), "Chemistry and Industry", 45, 1107 (1992), Japanese Unexamined Patent Publication Hei 5-306340), (c) a method wherein a dihydrosilane is subjected to dehydrogenation condensation polymerization in the presence of a metal catalyst (Chem. Lett., 913 (1991)), and (d) a method wherein a dichlorosilane is subjected to reductive polymerization using a specific metal in the presence of a specific Li salt and a metal halide. The methods (a) to (c) are known while the chemical polymerization method (d) is novel and is disclosed in the specification of Japanese Patent Application No. Hei 9-2325.

The novel chemical polymerization method (d) is

described below. According to the method, Mg or Mg alloy is acted on at least one of dihalosilanes in an aprotic solvent in the presence of a specific Li salt and a metal halide, giving a polysilane. The dihalosilane is reduced  
5 by Mg or Mg alloy and polymerized into a polysilane. The Mg or Mg alloy is consumed into halogenated Mg.

Examples of the aprotic solvent are polar solvents such as tetrahydrofuran, 1,2-dimethoxyethane, propylene carbonate, acetonitrile, dimethylformamide,  
10 dimethylsulfoxide, bis(2-methoxyethyl)ether, 1,4-dioxane and methylene chloride; and non-polar solvents such as toluene, xylene, benzene, n-pentane, n-hexane, n-octane, n-decane and cyclohexane. These solvents can be used either alone or in combination. Preferred solvents are a polar  
15 solvent used singly, a mixture of at least two different polar solvents and a mixture of polar and non-polar solvents. The mixture of polar and non-polar solvents is used preferably at a former : latter ratio of approximately 1 : 0.01-20. Tetrahydrofuran and 1,2-dimethoxyethane are  
20 more preferred as a polar solvent usable either alone or in mixture with other solvents. The concentration of the dihalosilane in the solvent is usually about 0.05 to about 20 mol/l, preferably about 0.2 to about 15 mol/l, more preferably about 0.3 to about 13 mol/l.

25 Examples of the Li salt are LiCl, LiNO<sub>3</sub>, Li<sub>2</sub>CO<sub>3</sub>,

$\text{LiClO}_4$ , etc. These Li salts can be used either alone or in combination. Of these Li salts,  $\text{LiCl}$  is the most preferred.

The concentration of the Li salt in the solvent  
5 is usually about 0.05 to about 5 mol/l, preferably about 0.1 to about 3 mol/l, more preferably about 0.15 to about 2 mol/l.

Preferred examples of the metal halide are  $\text{FeCl}_2$ ,  
 $\text{FeCl}_3$ ,  $\text{FeBr}_2$ ,  $\text{FeBr}_3$ ,  $\text{AlCl}_3$ ,  $\text{AlBr}_3$ ,  $\text{ZnCl}_2$ ,  $\text{SnCl}_2$ ,  $\text{CoCl}_2$ ,  
10  $\text{VCl}_3$ ,  $\text{TiCl}_4$ ,  $\text{PdCl}_2$ ,  $\text{SmCl}_2$ ,  $\text{SmI}_2$ , etc. Of these metal halides,  $\text{FeCl}_2$  is more preferred. The concentration of the metal halide in the solvent is usually about 0.01 to about 6 mol/l, preferably about 0.03 to about 4 mol/l, more preferably about 0.05 to about 3 mol/l.

15 The shape of Mg or Mg alloy is not limited insofar as the reaction is feasible. Examples include powders, granules, ribbons, cut pieces, agglomerates, rods, flat plates and the like. Of these shapes, preferred are those which are large in specific surface area such as  
20 powders, granules, ribbons, cut pieces, etc. As to the amount of Mg or Mg alloy to be used, the amount of Mg is 2 mols or more per mol of the dihalosilane used, and the amount of Mg alloy is such that the amount of Mg component is 2 mols or more per mol of the dihalosilane used. When  
25 the amount of Mg or the amount of Mg component in the Mg

alloy is more than 2 mols per mol of the dihalosilane used, the reaction time is shortened. Thus the use of at least 3 mols is more preferred and the use of at least 5 mols is the most preferred.

5           The chemical polymerization method is conducted as follows. For example, a dihalosilane, a Li salt, a metal halide and Mg or Mg alloy are placed, along with a solvent, into a hermetically closable reactor wherein preferably the mixture is mechanically or magnetically  
10 stirred to carry out the reaction. The shape of the reactor is not limited insofar as it has a structure which assures sealing.

          The reaction time is variable depending on the amount of Mg or Mg alloy, Li salt and metal halide to be  
15 used and is usually about at least 30 minutes. The molecular weight of the reaction product can be controlled by adjustment of the reaction time. The degree of polymerization to be attained in the chemical polymerization method is preferably about 5 to about 1000.

20           The reaction temperature ranges from -20°C to the boiling point of the solvent used, preferably about -10 to about 50°C, more preferably about -5 to about 30°C.

          When, for example, a dichlorosilane is used as the silane monomer for the synthesis of the polysilane of  
25 the formula (1), an alkyltrichlorosilane and p-ethylbromo-

benzene are subjected to the Grignard reaction, whereby alkyl-(p-ethylphenyl)dichlorosilane can be easily prepared. On the other hand, when a dihydrosilane is used as the silane monomer, an alkylchlorodihydrosilane and p-ethylbromobenzene are subjected to the Grignard reaction, whereby alkyl-p-ethylphenyldihydrosilane can be produced.

The hole transporting material of the second invention is the polysilane represented by the formula (2). The second invention is substantially the same as the first invention except that the polysilane of the formula (2) is a copolymer formed from a silicon unit having p-ethylphenyl group and  $R_1$  at the side chain and other silicon unit.

$R_2$  and  $R_3$  in the other silicon unit are hydrogen atom, alkyl group having 1 to 10 carbon atoms, aryl group, alkoxy group, amino group and silyl group.

$R_1$ ,  $R_2$  and  $R_3$  in the formula (2) may be different from each other or at least two of them may be the same. Examples of the alkyl group include those having about 1 to about 10 carbon atoms among which those having 1 to 6 carbon atoms are more preferred. Examples of the aryl group are phenyl, naphthyl, p-alkoxyphenyl, etc. Examples of the alkoxy group are those having about 1 to about 10 carbon atoms among which those having 1 to 6 carbon atoms are more preferred. When  $R_1$ ,  $R_2$  and  $R_3$  are alkyl, aryl, alkoxy, amino and silyl, the hydrogen atom thereof may be

substituted with other functional group such as alkyl, aryl or alkoxy (having the same number of carbon atoms as above).

In the formula (2),  $l$  is a positive number, and  
5  $m$  is zero or a positive number.  $l+m$  is in the range of 10 to 20000, more preferably about 15 to about 5000, most preferably about 20 to about 1000. If  $l$  is too small in  $l/m$ , the effect of p-ethyl group is not fully produced. Consequently  $l/m$  is preferably at least 0.3, more  
10 preferably at least 0.5.

The polysilane of the formula (2) can be prepared in the same manner as that of the formula (1) by selecting the corresponding silane monomer as the starting material.

#### Effects of the Invention

15 According to the present invention, the following remarkable effects can be achieved.

(a) The hole transporting materials of the invention permit proper injection of holes from a charge generation layer or an electrode. Consequently the  
20 produced electrophotographic photoreceptors have a significantly improved photosensitivity and the produced organic electroluminescent devices have an enhanced light emitting efficiency.

(b) The polysilanes of the invention can be  
25 easily formed into a film, and thus can form a hole

transporting layer which has a good film-forming property and high flexibility.

Best Mode for Carrying Out the Invention

Given below are Examples to further clarify the  
5 features of the present invention.

Example 1

Synthesis of dichlorosilane

The air in a 50 ml 3-necked flask was replaced by argon gas. Then, 1.4 g of Mg (THF 10 ml) useful for  
10 Grignard reaction was placed into the flask to which 10 g of p-bromoethylbenzene (THF 20 ml) was added dropwise, giving a Grignard reagent. Thereafter 9.7 g of methyltrichlorosilane (THF 25 ml) was placed into a 100 ml 3-necked flask to which the obtained Grignard reagent was  
15 added dropwise over 30 minutes, followed by 3-hour stirring.

To the reaction mixture was added 60 ml of hexane for salting-out, giving a white precipitate. The white precipitate was filtered off, the solvent was distilled  
20 off, 60 ml of hexane was added for salting-out again, the white precipitate was filtered off, the solvent was distilled off and the residue was distilled under reduced pressure (boiling point of 80°C, 2 mmHg), whereby 5.8 g of (p-ethylphenyl)methyldichlorosilane was produced. An IR  
25 chart and a  $^1\text{H}$ -NMR chart of the obtained dichlorosilane are

shown in FIG. 1 and FIG. 2, respectively.

Synthesis of polysilane

Anhydrous lithium chloride (0.4 g ) and 0.24 g of anhydrous ferrous chloride were placed into a 30 ml 3-necked flask (hereinafter referred to as "reactor") having a three way stop-cock, an anode of Mg (1 cm (diameter) X 5 cm) and a cathode of stainless steel ("SUS 304") (1 cm X 1 mm X 5 cm). The mixture was heated to 50°C and the pressure was reduced to 1 mmHg to dry the lithium chloride and ferrous chloride. Thereafter deoxidized dry nitrogen was introduced into the reactor, followed by addition of 15 ml of tetrahydrofuran dried over sodium-benzophenoneketyl. Then, 2.2 g (10 mmols) of (p-ethylphenyl)methyl dichlorosilane purified by distillation was added with a syringe. The reaction mixture was stirred by a magnetic stirrer and a current was applied from a constant current power source while maintaining the reactor at room temperature with a water bath. A current was passed for about 21.3 hours for the passed electricity to reach 4.0 F/mol based on dichlorosilane.

After completion of reaction, 20 ml of 1N hydrochloric acid was added to the reaction mixture, followed by addition of 80 ml of distilled water. The mixture was extracted with 100 ml of ether and reprecipitated by addition of 80 ml of poor solvent ethanol

and 4 ml of good solvent tetrahydrofuran.

The above procedure gave (p-ethylphenyl) methylpolysilane having a weight average molecular weight of 21300 in a yield of 49%. A  $^1\text{H}$ -NMR chart and a  $^{29}\text{Si}$ -NMR chart of the obtained polysilane are FIG. 3 and FIG. 4, respectively.

The obtained polysilane was evaluated as a hole transporting material in the following manner. The results are shown below in Table 1 together with the results of evaluation made in subsequent Examples and Comparative Examples. In Table 1, the polysilanes obtained in Examples 1-7 are indicated as Samples 1-7, respectively and the polysilanes obtained in Comparative Examples 1-4 are indicated as Samples 8-11, respectively.

15 Evaluation of film-forming property and flexibility

A 10 wt% (wt% will be hereinafter referred to simply as "%") toluene solution of polysilane was cast on a 100  $\mu\text{m}$ -thick aluminum substrate. The coated substrate was dried at 55°C for 2 hours under pressure being reduced by a rotary pump. The thickness of the polysilane film was about 25  $\mu\text{m}$ . The polysilane-coated aluminum substrate was bent and visually inspected for the occurrence or non-occurrence of cracks to evaluate the film-forming property and the flexibility.

25 Evaluation of hole transporting characteristic

A 25% toluene solution of polysilane was spin-coated on an aluminum-deposited glass substrate. The coated substrate was dried at 55°C for 2 hours under pressure being reduced by a rotary pump, whereby a thin  
5 film of polysilane having a thickness of about 5.0  $\mu\text{m}$  was formed. A semitransparent gold film was formed as a top electrode by DC sputtering.

The time of flight of the obtained sample was measured by direct excitation of nitrogen pulse laser  
10 (wavelength 337 nm) to determine from the transit pulse shape whether transport was dispersive or non-dispersive. The hole drift mobility was also evaluated from the measurement.

#### Evaluation of electrophotographic property

15 A solution was prepared by dispersing a mixture of titanyl phthalocyanine, polyvinyl butyral and cellosolve acetate at a weight ratio of 1 : 1 : 18 by a ball mill. The solution was bar-coated on a 100  $\mu\text{m}$ -thick aluminum substrate and dried to form a charge generation layer  
20 having a thickness of about 0.5  $\mu\text{m}$ . A 30% toluene solution of polysilane was bar-coated on the charge generation layer. The film was dried in an air-circulation oven at 100°C for about 1 hour.

The half-decay exposure of the obtained sample  
25 was measured by a static-mode electrophotographic

measurement using "EPA-8200" manufactured by Kawaguchi  
Denki Co., Ltd.

Evaluation of electroluminescent property

A 1500 Å-thick hole injection layer was spin-  
5 coated from a 5% toluene solution of polysilane on an ITO  
deposited glass substrate. Alq<sub>3</sub> {tris(8-quinolinolato)-  
aluminum (III)} light emitting layer (500 Å) was formed by  
vacuum deposition. A cathode (1500 Å) was formed by vacuum  
10 deposition using an alloy of Mg and Ag at a weight ratio of  
10 : 1, whereby an electroluminescent device was produced.

15 V was applied to the device. The output of  
emitted light was measured by a PIN photodiode.

Example 2

Dichlorosilane was prepared in the same manner as  
15 in Example 1. Then, a polysilane was synthesized from the  
obtained dichlorosilane as the starting material by the  
Kipping method.

Synthesis of polysilane

A mechanical stirrer and a reflux condenser were  
20 fitted to a three-necked flask. Then the air inside the  
reactor was replaced with argon gas. Into the reactor were  
placed 9.3 g of 40% sodium dispersion (manufactured by  
Aldrich Chemical Co., Ltd.), 83 ml of dry toluene and 24 ml  
of diglyme. The mixture was heated in an oil bath (bath  
25 temperature 130°C), followed by adding 17.6 g (80 mmols) of

(p-ethylphenyl)methyldichlorosilane. Thereafter the mixture was continuously heated at 110°C for 5 hours. After stopping heating, stirring was continued overnight. Then, 25 ml of 2-propanol was added to the reaction  
5 mixture, followed by addition of 160 ml of 1N hydrochloric acid and 640 ml of distilled water. The mixture was extracted with 800 ml of ether and reprecipitated by addition of 320 ml of poor solvent ethanol and 16 ml of good solvent tetrahydrofuran.

10 The above procedure gave (p-ethylphenyl)-methylpolysilane having a weight average molecular weight of 34300 in a yield of 22%.

#### Example 3

6.0 g of granular magnesium, 1.6 g of anhydrous  
15 lithium chloride (LiCl) and 0.96 g of anhydrous ferrous chloride ( $\text{FeCl}_2$ ) were placed into a 100 ml eggplant type flask equipped with a three way stop-cock. The mixture was heated to 50°C and the pressure was reduced to 1 mmHg to dry the contents of the reactor. Thereafter dry argon gas  
20 was introduced into the reactor after which 60 ml of tetrahydrofuran dried over sodium-benzophenoneketyl was added, followed by stirring at room temperature for about 30 minutes. Then, 8.8 g (40 mmols) of (p-ethylphenyl)methyldichlorosilane purified by distillation  
25 was added with a syringe, followed by stirring at room

temperature for about 12 hours. After completion of reaction, the reaction mixture was poured into 50 ml of 1N hydrochloric acid and was extracted with 100 ml of ether. The ether layer was washed twice with 50 ml of pure water  
5 and dried over anhydrous magnesium sulfate. Then the ether was distilled off, giving a crude polysilane containing a low molecular component. The crude polysilane was reprecipitated with 20 ml of good solvent tetrahydrofuran and 400 ml of poor solvent ethanol.

10 The above procedure gave (p-ethylphenyl)methylpolysilane having a weight average molecular weight of 15600 in a yield of 49%.

#### Example 4

A reaction for synthesis of polysilane was  
15 carried out in the same manner as in Example 1 with the exception of using 2.3 g (10 mmols) of (p-ethylphenyl)-ethyldichlorosilane in place of 2.2 g of (p-ethylphenyl)-methyldichlorosilane. This procedure gave (p-ethylphenyl)-ethylpolysilane with a weight average molecular weight of  
20 16400 in a yield of 40%.

#### Example 5

A reaction for synthesis of polysilane was carried out in the same manner as in Example 1 with the exception of using a mixture of 1.1 g (5 mmols) of (p-  
25 ethylphenyl)methyldichlorosilane and 0.96 g (5 mmols) of

methylphenyldichlorosilane in place of 2.2 g of (p-ethylphenyl)methyldichlorosilane. This procedure gave (p-ethylphenyl)methyl-co-methylphenylpolysilane with a weight average molecular weight of 14300 in a yield of 47%.

5    Example 6

A reaction for synthesis of polysilane was carried out in the same manner as in Example 1 with the exception of using a mixture of 1.1 g (5 mmols) of (p-ethylphenyl)methyldichlorosilane and 0.99 g (5 mmols) of  
10   cyclohexylmethyldichlorosilane in place of 2.2 g of (p-ethylphenyl)methyldichlorosilane. This procedure gave (p-ethylphenyl)methyl-co-cyclohexylmethylpolysilane with a weight average molecular weight of 19600 in a yield of 37%.

Example 7

15        A reaction for synthesis of polysilane was carried out in the same manner as in Example 1 with the exception of using a mixture of 1.1 g (5 mmols) of (p-ethylphenyl)methyldichlorosilane and 1.3 g (5 mmols) of di-n-hexyldichlorosilane in place of 2.2 g of (p-ethylphenyl)methyldichlorosilane. This procedure gave (p-ethylphenyl)methyl-co-di-n-hexylpolysilane with a weight  
20   average molecular weight of 14400 in a yield of 33%.

Comparative Example 1

A reaction for synthesis of polysilane was  
25   carried out in the same manner as in Example 1 with the

exception of using 1.9 g (10 mmols) of methylphenyldi-  
chlorosilane in place of 2.2 g of (p-ethylphenyl)methyl-  
dichlorosilane. This procedure gave methylphenylpolysilane  
with a weight average molecular weight of 17800 in a yield  
5 of 51%.

#### Comparative Example 2

A reaction for synthesis of polysilane was  
carried out in the same manner as in Example 1 with the  
exception of using 2.5 g (10 mmols) of (p-t-butylphenyl)-  
10 methyldichlorosilane in place of 2.2 g of (p-ethylphenyl)-  
methyldichlorosilane. This procedure gave (p-t-butyl-  
phenyl)methylpolysilane with a weight average molecular  
weight of 13700 in a yield of 18%.

#### Comparative Example 3

15 A reaction for synthesis of polysilane was  
carried out in the same manner as in Example 1 with the  
exception of using 2.1 g (10 mmols) of (p-methylphenyl)-  
methyldichlorosilane in place of 2.2 g of (p-ethylphenyl)-  
methyldichlorosilane. This procedure gave (p-methyl-  
20 phenyl)methylpolysilane with a weight average molecular  
weight of 19900 in a yield of 40%.

#### Comparative Example 4

A reaction for synthesis of polysilane was  
carried out in the same manner as in Example 1 with the  
25 exception of using 2.7 g (10 mmols) of (p-biphenyl)methyl-

dichlorosilane in place of 2.2 g of (p-ethylphenyl)methyl-  
dichlorosilane. This procedure gave (p-biphenyl)methyl-  
polysilane with a weight average molecular weight of 10700  
in a yield of 17%.

Table 1

| Sample | Film-forming property | Hole transporting characteristic |                                                                   | Electrophotographic property   | Electroluminescent property |
|--------|-----------------------|----------------------------------|-------------------------------------------------------------------|--------------------------------|-----------------------------|
|        | Flexibility           | Pulse shape                      | Hole mobility<br>( $10^{-4} \text{ cm}^2/\text{V}\cdot\text{s}$ ) | Half-decay exposure<br>(Lux·s) | Output of emitted light     |
| 1      | A                     | A                                | 3.0                                                               | 0.71                           | 100                         |
| 2      | A                     | A                                | 2.1                                                               | 0.86                           | 84                          |
| 3      | A                     | A                                | 2.4                                                               | 0.88                           | 88                          |
| 4      | A                     | A                                | 2.3                                                               | 1.00                           | 57                          |
| 5      | A                     | A                                | 2.7                                                               | 0.93                           | 71                          |
| 6      | A                     | A                                | 2.4                                                               | 1.21                           | 70                          |
| 7      | A                     | A                                | 2.2                                                               | 1.29                           | 53                          |
| 8      | B                     | A                                | 2.6                                                               | 1.57                           | 22                          |
| 9      | B                     | A                                | 0.9                                                               | 6.14                           | 14                          |
| 10     | B                     | B                                | 0.4                                                               | Failed                         | 6                           |
| 11     | C                     | B                                | 0.5                                                               | Failed                         | 0                           |

(Note)

(1) Samples 1-7 are the polysilanes produced in Examples 1-7, respectively and Samples 8-11 are the polysilanes produced in Comparative Examples 1-4, respectively.

(2) The film-forming property and the flexibility were evaluated according to the following criteria:

A...No crack occurred after bending.

B...No crack occurred before bending, but crack was developed by bending.

C...Crack existed before bending.

(3) Pulse shape:

A...non-dispersive type

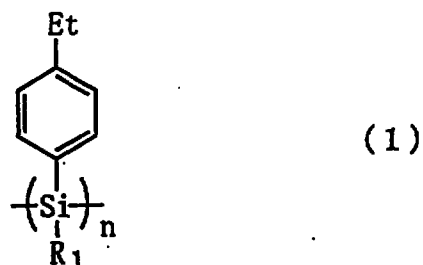
B...dispersive type

(4) Output of emitted light: a relative value when the output of Sample 1 was taken as 100.



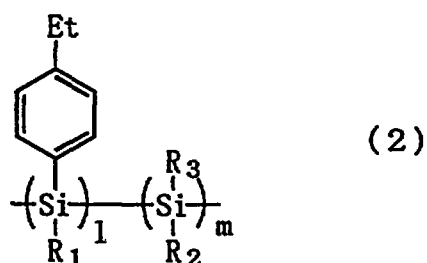
CLAIMS:

1. A hole transporting material which has a structure represented by the following formula (1) and which is excellent in film-forming property and hole transporting characteristic



wherein  $\text{R}_1$  is hydrogen atom and alkyl group,  $\text{R}_1$  may be the same or at least two of them may be different from each other and  $n$  is in the range of 10 to 20000.

2. A hole transporting material which has a structure represented by the following formula (2) and which is excellent in film-forming property and hole transporting characteristic



wherein  $\text{R}_1$  is hydrogen atom and alkyl group,  $\text{R}_2$  and  $\text{R}_3$  are hydrogen atom, alkyl group, aryl group, alkoxy group, amino

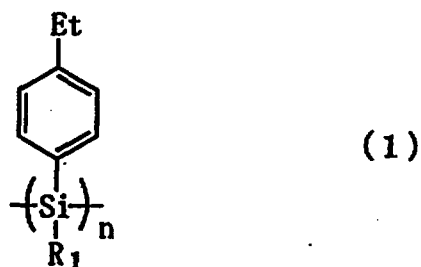


-25-

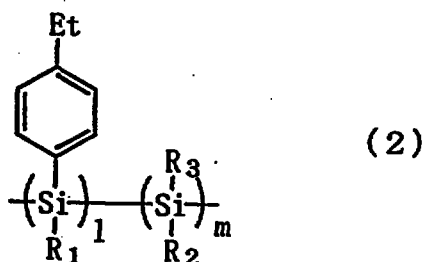
group and silyl group,  $R_1$ ,  $R_2$  and  $R_3$  may be the same or at least two of them may be different from each other,  $l$  is a positive number,  $m$  is zero or a positive number, and  $l+m$  is in the range of 10 to 20000.

ABSTRACT

This invention provides a hole transporting material which has a structure represented by the following formula (1) or formula (2) and which is excellent in film-forming property and hole transporting characteristic



wherein  $\text{R}_1$  is hydrogen atom and alkyl group,  $\text{R}_1$  may be the same or at least two of them may be different from each other and  $n$  is in the range of 10 to 20000,



wherein  $\text{R}_1$  is hydrogen atom and alkyl group,  $\text{R}_2$  and  $\text{R}_3$  are hydrogen atom, alkyl group, aryl group, alkoxy group, amino group and silyl group,  $\text{R}_1$ ,  $\text{R}_2$  and  $\text{R}_3$  may be the same or at least two of them may be different from each other,  $1$  is a positive number,  $m$  is zero or a positive number, and  $1+m$  is in the range of 10 to 20000.

FIG. 1

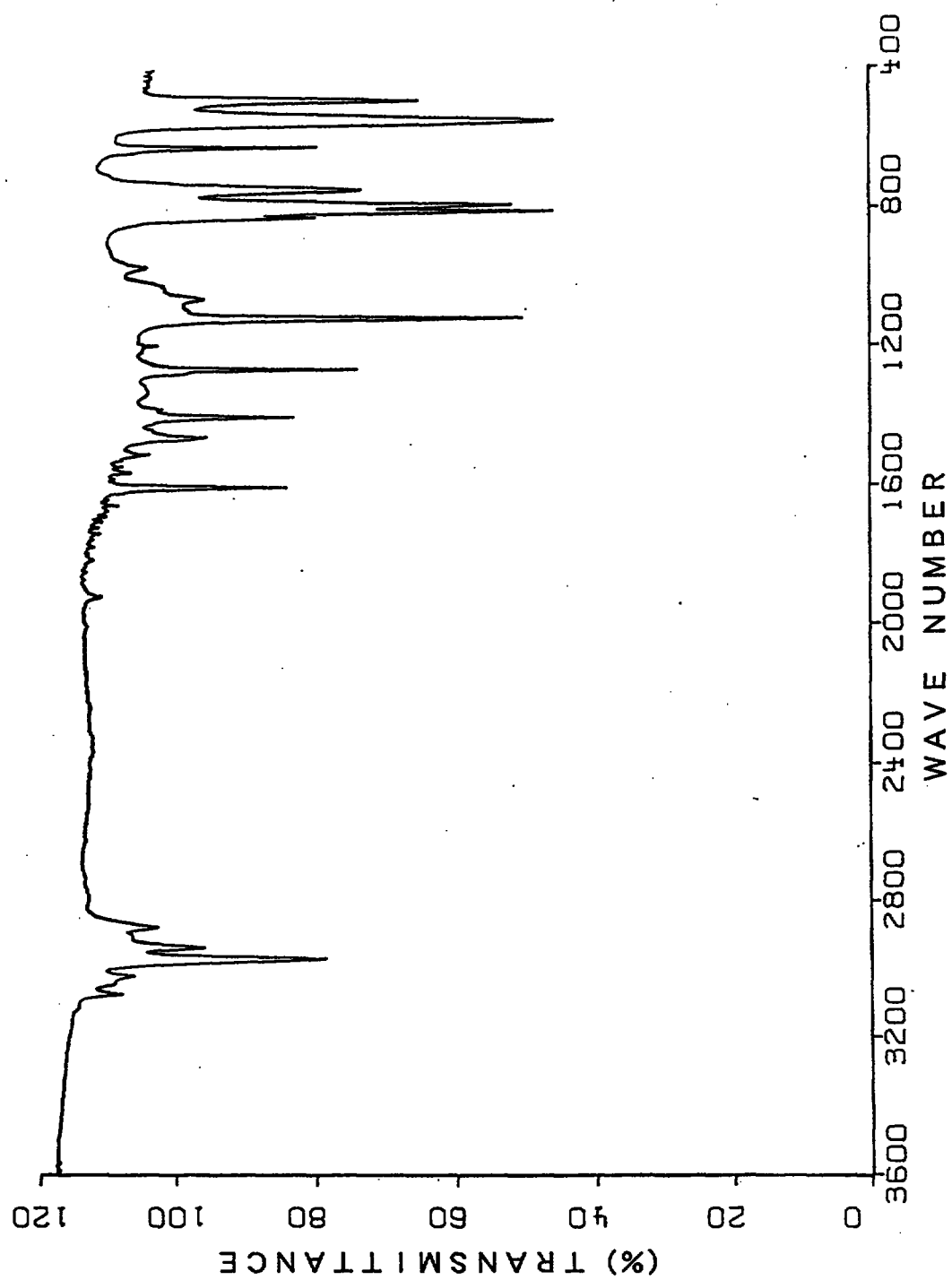


FIG. 2

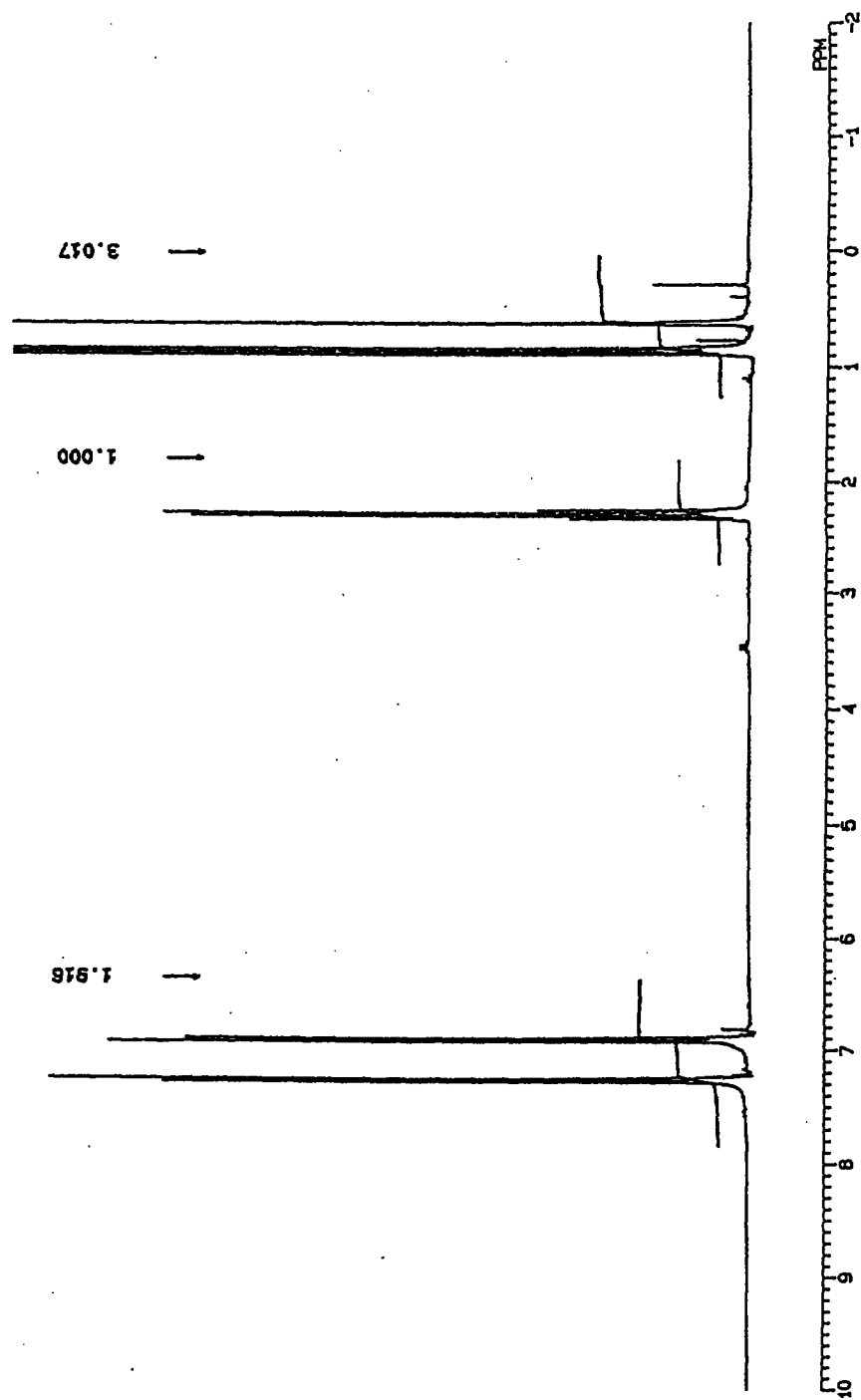
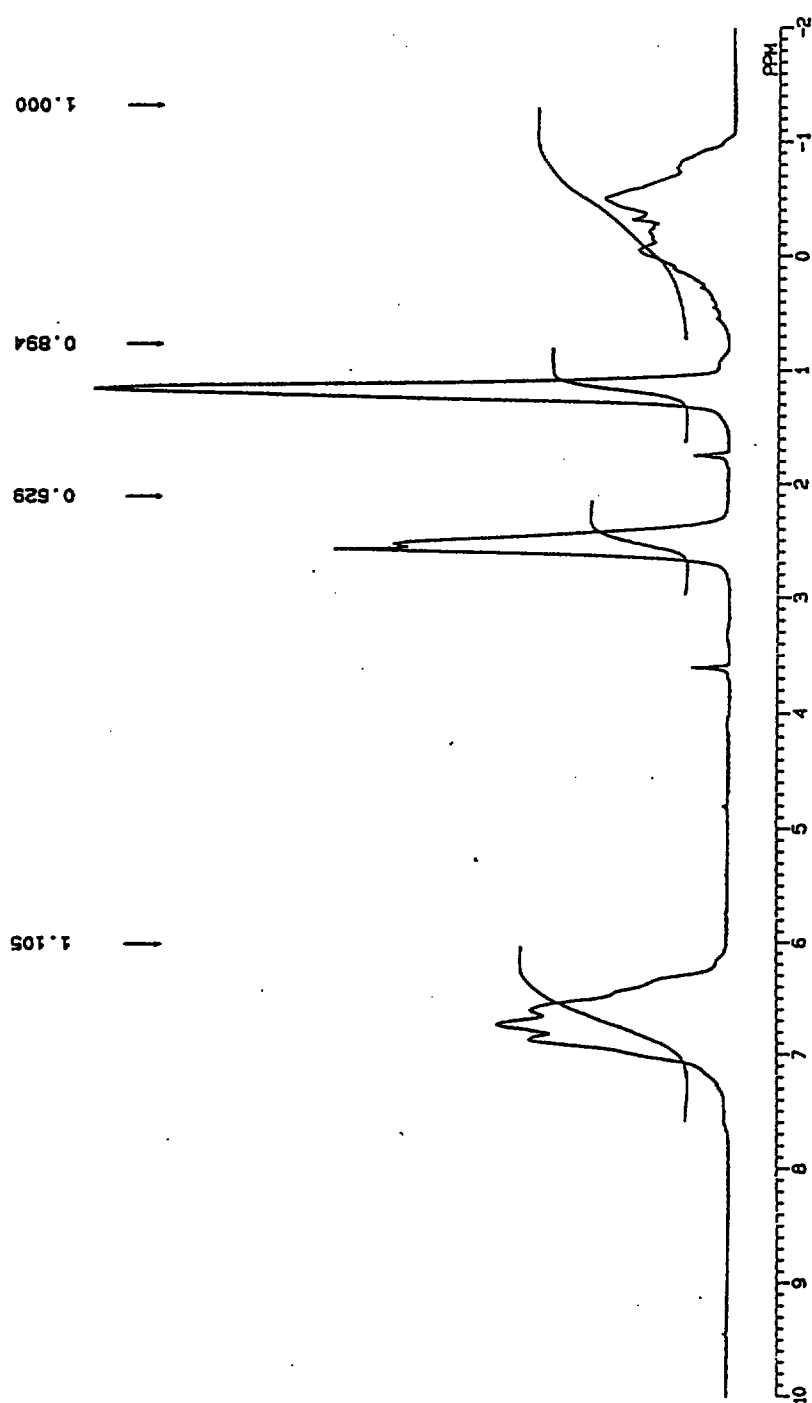


FIG. 3



**FIG. 4**

