METHOD OF PRODUCING MICROSTRUCTURES

SI-POLYMER

BOTTOM LAYER

SUBSTRATE

EXPOSURE DEVELOPMENT

ETCHING IN O2-PLASMA

ETCHING SUBSTRATE

REMOVE POLYMER

The invention relates to method of providing a microstructure in electric conductors, semiconductors and insulators utilizing a multilayer resist system, wherein in the image layer a siliceous polymer comprising chemically unstable side groups, and an initiator are used, which initiator generates, under the influence of radiation, a catalyst which in turn chemically modifies these side groups, the silicon content of this polymer being such that upon treatment with oxygen plasma a closed network of silica is formed on the surface of the polymer, to a multilayer resist system having positive and/or negative tone for producing microstructures, and to siliceous polymers suitable therefor.
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Title: Method of producing microstructures.

The invention relates to a method of providing a microstructure in electric conductors, semiconductors and insulators utilizing a multilayer resist system, to a multilayer resist system having positive and/or negative tone for producing microstructures, and to siliceous polymers suitable therefor.

Presently, in the world of resist research two main streams can be distinguished in the development of new products:

- resists with high sensitivity based on a catalytically enhanced exposure reaction;
- resists for high lateral resolution based on incorporated silicon and oxygen plasma processing.

In addition, the above-mentioned items are subject to the trend of moving towards increasingly smaller wavelengths, as far as optically sensitive resists are concerned.

Resists with a catalyzed exposure reaction are substantially purely organochemical polymers. To the polymer a so-called initiator is added. By conversion of the initiator molecule, an irradiated quantum (for instance a photon or an electron) generates a reactive product, for instance a proton, which will subsequently function as a catalyst in the chemical conversion of a multiplicity of resist molecules. This so-called chemical amplification has been developed in all sorts of forms. The most common variant is the acid-catalyzed exposure reaction in which a H\(^+\) ion is formed by exposure, subsequently effecting a multiplicity of polymer conversions.

Positive as well as negative resists have been realized. Systems have even been developed which are positive or negative, depending on the polarity of the developing liquid. The initiators have been designed such that the exposure reaction can be effected by photons (deep UV), electrons or X-ray quanta. All these resists are used in a
one-layer mask and are not suitable for the ultra-high resolution which can be realized in multilayer approaches.

Siliceous resist systems are based on the principle that after exposure, silicon is selectively left behind in the top layer of the mask. This may take place in a two-layer configuration, wherein the bottom layer is an organochemical polymer and the top layer consists of a siliceous polymer. Via exposure, the pattern is generated in the top layer. However, this is also possible in a one-layer configuration, wherein, after exposure of a normal organochemical resist system, silicon-containing molecules are selectively incorporated into the unexposed surfaces by exposure to suitable vapors or liquids. In both configurations, as final step an oxygen plasma follows, with the non-siliceous portions being etched in the plasma and the siliceous portions remaining unaffected with a high lateral precision. For the one-layer variant, all kinds of product developments are in progress, both with regard to the radiation-sensitive acceptor polymers and the siliceous molecules to be incorporated.

In the two-layer mask variant siliceous resists have been developed on the basis of polysiloxanes which have an excellent etching resistance due to the high silicon content, but which are not very sensitive from a lithographic viewpoint. These resist systems all have a negative tone: what is exposed will remain unaffected after development.

Also, siliceous polymers have been synthesized wherein the main chain is purely organic and the silicon is incorporated via side chains. These polymers may have an excellent sensitivity, but the etching resistance is insufficient because of the relatively low silicon content. In this class, both positive and negative resists have been realized.

In the arrangement with a two-layer mask, the imaging function and the actual mask function are separated in two separate layers, with the advantage that a superior resolution is obtained.
The procedure of a two-layer mask is as follows (see also Fig. 1): after exposure and development of the pattern in the top (image) layer, the pattern is subsequently transferred, via dry-etching in oxygen plasmas, into the bottom mask layer with a lateral precision of ca. 5 nm. After this, the actual pattern transfer into the underlying material layer can take place in plasmas containing fluorine (F) and/or chlorine (Cl). For the bottom mask layer, polymers have been developed that meet the desired etching characteristics: 1) readily capable of being etched in oxygen plasma and 2) optimally resistant to F and Cl plasmas.

In this connection, as is already indicated above, the following main characteristics are essential to the top layer:

1. High sensitivity and high contrast during the pattern definition;
2. High etching resistance to oxygen plasmas during the pattern transfer.

Until the time of the present invention, the general situation was that products had either one or the other main characteristic.

Therefore, the object of the invention is to provide siliceous resist systems for two-layer mask purposes, having:

1) a high sensitivity through an exposure reaction based on catalysis, and
2) a high etching resistance in oxygen plasmas.

A next object is the realization of resists having a positive and/or negative tone, depending on the polarity of the developer.

More particularly, the present invention is directed to the lithographic action of new siliceous resist systems for microfabrication. These systems are both resist systems having a positive tone and resist systems having a negative tone or a combination of the two.

According to a first variant of the invention, the invention relates to a method of providing a microstructure in electric conductors, semiconductors and insulators utilizing a
multilayer resist system, wherein in the image layer a
siliceous polymer, comprising chemically unstable side groups,
and an initiator are used, which initiator generates, under
the influence of radiation, a catalyst which in turn
chemically modifies these side groups, the silicon content of
this polymer being such that upon treatment with oxygen plasma
a closed network of silica is formed on the surface of the
polymer.

According to a second variant of the invention, the
invention relates to a multilayer resist system having
positive and/or negative tone for producing microstructures,
characterized in that the image layer contains a siliceous
polymer comprising chemically unstable side groups, and an
initiator, which initiator, under the influence of radiation,
generates a catalyst, which in turn modifies these side
groups, the silicon content of this polymer being such that
upon treatment with oxygen plasma a closed network of silica
is formed on the surface of the polymer.

According to a third variant of the invention, the
invention relates to three groups of new polymers which are
suitable for use in the first two aspects of the invention.

The invention is based on, for instance, the use of
the specific polymers in microlithography, one of the
essential aspects being that under the influence of a
catalyzed exposure reaction, one or more groups are modified
chemically in the siliceous polymer, after which, by means of
a suitable developer, the exposed or, conversely, the
unexposed portion can be removed.

Another important aspect of the siliceous polymer is
that the silicon content is so high that upon treatment with
oxygen plasma, as is also used for etching, a substantially
closed network of silica is formed.

As a result, in the conventional etching with oxygen
plasma, in the first instance, a layer of silica is formed at
the surface of the mask.

This permits the image to be transferred to the
underlying layers with very great precision.
Consequently, in the polymer used for the top layer chemically unstable side groups should be present which are chemically converted under the influence of an initiator-generated catalyst, typically a proton, with a high efficiency, i.e. which are chemically amplifiable.

The polymers containing these side groups may have different structures. A first group consists of the polymers having a SiO main chain, having attached thereto the chemically unstable side groups (formula 3), wherein

\[ \text{CH-CH}_2 \]

A represents a \( \text{CH}_2-\text{CH}_2 \) or a \( \text{CH}_3-\text{CH}_2 \) group.

A second group also has a SiO-based structure, but in the form of a so-called ladder polymer (formula 13), wherein R represents a dihydropyrane or a methoxy-dihydropyrane group.

A third group consists of organochemical copolymers having chemically unstable side groups and siloxane macromers grafted thereon.

In this connection, by siloxane macromers or siliceous macromers, siloxane polymers are meant that can be grafted on the main chain. An example thereof is the compound of formula 8 of the formulae sheet, wherein n is an integer indicating the degree of polymerization of the siloxane. The amount of silicon in the polymer is of importance to the properties thereof.

Suitable monomers containing unstable side groups are the monomers such as the modified styrenes (4-t-butoxy-carbonyloxystyrene, or 4-t-butoxystyrene), or t-butyl methacrylate, but it is also possible to use, for instance, a monomer containing a glycidyl group, such as glycidyl methacrylate. Examples of suitable combinations of monomers in a polymer of this third group are given in formulae 9-12 and 14 of the formulae sheet.

Generally, the indicated components in the copolymers will be randomly present in the copolymer, v, x and y indicating the molar proportions of each monomer in the copolymer.
In formula 9, m equals 0 or 1, i.e. the formula relates both to 4-t-butoxycarbonyloxy and to 4-t-butoxystyrene.

It is essential that after exposure and development, a closed network of silica is formed from the polymer during treatment in oxygen plasma. Through this, in the first seconds of the treatment with oxygen plasma, the formation of a network of silica is achieved in the top nanometers of the material, which network closes the top layer for further oxidation, yielding a very good and sharp transfer of the image.

According to the invention, it is among other things important that the side chains comprise unstable chemical groups, such as, for instance t-butoxy groups, or t-butoxycarbonyloxy groups or epoxy groups, producing a positive and/or negative tone on the basis of a catalyzed exposure reaction.

The incorporation of these chemically unstable side groups can take place in various manners. In the polymers based on siloxanes, this can for instance be effected through hydrosilylation of a polyhydrosiloxane with a suitable \( \alpha, \beta \)-unsaturated compound, for instance 4-t-butoxycarbonyloxy- styrene, 4-t-butoxystyrene or t-butyl methacrylate. The addition of this \( \alpha, \beta \)-unsaturated compound can take place both via the \( \alpha \) and via the \( \beta \) carbon, resulting in the two given meanings of the term A in for instance formula 3.

In the polymers based on an organochemical 'backbone', the chemically unstable group can later be attached to the main chain, or, preferably, a monomer containing the chemically unstable side group can be polymerized into the main chain. The side group containing silicon macromer (or siliceous macromonomer) can simultaneously be incorporated as comonomer, but it is also possible to graft the macromer on the main chain later.

In these polymers, in addition to the two components already discussed, other substantially non-reactive monomers can be incorporated as well to improve the properties of the
polymer. Suitable monomers are for instance styrene, α-methylstyrene, bromostyrene, acrylates, methacrylates and other α, β-unsaturated compounds.

Another component of the top layer is the initiator.

Under the influence of radiation, this initiator should generate a catalyst, which catalyzes a multiplicity of conversions in the polymer. Such catalysts are known per se, for instance for the use in one-layer masks with completely organochemical polymers. According to the invention, preferably an initiator is used generating a catalyst for the acid-catalyzed chemical amplification. Examples of such initiators are sulfonium salts or iodonium salts.

The invention will now be explained in and by some examples.

Examples

General procedures and materials

All reactions are carried out under dry, oxygen-free nitrogen utilizing standard Schlenk techniques. Tetrahydrofuran (THF) (Janssen) is dried on molecular sieves (4Å) and subsequently distilled from sodium/benzophenone under nitrogen. Toluene (Janssen) is dried on sodium and distilled from this drying agent under nitrogen. Diethyl ether is dried with anhydrous calcium chloride and subsequently distilled from sodium under nitrogen. n-Hexane (Merck) is dried on sodium and subsequently distilled from sodium under nitrogen. The p.a. solvents 2-propanol (Merck), methanol (Merck), chloroform (Merck) and dichloromethane (Merck) are used as received. 4-t-Butoxycarbonyloxystyrene (TBCS, formula 2) is synthesized according to the method of J.M.J. Fréchet, E. Eichler, H. Ito and C.G. Willson, Polymer 24 (1983) 995 and additionally purified over an alumina column (Merck II-III, 70-230 mesh, ASTM), with hexane being used as eluent. 4-t-Butoxystyrene (formula 4) is synthesized according to
the method of D.A. Coulon, J.V. Crivello, J.L. Lee and M.J. O'Brien, Macromolecules 22 (1989) 509. p-Bromostyrene (Janssen) is used as obtained. t-Buyl methacrylate (TBMA, formula 5) (Tokyo Kasei Kogyo Co.) is distilled in vacuum over calcium hydride and stored under nitrogen at -20 °C. Glycidyl methacrylate (GMA) (Janssen) is distilled in vacuum over calcium hydride. Benzoyl peroxide (BPO) (Aldrich) is used as obtained. The liquids 3,4 dihydro-2H-pyran (Janssen) and 3,4-dihydro-2-methoxy-2H-pyran (Janssen) are distilled over calcium hydride and stored under dry nitrogen. Hexamethylcyclotrisiloxane (D₃, formula 6) (Hüls-Petrarch) is sublimed under vacuum and stored under nitrogen at -20°C. The polymethylhydrosiloxanes PMHS₃₅ (Merck) and PMHS₈₀ (Petrarch) are dried before use under vacuum at 40°C. Polyphenylsilsesquioxane (Mₙ=9500, D=3.5) (Petrarch), phenyltriethoxysilane (Petrarch) and 3-(methacryloxy)propyl-dimethylchlorosilane (Petrarch) are used as received. Karstedt catalyst (Petrarch) is used as obtained. Azobisisobutyronitrile (AIBN, Janssen) is recrystallized from methanol and stored at 10°C.

Example 1

Hydrosilylation of PMHS₃₅ with TBCS

Synthesis

Into a baked-out schlenk vessel, 0.51 g (0.23 mmol) PMHS₃₅, 3.6 g (16.8 mmol) TBCS and 10 ml toluene are introduced. To the colorless solution, 3 drops of Karstedt catalyst are added. After stirring for 24 hours at 32°C, the light-yellow solution is precipitated in 150 ml methanol. The methanol is decanted from the yellow solid, after which the product is washed 3 times with 10 ml methanol. Subsequently, the product is dissolved in 10 ml toluene and stirred for 3 hours with some spatula pinches of active carbon. The active carbon is filtered off, after which the toluene solution is precipitated in 150 ml methanol. The methanol is decanted and
subsequently the white solid polymer is dried under high vacuum at room temperature. The total yield is 0.95 g (53%).

Similarly, again with approximately a double overmeasure of TBCS, the hydrosilylation of PMHS$_{80}$ is carried out. Yield 55%.

Similarly to the above-mentioned syntheses, hydrosilylation reactions are also carried out with 4-t-butoxystyrene (TBS) and t-butyl methacrylate (TBMA). Yield for combination of TBS with PMHS$_{35}$ 40%; for PMHS$_{80}$ 50%. Yield for combination of TBMA with PMHS$_{35}$ 30%; for PMHS$_{80}$ 40%.

**Lithographic action**

The carboxyloxy group in each side chain is converted into an OH group under the influence of the added initiator:

\[
\text{INITIATOR} \xrightarrow{hv} \text{H}^+ \\
\]

\[
| \\
O \\
| \\
C=O \\
| \\
O^t\text{Bu} \\
\]

\[
\text{H}^+ \\
| \\
\text{OH} \\
\]

Depending on the polarity of the developer, either the original carboxyloxy product (non-polar) or the formed alcohol (polar) dissolves. Accordingly, the resist system has a positive or negative tone. According to a comparable mechanism, the t-butoxy-ether and t-butoxy-ester groups in the compounds of polysiloxanes with TBS and TBMA change into the corresponding alcohol and carboxylic acid respectively:
Poly(4-t-butoxycarbonyloxystyrene)-g-poly(dimethylsiloxane)

Synthesis

A 50% (weight) solution of D₃ in THF is degassed thoroughly, followed by adding a stoichiometric amount of (1.5 M) t-butyl lithium in pentane, under nitrogen atmosphere and magnetic stirring. After 3 hours, the reaction mixture is cooled to 0°C, followed by adding [3-(methacryloxy)propyl]-dimethylchlorosilane. The reaction mixture is stirred vigorously at room temperature for 1 hour. The macromer is now precipitated in methanol. The LiCl is removed by purifying the macromer over a column of alumina with diethyl ether as eluent. The product, obtained substantially in quantitative yield, is dried under vacuum at room temperature.
Subsequently, the macromer is polymerized in a 20% (weight) solution in toluene via a free-radical mechanism, with TBMS with 2 mol. % (based on comonomer) azo-bis(isobutyrtonitril) as initiator. The solution was degassed and stirred at 60°C for 3 days, followed by adding a small amount of CH₂Cl₂. The copolymer with TBMS is precipitated in 2-propanol and subsequently washed intensively with 2-propanol. The copolymer is dried in vacuum. Yield 70%.

Lithographic action
The mechanism is as indicated in Example 1. Accordingly, depending on the polarity of the developer, the resist system has a positive or negative tone.

Example 3

Poly(t-butyl methacrylate)-g-poly(dimethylsiloxane)

Synthesis
The macromer (see Example 2) is polymerized in a 20% (weight) solution in toluene via a free-radical mechanism, with TBMA with 2 mol. % (based on comonomer) azo-bis(isobutyronitril) as initiator. The copolymer with TBMS is precipitated in 2-propanol. The crude copolymer solution is purified via dialysis. The dialyzed product is dissolved in chloroform and precipitated in methanol/water (3:1). The purified copolymeric final product is dried in vacuum. Yield 90%.

Lithographic action
The mechanism is as indicated in example 1. Accordingly, depending on the polarity of the developer, the resist system has a positive or negative tone.
Example 4

Poly(glycidyl methacrylate)-g-poly(dimethyldisiloxane)

Into a baked-out two-necked flask provided with septum, 1.04 g GMA, 0.15 g macromer, 2.5 ml butanone, 1.5 ml benzene and 30 mg BPO are introduced. This is degassed 3 times and subsequently stirred for 3 hours at 64°C. Subsequently, 1 ml dichloromethane is added to the viscous reaction mixture and stirred for another 15 minutes. The polymer is precipitated in 120 ml 2-propanol. The white, flocculent polymer is filtered off and washed 3 times with 2-propanol. Finally, the polymer is dried at 50°C under vacuum. Yield 45%.

Lithographic action

Under the influence of the exposure, the initiator molecule generates an acid which subsequently causes the below condensation reaction to proceed catalytically. The product is insoluble. The resist system has a negative tone.
Example 5

Copolymer of p-bromostyrene, glycidyl methacrylate and the siliceous macromer

The same procedure as in example 4 is used, with the proviso that in this example 1.04 g GMA, 0.15 g macromer and 0.16 g p-bromostyrene are used. After 18.5 hours, 1 ml dichloromethane is added to the viscous solution and stirred for another 15 minutes. The polymer is precipitated in 150 ml 2-propanol, after which the white precipitated polymer is filtered off and washed 3 times with 15 ml 2-propanol. Finally, the polymer is dried at 50°C under vacuum. The yield of white solid polymer was 89%.

Lithographic action

The mechanism is as indicated in example 4. The resist system has a negative tone.

Example 6

Tetrahydropyranyl protected polysilsesquioxane

Synthesis

A solution of 3.16 mmol polyphenylsilsesquioxane (Mₙ=9500) and 7.43 mmol 3,4-dihydro-2H-pyran or 3,4-dihydro-2-methoxy-2H-pyran in 20 ml THF is added dropwise to 6 ml HCl-saturated diethyl ether at 0°C. After stirring this mixture for 3 days at room temperature, the white solution is extracted twice with 3% KOH solution. The organic layer is dried over anhydrous MgSO₄, filtered and evaporated under reduced pressure. The solid white-colored polymer is dried under high vacuum at 60°C. Yield 86% (with 3,4-dihydro-2H-pyran) and 84% (with 3,4-dihydro-2-methoxy-2H-pyran).
Lithographic action
Under the influence of the exposure, the initiator generates an acid which subsequently causes a condensation reaction to proceed catalytically. The product is insoluble. The resist system has a negative tone.

Example 7
Copolymer of styrene-phosphazene derivative, glycidyl methacrylate and the siliceous macromer

The same procedure as in example 4 is used, with the proviso that in this example 0.44 g GMA, 0.45 g macromer and 0.45 g styrene-phosphazene derivative are used. After 48 hours, 1 ml dichloromethane is added to the viscous solution and stirred for another 15 minutes. The polymer is precipitated in 125 ml 2-propanol. After centrifugation, the white precipitated polymer is filtered off and precipitated again from toluene in 2-propanol. After filtering off and washing 3 times with 15 ml 2-propanol, the polymer is dried at 40°C under vacuum. The yield of white solid polymer was 72%.

Lithographic action
The mechanism is as indicated in example 4. The resist system has a negative tone.
1. A method of providing a microstructure in electric conductors, semiconductors and insulators utilizing a multilayer resist system, wherein in the image layer a siliceous polymer comprising chemically unstable side groups, and an initiator are used, said initiator generating, under the influence of radiation, a catalyst which in turn chemically modifies said side groups, the silicon content of said polymer being such that upon treatment with oxygen plasma a closed network of silica is formed on the surface of the polymer.

2. A method according to claim 1, characterized in that said siliceous polymer comprises chemically unstable side groups selected from the group consisting of polymers whose main chain contains silicon and oxygen atoms, polymers whose main chain is based on carbon atoms, which polymers also contain silicon-containing macromeric side groups, and Si-O-Si ladder polymers.

3. A method according to claim 2, characterized in that as said siliceous polymer a polymer is used having a main chain based on \((-\text{SiO})_n\)\(^{-}\). said chain containing one or more substituents with an unstable chemical group.

4. A method according to claim 3, characterized in that the unstable chemical group is selected from t-butoxy-styrene, t-butoxycarbonyloxy-styrene, t-butyl methacrylate and epoxy.

5. A method according to claim 2, characterized in that said siliceous polymer is a homo- or copolymer of an \(\alpha, \beta\)-unsaturated monomer with a chemically unstable side group and an \(\alpha, \beta\)-unsaturated monomer with a siliceous side group.

6. A method according to claim 5, characterized in that one of the polymers of formulae 9-12 of the formulae sheet is used.

7. A method according to claim 2, characterized in that said Si-O-Si ladder polymer meets formula 13 of the formulae sheet.
8. A multilayer resist system having positive and/or negative tone for producing microstructures, characterized in that the image layer contains a siliceous polymer comprising chemically unstable side groups, and an initiator, said initiator generating, under the influence of radiation, a catalyst, which in turn chemically modifies said side groups, the silicon content of said polymer being such that upon treatment with oxygen plasma a closed network of silica is formed on the surface of the polymer.

9. A multilayer resist system according to claim 8, characterized in that said siliceous polymer is selected from the group consisting of polymers whose main chain contains silicon and oxygen atoms, polymers whose main chain is based on carbon atoms, said polymers also containing silicon-containing polymeric side groups, and Si-O-Si ladder polymers.

10. A siliceous polymer suitable for use in the method according to claims 1-7, or the system according to claim 8 or 9, whose main chain contains silicon and oxygen, while the chemically unstable side group contains a group which is amplifiable under the influence of a catalyzed exposure reaction, the silicon content of said polymer being such that upon treatment with oxygen plasma a closed network of silica is formed on the surface of the polymer.

11. A siliceous polymer according to claim 10, characterized by formula 3 of the formulae sheet.

12. A siliceous polymer suitable for use in the method according to claims 1-9, whose main chain is based on carbon atoms, said polymer containing chemically unstable side groups and silicon-containing side groups.

13. A siliceous polymer according to claim 12, characterized in that it is a homo- or copolymer of an \( \alpha, \beta \)-unsaturated monomer with a chemically unstable side group and an \( \alpha, \beta \)-unsaturated monomer with a siliceous side group.

14. A siliceous polymer according to claim 12, characterized in that it meets any one of formulae 9-12 of the formulae sheet.
15. A siliceous polymer according to claim 10, characterized in that it meets formula 13 of the formulae sheet.

16. A siliceous polymer according to claim 12, characterized in that it meets formula 14 of the formulae sheet.
Si-polymeer
onderlaag
substraat
belichten ontwikkelen
etsen in $O_2$-plasma
etsen substraat
verwijderen polymeer


1. \[
\begin{align*}
\text{CH}_3 &\quad \text{Si} \quad \text{O} \quad \text{Si} \quad \text{CH}_3 \\
\text{CH}_3 &\quad \text{Si} \quad \text{O} \quad \text{Si} \quad \text{CH}_3 \\
\end{align*}
\]

2. \[
\begin{align*}
\text{CH}_3 &\quad \text{C} \quad \text{O} \quad \text{C} \quad \text{CH}_3 \\
\text{CH}_3 &\quad \text{O} \quad \text{C} \quad \text{CH}_3 \\
\end{align*}
\]

3. \[
\begin{align*}
\text{CH}_3 &\quad \text{Si} \quad \text{O} \quad \text{Si} \quad \text{CH}_3 \\
\text{CH}_3 &\quad \text{Si} \quad \text{O} \quad \text{Si} \quad \text{CH}_3 \\
\end{align*}
\]

4. \[
\begin{align*}
\text{CH}_3 &\quad \text{C} \quad \text{O} \quad \text{C} \quad \text{CH}_3 \\
\text{CH}_3 &\quad \text{O} \quad \text{C} \quad \text{CH}_3 \\
\end{align*}
\]

5. \[
\begin{align*}
\text{CH}_3 &\quad \text{C} \quad \text{O} \quad \text{C} \quad \text{CH}_3 \\
\text{CH}_3 &\quad \text{O} \quad \text{C} \quad \text{CH}_3 \\
\end{align*}
\]

6. \[
\begin{align*}
\text{CH}_3 &\quad \text{Si} \quad \text{O} \quad \text{Si} \quad \text{CH}_3 \\
\text{CH}_3 &\quad \text{Si} \quad \text{O} \quad \text{Si} \quad \text{CH}_3 \\
\end{align*}
\]

7. \[
\begin{align*}
\text{CH}_3 &\quad \text{C} \quad \text{O} \quad \text{C} \quad \text{CH}_3 \\
\text{CH}_3 &\quad \text{O} \quad \text{C} \quad \text{CH}_3 \\
\end{align*}
\]

8. \[
\begin{align*}
\text{CH}_3 &\quad \text{C} \quad \text{O} \quad \text{C} \quad \text{CH}_3 \\
\text{CH}_3 &\quad \text{O} \quad \text{C} \quad \text{CH}_3 \\
\end{align*}
\]
A. CLASSIFICATION OF SUBJECT MATTER

| IPC  | G03F7/075 | H01L21/312 | C08G77/14 | C08G77/38 | C08F283/12 |

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

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<th>Minimum documentation searched (classification system followed by classification symbols)</th>
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<td>G03F HO1L C08G C08F</td>
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</table>

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>X</td>
<td>EP,A,0 466 025 (NIPPON TELEGRAPH AND TELEPHONE CORPORATION) 15 January 1992 see page 13 - page 14; claims; figure 1</td>
<td>1-4, 8-10</td>
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<td>Y</td>
<td>US,A,4 481 049 (E. REICHMANIS ET AL.) 6 November 1984 see column 2, line 30 - line 40</td>
<td>5, 11,12</td>
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<td>X</td>
<td>PATENT ABSTRACTS OF JAPAN vol. 11, no. 162 (P-579) (2609) 26 May 1987 &amp; JP,A,61 294 432 (NIPPON TELEGR &amp; TELEPH CORP) 25 December 1986 see abstract</td>
<td>5, 12,13</td>
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Further documents are listed in the continuation of box C.

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- **&**: Document member of the same patent family.

Date of the actual completion of the international search: 10 March 1994

Date of mailing of the international search report: 22.03.94

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Authorized officer

Dupert, J-M
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