United States Patent

Miyamoto et al.

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[45] **Oct. 31, 1972**

[54] **METHOD FOR PRINTING ELECTRICAL CIRCUITS ON SUBSTRATES**

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[22] Filed: **Oct. 5, 1970**

[21] Appl. No.: **77,909**

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[63] Continuation-in-part of Ser. No. 720,040, April 10, 1968, abandoned.

[30] **Foreign Application Priority Data**

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Sept. 30, 1967 Japan 42/62751
Oct. 28, 1967 Japan 42/69011

[52] **U.S. Cl.** **101/170,** 101/41, 101/163, 106/1, 252/514

[51] **Int. Cl.** **B41m 3/08**

[58] **Field of Search**.....101/41–44, 163, 101/170, 426; 117/227, 212, 123 B; 252/514, 212; 106/1, 19, 23, 30; 29/625; 260/33.2, 33.4, 370, 40, DIG. 38

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Primary Examiner—J. Reed Fisher
Attorney—Flynn and Frishauf

[57] **ABSTRACT**

A method for forming an electrical circuit on a substrate by printing wherein a fluid ink material which consists of a resin solution and one of insulating, dielectric and conductive materials in powder dispersed in the solution is used. The ink material is replaced from an integlio plate to a silicone rubber transcriber and then printed on the substrate.

4 Claims, 12 Drawing Figures

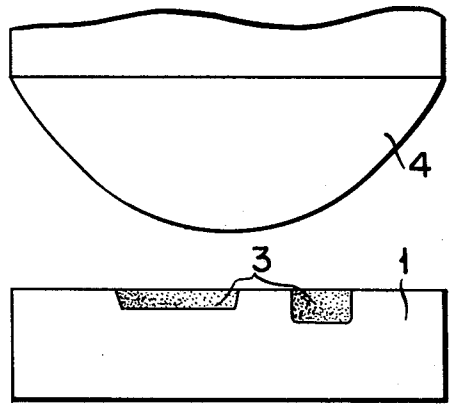


FIG. 1A

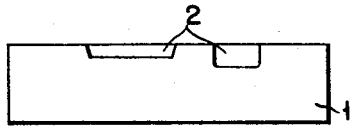


FIG. 1B

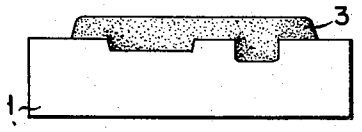


FIG. 1C

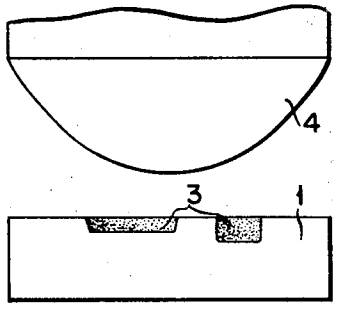


FIG. 1D

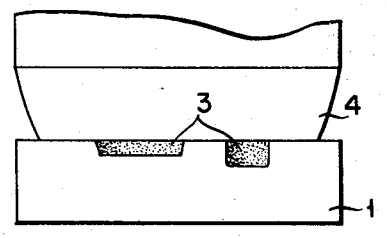


FIG. 1E

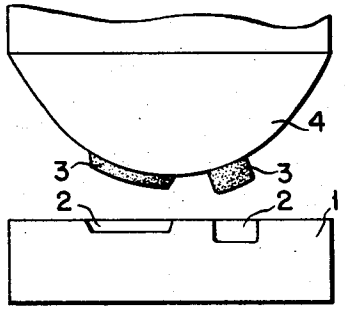


FIG. 1F

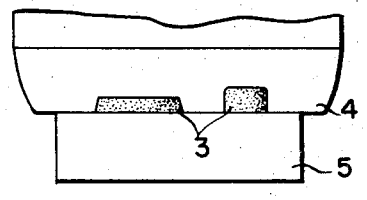


FIG. 1G

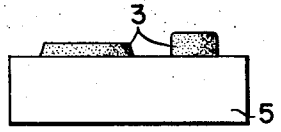


FIG. 2

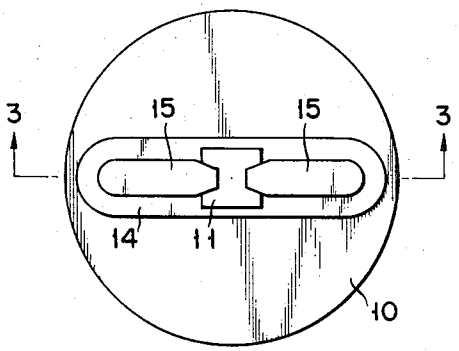


FIG. 3

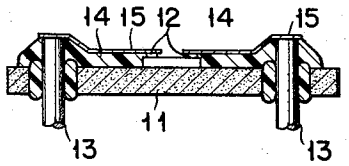


FIG. 4

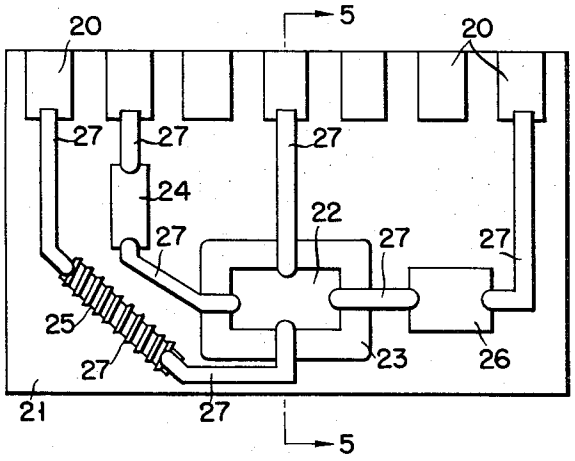


FIG. 5

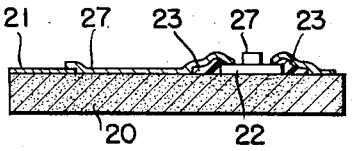
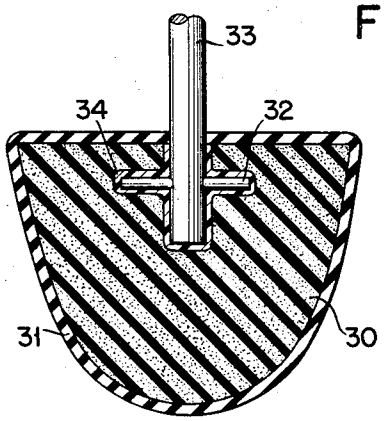


FIG. 6



METHOD FOR PRINTING ELECTRICAL CIRCUITS ON SUBSTRATES

CROSS-REFERENCE TO RELATED APPLICATION

This is a Continuation-in-part of U.S. application SER No. 720,040, filed Apr. 10, 1968 which has been abandoned.

The present invention relates to a method for printing an electrical circuit on the surface of a substrate, using fluid ink having the prescribed electrical properties.

The employment of printing techniques in forming an electrical circuit on the surface of a substrate is well known, and is already established as a print wiring method. This printing method comprises depositing ink material of the prescribed electrical properties on the surface of a substrate through both a stencil sheet carrying the prescribed print pattern and a fine screen for supporting the stencil sheet evenly. However, where a surface to be printed is not flat, this method fails to form a good print pattern so that it is not adapted for the formation of a stereometric circuit with an irregular surface, for example, a hybrid integrated circuit. Another drawback of the screen print is a prominent tendency toward the occurrence of repelling caused by the attachment of part of the ink to the screen meshes. If printing is carried out through a screen in which repelling has appeared the resultant print pattern will fail to have the prescribed electrical properties.

On the other hand, a conductive ink material already proposed for use in the formation of an electrical circuit by screen printing consists of a synthetic resin solution containing silver powders 10 to 60 microns in particle size. This known ink material comprises a binder usually consisting of epoxy compounds and a curing agent of amine compounds therefor. Due to the high hydrophilic character of the amine compounds, however, the print circuit formed from such ink is sensitive to variations in humidity.

The present invention provides a method for printing electrical circuits on substrates which comprises the stage of filling into recesses in an intaglio printing plate corresponding to the prescribed circuit pattern an ink material formed from one of insulating, dielectric and conductive materials in powders and a binder component consisting of a synthetic resin solution, transposing the filled ink onto the surface of a silicone rubber transcriber by pressing it to the surface of the intaglio printing plate and after removal, again pressing the transcriber to the surface of a substrate so as to replace the transcribed ink onto the surface of the substrate.

The present invention enables the ink transposed to the surface of the transcriber in the prescribed pattern to be tightly attached to the surface of the substrate due to the elasticity of the transcriber, even where there are irregularities on the surface of the substrate and consequently an electrical circuit to be formed on the surface of the substrate in exact conformity to the prescribed pattern. When printed on the surface of the substrate to form an electrical circuit, the ink containing any of the powdered insulating, dielectric and conductive materials will produce on said surface an insulating, dielectric or conductive member according to the kind of material contained.

Unlike the screen printing method, the present invention enables the ink pattern formed in the recesses of an intaglio printing plate to be directly transposed onto the substrate without passing through a screen, thus permitting elaborate and complicated patterns to be formed. Coupled with the possibility of forming a print circuit on a substrate having an irregular surface, the aforementioned fact is an important factor to render the present invention well adapted particularly for the preparation of a hybrid integrated circuit.

This invention can be more fully understood from the following detailed description when taken in connection with reference to the accompanying drawings, in which:

FIGS. 1A to 1G are profiles showing the sequential steps of the printing method according to the present invention;

FIG. 2 is a plain view of an electrical part provided with an electrical circuit prepared according to the invention;

FIG. 3 is a section taken along the line 3—3 in FIG. 2;

FIG. 4 is a plain view of another electrical part provided with an electrical circuit prepared according to the invention;

FIG. 5 is a section taken along line 5—5 in FIG. 4; and

FIG. 6 is a section of a silione rubber transcriber used in this invention.

There will now be described the present invention by reference to the accompanying drawings. Throughout FIGS. 1A to 1G, reference numeral 1 indicates an intaglio printing plate having a depressed circuit pattern 2 formed on the surface. 3 and 4 respectively are an ink material and a silicone rubber transcriber. The transcriber 4 has an outwardly curved surface, which is used in the transcription of ink.

First on the surface of the intaglio printing plate 1 is spread a sufficient amount of ink material 3 to fill up recesses 2 provided therein. Excess amounts of the ink are removed by a proper cleaning means. (FIGS. 1A to 1C). The silicone rubber transcriber 4 is pressed on the surface of the intaglio printing plate 1. As described above, the transcription surface of the transcriber 4 is outwardly curved at ordinary times. However, when the elastic transcriber 4 is pressed on the intaglio printing plate 1 with an adequate magnitude of pressure, the curved surface of the transcriber 4 is closely attached to the surface of the intaglio printing plate 1 within the prescribed area of the latter. When the transcriber 4 is removed from the intaglio printing plate 1, the ink 3 filled into the recesses 2 of the plate 1 is transferred to the transcription surface of the transcriber 4 (FIG. 1E). The transcriber 4 now carrying the ink 3 is pressed on the surface of a substrate 5 to be printed with sufficient pressure tightly to replace the ink 3 onto the surface of the substrate 5 (FIG. 1F). Finally, the transcriber 4 is taken off the substrate 5. The foregoing operation produces, as shown in FIG. 1G, a circuit pattern on the surface of the substrate.

The ink material used in the printing of an electrical circuit according to the present invention is in a pasty form of adequate viscosity. This viscosity has a close bearing on the ease of transcribing the ink from the intaglio printing plate to the transcriber and then to the

substrate, and varies with the kinds and proportions of synthetic resins and solvents used. It has been experimentally disclosed that the ink has the best transferability when it has an apparent viscosity of more than 20,000 centipoises and a dilatant fluidity as measured by a reometer.

The synthetic resins used in the present invention include phenol resins, rosin-modified phenol resin, glycerine modified rosin phenol resin, pentaerythritol-modified phenolated alkyd resin, vinyl alkyd resin, oil-modified alkyd resin, melamine resin, silicon-modified melamine resin; and silicon resin and the like. The resin is present in the ink material in an amount of from about 4 to about 18 percent by weight. Suitable solvents are, for example, ethylene glycol (197.2°C) (The numeral shown in parentheses denotes a melting point. This applies hereinafter), diethylene glycol (244.5°C), propylene glycol (187.4°C), dipropylene glycol (230°C), hexylene glycol (120° to 197°C), polyethylene glycol (195° to 200°C), diethylene glycol monomethyl ether (194°C), diethylene glycol monethyl ether (202.2°C), diethylene glycol monobutyl ether (230°C), triethylene glycol monoethyl ether (255.4°C), tripropylene glycol monoethyl ether (230°- monomethyl C), tripropylene monethyl ether (255°C), ethyl cellosolve (135.1°C) and n-butyl cellosolve (171°C). From about 2 to about 25 percent by weight of solvent is used in the ink material.

The solvent should be removed from the ink after completion of printing on the substrate, because the solvent, if remaining in the ink, will degrade its electrical properties. Also where the ink is used in printing an electrical circuit on a substrate carrying a semiconductor element, the ink should be dried at as low temperatures as possible in order to prevent the deterioration of the properties of the semiconductor element. On the other hand, if the solvent has too low a boiling point, the ink will be dried very rapidly, causing its viscosity to rise sharply before printing is completed. Therefore, it is preferable to select those solvents whose boiling point ranges between 120° and 280°C. The boiling points of the above-listed solvents fall within this range.

If the manufacture of a synthetic resin desired for use in the present invention already involves a solvent which is having a lower boiling point than the aforementioned range, then said solvent will be replaced by one whose boiling point falls within the aforesaid range of from 120° to 280°C. The replacement of solvents can be easily performed by adding a higher boiling solvent to a solution of synthetic resin and evaporating a lower boiling solvent with stirring at room temperature or with heat.

The ink material used in the present invention is formed from a solution of the aforementioned synthetic resins, to which is added any of powdered conductive, dielectric and insulating materials. Suitable conductive materials are metals of good conductivity such as silver, copper, aluminum, or carbon, these conductive materials being dispersed in a solution of synthetic resins in the form of powders having a particle size of, for example, 0.005 to 15 microns, or preferably 0.01 to 5 microns. The dielectric materials are, for example, barium titamate, strontium titanate, and the like, and the insulating materials may consist of aluminum oxide, silica and the like. These dielectric and insulating materials are introduced into the aforesaid solution of synthetic resins in the form of very fine powders as is the case with the conductive materials.

When the ink containing powders of a conductive material is printed in the prescribed pattern, it will have such electrical properties as can be utilized as a conductor or resistor. Provided the specific resistance of the conductive material is the same, the electric resistance of the pattern thus formed will vary with the particle size of the powdered conductive material as well as its proportion in the ink. This is true of the powders of dielectric and insulating materials. To form a resistor from such ink, it is generally preferred that the specific resistance of the ink film be of the order of 2×10^{-4} ohm-cm or higher after drying. On the other hand where a capacitance element is to be formed, the ink film is desired to have a capacity ranging from dozens of picofarads to several microfarads. To import such electrical properties to the ink film, it is required that the powders of conductive or dielectric material be contained in the ink at the rate of 45 percent by weight.

The proportions of powdered conductive, dielectric or insulating materials dispersed in an ink material affect the electrical properties and adaptability for printing demanded of said ink material. To obtain the good adaptability of ink for printing, it is necessary that the proportion of powders incorporated therein be 94 percent by weight or less. Therefore from the standpoint of the electrical properties and adaptability for printing of the ink material, the proportions of powders to be included therein are limited to a range of 45 to 94 percent by weight.

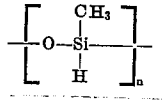
When the ink material which has been afforded the properties of a conductor, resistor or dielectric due to the introduction of the prescribed type of powders is printed on the surface of a substrate in the specified pattern, then there will be formed circuit parts functioning as a conductor, resistor, reactance element or insulator as the case may be. Consequently where ink patterns of different electrical properties are formed on the same surface of a substrate in laminates, if required, by inserting layer of separate insulating ink material between them, then it will be possible to construct a complicated electrical circuit in an extremely limited area.

FIGS. 2 and 3 present a semiconductor circuit element prepared by the printing method of the present invention. The circuit element comprises a disc-like stem 10, a semi-conductor element 11 fixed to the surface of the stem 10 and a pair of terminal lines 13 penetrating through the stem 10, the semiconductor element 11 having a pair of electrodes 12 provided on the upper surface thereof. On the surface of the stem 10 around the semiconductor element 11 and a pair of terminal lines 13 there are disposed an insulating layer 14 formed from an insulating ink material, and a conductive layer 15 for connecting the aforesaid electrodes 12 composed of a conductive ink material to the upper ends of the terminal lines 13. According to the printing method of the present invention, the assembly of the insulating layer 14 and conductive layer 15 is constructed by first forming the insulating layer 14 and then after it is dried, superposing the conductive layer 15 thereon.

FIGS. 4 and 5 present another electrical circuit prepared by the method of the present invention. This circuit element belongs to the group of hybrid integrated circuits. This embodiment involves a plastic or ceramic substrate **21** having a large number of terminals **20** formed on one transverse edge. In the central part of the substrate **21** is fixed a semiconductor element, for example, an integrated circuit element **22**. On the surface of the substrate **21** are printed various circuit parts in accordance with the prescribed circuit patterns. The circuit parts comprise an insulating layer **23** formed from an insulating ink material and covering the exposed surface of the substrate **21** and the sides of the integrated member **22**, a resistor layer **24** consisting of an ink material having a prescribed specific resistance, a coil member **25** comprised of a conductive ink material, a condenser layer **26** composed of dielectric and insulating ink materials and a plurality of conductive layers **27** prepared from a conductive ink material.

The circuit elements shown in FIGS. **2** to **5** cause irregularities on the surface of the substrate on which an electrical circuit is to be constructed. The printing of an electrical circuit on such an uneven substrate surface was deemed difficult or impossible with the conventional screen printing techniques. In contradistinction to this, it has been confirmed that the present invention enables printing on an irregular surface to be carried out with considerable ease.

It has been disclosed that the ink material used in the present invention will be prominently improved in transferability and adhesivity to the substrate surface, if it contains 0.02 to 5 percent by weight of cyclic polymethylsiloxane expressed by the general formula below:



(where *n* is an integer from 3 to 6)

An ink material of good transferability and adhesivity permits the printing of a more elaborate circuit pattern. Further, the addition of the aforementioned cyclic polymethylsiloxane will render the resultant ink film for more resistant to humidity than in the case where its use is omitted. On the other hand, to limit the adhesivity of ink material to the intaglio printing plate, it is permissible to treat the surface of the plate with the above-mentioned polymethylsiloxane.

The thickness of an ink film to be printed on the substrate surface is substantially defined by the depth of recesses provided in the intaglio printing plate. Namely, accordingly as it is desired to print a thick or thin ink film on the substrate surface, there is formed a deep or shallow recess in the intaglio printing plate. However, the depth of the recess affects the electrical properties of the circuit pattern printed. In other words, too thick an ink film deposited on the transcriber will cause excess ink material to run out of the prescribed pattern when the transcriber is pressed to the substrate. Conversely, where the film is too thin, there will appear within areas of different electrical properties, even though the film may initially be prepared from a single kind of ink material. It has been experimentally found that the printing of an ink film of good electrical properties in a clear-cut pattern can be effected if the film has a thickness of 3 to 75 microns, or preferably 10 to 50 microns. However, where an additional insulating material is used to ensure the insulation of an electrical circuit or the end portions of a semiconductor element the overall thickness of a film printed will be allowed to be 1,000 microns max.

It is necessary that the transcriber used in the invention should be formed of silicone rubber at least at its surface contacting ink material. Experiments show a defect that the use of an elastic material other than silicone rubber, such as natural or synthetic rubber, will decrease the adhesivity of the ink material onto the transcriber, so that a sufficient amount of the ink fed in the recesses formed in the intaglio printing plate will not be transferred onto the transcriber surface, or will greatly increase the adhesivity causing it impossible to transfer the entire amount of the ink adhered on the transcriber surface to the substrate surface.

The arrangement of one example of the transcriber which may preferably used in the invention is illustrated in FIG. **6**.

The reference numeral **30** indicates a sponge silicone rubber with its bottom surface outwardly curved. The entire surface of the sponge silicone rubber **30** is covered with a thin layer of silicone rubber **31**. In the body of the rubber **30** is partly inserted a bar **33** having branches **32**, through which power is transmitted to the transcriber. The connection between the bar **33** and the sponge silicone rubber **30** may be effected using a silicone bonding agent **34**, such for example as, PTV 731 produced by Dow Corning Co. The silicone rubber **31** may be deposited on the sponge silicone rubber **30** without a particular bonding agent, since a part of the silicone rubber **31** may serve as a bonding agent when it is introduced into open cells of the sponge silicone rubber **30**.

Preferred example of the silicone rubber **31** include 601RTV, 860RTV, 881RTV, 882RTV, 40C, A–400, Silastic 140, Silastic 731RTV and Silastic 732RTV of Dow Corning, and TSE211-4u, TSE211-5u, TSE211-6u, TSE211-7u, TSE211-8u, TSE220-5u, TSE220-7u, TSE240-5u and TSE240-6u of Tokyo Shibaura Electric Co., Ltd., Japan, which are to be used in combination with a valcanization agent such as CE50, CE51, CE52, CE53 marketed by Tokyo Shibaura Electric Co., Ltd. Examples of the sponge silicone rubber **30** include those marketed under the name TSE250U and YE3086 by Tokyo Shibaura Electric Co., Ltd.

Provided that the surface of the transcriber is formed of silicone rubber, the inner elastic body is not restricted to sponge silicone rubber, but may be formed of other synthetic rubber, such as, foamed urethane, natural rubber, butadiene rubber or styrene-butadiene rubber.

As described above, the inside of the transcriber is formed of soft and easily deformable sponge silicone rubber, the transcriber is particularly advantageous for printing electrical circuits over a large space. For example, when a relatively long conductor having a

length of 25mm and a width of 100 microns is to be printed with a conductive ink, the use of the transcriber made entirely of silicone rubber will result in insufficient printing at both ends of the printed conductor due to the great hardness of the transcriber, so that the conductor produced will have a widely varied resistance value of about 4Ω to 10 KΩ and often tends to incapable of being conductive. In contrast the transcriber of the construction as shown in FIG. 6 will produce a conductor of a resistance value of about 1.7 Ω, so that stable printing is possible. When an electrical circuit is to be printed on a narrow space, it is unnecessary that the inside of the transcriber is necessarily formed of a soft, readily deformable material, such as, sponge silicone rubber, as shown in FIG. 6, and the entire structure may be formed solely of silicone rubber. Further, the transcriber used in this invention is applicable for transferring a colored, low melting point glass powder onto a glass surface in the form of ink.

There will now be described the electrical properties of films formed on the substrate surface from various kinds of ink material according to the process of the present invention, using an intaglio printing plate carrying recesses 0.1 mm wide, 10 microns thick, and 3.5 mm long. After printing, the ink film was measured for its electrical properties, for example, resistance by being dried 30 minutes at 150°C. The measurements given below represent the average values of a large number of films prepared under the same conditions, the percentage shown opposite to the values of resistance denoting the extent of variations therein.

1. Silver powders		
(average particle size 5 microns; particle size distribution 0.01 to 15 microns)	62	wt %
Rosin-modified phenol resin[a]		
(average particle size 5 microns)	18	"
Dipropylene glycol	6.0	"
Glycerine	14	"
Resistance	1.8 ohm ± 10 %	

a: HITANOL 30G, marketed by Hitachi Kasei Co., Ltd., Japan, having the following properties:

Softening point (ASTME 28)	126°–135°C.
Acid Number	10–20

2. Silver powders	75	wt %
(average particle size 5 microns)		
Rosin-modified phenol resin[b]	9.0	"
Pentaerythritol	7.0	"
Diethylene glycol monobutyl ether	7.0	"
Resistance	1.5 ohm ± 8 %	

b: HITANOL 50G (same marketer as *a*), having the properties:

Softening point (ASTME 28)	146°–155°C.
Acid Number	10–20

3. Silver Powders		
(average particle size 5 microns)	85	wt %
Phenol resin[c]	10	"
Propylene glycol	5.0	"
Resistance	1.1 ohm ± 8 %	

c: Product number AP–107 of Gunei Chemical Co., Ltd., which dissolves in alcohol and has excellent moisture-proofing proofing properties and electrical insulating character. It has a viscosity, at 25°C., of 100–300 centipoises. Non-volatile materials comprise 58–62 percent by weight.

4. Silver powders		
(average particle size 5 microns)	60	wt %
Rosin-modified phenol[d]	15	"
Dipropylene glycol	6.0	"
Glycerine	14	"
Resistance	2.0 ohm ± 12 %	
5. Silver powders		
(average particle size 5 microns)	78	wt %
Phenolated alkyd resin[d]	12	"
Dipropylene glycol	5.0	"
Ethyl cellosolve	5.0	"
Resistance	1.5 ohm ± 10 %	

d: HARIPHTHAL 193 HV, marketed by Harima Kasei Co., Japan, having the following properties:

Phthalic anhydride content, wt %	33
Acid Number (varnish)	<8
Non-volatile matter, wt %	55 ± 1

6 Silver powders		
(average particle size 5 microns)	90	wt %
Rosin-modified phenol resin[a]	6.0	"
Diethylene glycol monobutyl ether	4.0	"
Resistance	0.7 ohm ± 10 %	
7. Silver powders		
(average particle size 5 microns)	94	wt %
Rosin-modified phenol resin[a]	4.0	"
Ethyl cellosolve	2.0	"
Resistance	0.6 ohm ± 8 %	

The following measurements relate to ink materials containing polymethylsiloxane. To disclose the resistance to humidity of the film formed from such ink material, the measurements are concerned with the electrical properties displayed in an atmosphere of high temperature and humidity.

8. Silver powders		
(average particle size 5 microns)	70	wt %
Rosin-modified phenol resin[b]	20	"
Diethylene glycol monobutyl ether	5.0	"
Polymethyl siloxane (30 % solution in toluene)	5.0	"
Resistance:		
After drying	1.4 ohm ± 10 %	
After 25 hr. at 50°C 65 % R.H.	1.6 ohm ± 11 %	
9. Silver powders		
(average particle size 5 microns)	75	wt %
Melamine resin[e] (50 % solution in butyldioxytol)	18	"
Polymethylsiloxane (30 % solution in toluene)	7.0	"
Resistance:		
27°C, 65 % R.H.	1.5 ohm ± 10 %	
After 25 hr. at 50°C, 80 % R.H.	1.7 ohm ± 12 %	

e: MELAN 20, marketed by Hitachi Kasei Co., Ltd., having the properties:

Acid Number	<0.5
Density, 20°C.	0.98–1.00
Non-volatile matter, wt %	50 ± 2
Solvent	butanol or xylene

10 Silver powders		
(average particle size 5 microns)	75	wt %
Rosin-modified phenol resin[b]	9.0	"
Pentaerythritol-modified phenol resin	9.0	"
Butyl carbitol	6.9	"
Polymethylsiloxane (30 % solution in toluene)	0.1	"
Resistance:		
27°C, 65 % R.H.	1.5 ohm ± 10 %	
After 24 hr. at 50°C, 80 % R.H.	1.7 ohm ± 12 %	
11. Silver powders		
(average particle size 5 microns)	80	wt %
Rosin-modified phenol resin[b]	15	"
Butyl carbitol	3.0	"
Polymethylsiloxane (30 % solution in toluene)	2.0	"
Resistance:		
27°C, 65 % R.H.	1.8 ohm ± 12 %	
After 24 hr, at 50°C, 80 % R.H.	2.0 ohm ± 15 %	
12. Silver powders		
(average particle size 5 microns)	75	wt %
Rosin-modified phenol resin[a]	18	"
Butyl carbitol	5.0	"
Polymethylsiloxane (30 % solution in toluene)	2.0	"
Resistance:		
27°C, 65 % R.H.	1.4 ohm ± 10 %	
After 24 hr. at 50°C, 80 % R.H.	1.5 ohm ± 10 %	

The following measurements were made on the ink films formed from a solution of synthetic resin whose low boiling solvent was replaced by another solvent boiling within the range of 120° to 280°C. Each film was satisfactorily bonded with the substrate and displayed the prescribed electrical properties.

13. **Silver powders**

	(average particle size 5 microns)	82	wt %
	Melamine resin[e]		
	(50 % solution in butyl carbitol)	18	"
	Resistance	1.7 ohm ± 12 %	
14.	Silver powders		
	(average particle size 5 microns)	75	wt %
	Resistance	1.4 ohm ± 13 %	

[f] Product Number TSR-144, marketed by Tokyo Shibaura Electric Co., Ltd., Japan, having the following properties:

Density, 25°C	1.01 ± 0.02
Viscosity, 25°C, poise.	0.5 to 1.5
Non-volatile matter, wt %	50 ± 2
Solvent	xylene or toluene

15.	Silver powders		
	(average particle size 5 microns)	70	wt %
	Melamine resin[e]		
	(50 % solution in dipropylene glycol)	30	"
	Resistance	1.4 ohm ± 11 %	

The following examples relate to insulating layers.

16.	Barium titanate powders		
	(average particle size 5 microns; particle size distribution 0.1 to 10 microns)	45	wt %
	Silicone resin[f]		
	(50 % solution in dipropylene glycol)	55	"
17.	Aluminum oxide powders		
	(average particle size 2 microns; particle size distribution 0.01 to 5 microns)	60	wt %
	Melamine resin[e]		
	(50 % solution in butyldioxytol)	40	"

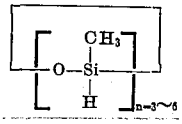
The present invention enables a good electrical circuit to be printed even on an irregular surface of a substrate. However, where the difference between the maximum and minimum heights of the substrate surface exceeds 90 microns then there will appear discontinuous areas in the film printed on the border line between these heights. Therefore, where it is desired to print an ink film in a manner to cover both the substrate surface and the surface of a semiconductor element, for example, a transistor element, integrated circuit element, thermistor or capacitor fitted to the substrate surface, then it is preferable to coat the sides of such element with an insulating ink material so as to smooth out the gap between the surfaces of the element and substrate.

As mentioned above, provided the difference in height between the irregularities on the substrate surface, does not exceed 90 microns, the process of the present invention enables circuit parts of the prescribed electrical properties to be easily printed on such surface, so that it is excellently adapted for the formation of an electrical circuit, for example, a hybrid integrated circuit which is demanded to have an extremely elaborate pattern. And the resultant electrical circuit has a far higher degree of reliability than that obtained by the prior art screen printing.

What is claimed is:

1. A method for printing electrical circuits on substrates comprising the steps of

filling into recesses in an intaglio printing plate corresponding to the prescribed circuit pattern an ink material formed from 45–94 parts by weight of at least one material selected from the group consisting of insulating, dielectric and conductive powders, 6–55 parts by weight of a solution of a synthetic resin, and a cyclic polymethylsiloxane having the general formula



pressing a silicone rubber transcriber to the surface of the intaglio printing plate and upon removal replacing the ink onto the surface of the transcriber, and

again pressing the transcriber to the surface of a substrate so as to transpose the ink deposited on the transcriber surface onto the surface of the substrate, said powders having an average particle size ranging from about 0.005 to about 15 microns, said resin solution comprising 4–18 parts by weight of a resin selected from the group consisting of a phenol resin, a rosin-modified phenol resin, a glycerin-modified-rosin phenol resin, a pentaerythritol-modified phenolated alkyd resin, a vinyl alkyd resin, an oil-modified alkyd resin, a melamine resin, a silicone-modified melamine resin, and a silicone resin, in 2–25 parts by weight of a solvent selected from the group consisting of a glycol and a glycol ether having a boiling point from about 135°C. to about 255°C., and said cyclic polymethylsiloxane being from about 0.02 to 5 percent by weight of said resin solution.

2. A method according to claim 1 wherein the substrate has a semiconductor element fixed to one side thereof, the sides of the semiconductor element are coated with an insulating material.

3. A method according to claim 2 wherein the semiconductor element is a transistor.

4. A method according to claim 2 wherein the semiconductor element is a hybrid integrated circuit.

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