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(54) Title: FORCE SENSITIVE RESISTOR UV INK

(57) Abstract: The present invention relates to radiation curable coatings for use in a printing and/or moulding process. More particularly, the present invention relates to pressure sensitive force sensing resistor formed from radiation curable coatings in the form of 100% or substantially 100% solids radiation curable coatings for use in a printing and/or moulding process wherein a substrate is printed with a wet radiation curable photopolymer to form images such as electrical circuits or other features used in the manufacture of sensors and touch sensors such as for example lines, squares, spirals, circles, or other geometric and non-geometric shapes. These are then coated directly on to a sensor with a radiation curable FSR ink to create a pressure sensitive electrode which can be used to control hand held or other devices.



FORCE SENSITIVE RESISTOR UV INK

FIELD OF THE INVENTION

The present invention relates to radiation curable coatings for use in a printing and/or moulding process. More particularly, the present invention relates to pressure sensitive force sensing resistor formed from radiation curable coatings in the form of 100% or substantially 100% solids radiation curable coatings for use in a printing and/or moulding process wherein a substrate is printed with a wet radiation curable photopolymer to form images such as electrical circuits or other features used in the manufacture of sensors and touch sensors such as for example lines, squares, spirals, circles, or other geometric and non-geometric shapes. These are then coated directly on to a sensor with a radiation curable Force Sensitive Resistor (FSR) ink to create a pressure sensitive electrode which can be used to control hand held or other devices

BACKGROUND OF THE INVENTION

In the prior art current water based and solvent based FSR ink technology cannot be printed directly on to a sensor circuit without the circuit remaining permanently on. The present invention addresses this problem and seeks to print radiation curable FSR ink directly onto a sensor arrangement printed on a plastic substrate e.g. polyester and then cured.

The present invention therefore addresses the problem of providing an improved method of forming pressure sensitive force sensing resistor formed from radiation curable coatings.

It is therefore an object of at least one aspect of the present invention to at least obviate or mitigate problems found in the prior art.

It is a further object of at least one aspect of the present invention to provide an improved method of forming pressure sensitive force sensing resistors.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided a curable photopolymer comprising:

- a curable resin present in an amount of 10% to 80% by weight;
- a mix of conductive particles between 0.2% and 30% by weight;
- at least one filler between 1% to 15% by weight;
- at least one photoinitiator between 1% and 12% by weight;
- at least one additive between 0.1% and 2.5% by weight;

wherein the curable photopolymer is capable of being cured with energy of less than about 1,000 mJ and where there is no pre-drying prior to curing or imaging in a photoimaging

process.

The present invention provides an improved method of forming a radiation curable photopolymer which is capable of functioning as a pressure sensitive force sensing resistor when coated directly onto the electrode arrangement such as in Figure 1 and Figure 2.

5 Herein a Force Sensitive Resistor (FSR) is a material whose resistance changes when a force or pressure is applied.

The force-sensing resistors of the present invention may consist of a conductive polymer, which changes resistance in a predictable manner following application of force to its surface.

10 The conductive polymer may comprise both electrically conducting and non-conducting particles suspended in a matrix.

The particles may be sub-micron such as in the nanometre range in size, and may be formulated to reduce the temperature dependence, improve mechanical properties and increase surface durability.

15 Applying a force to a surface of the sensor may cause particles to touch conducting electrodes, changing the resistance of the force sensing resistor.

The UV radiation curable ink used to form the curable photopolymer also inherently shows a wide variation of electrical resistance upon mechanical deformation allowing the use of 2D and 3D force sensors and sensor matrices on both rigid and flexible substrates to be used for example in embedded sensor applications or touch interactive surfaces or even printed strain gauges and other sensing equipment. The UV curable photopolymer of the present invention may therefore be described as a Force Sensitive Resistor ink.

The radiation curable FSR ink may be printed directly onto a sensor arrangement.

25 The FSR ink may be printed separately on a plastic substrate e.g. polyester and then brought into contact with radiation energy.

The UV curable FSR ink may have high resistance in the steady state. The resistance may drop with pressure touch sufficiently to allow activation of a control circuit.

The UV curable FSR ink may be essentially 100% solids and may cure with any UV combination of light sources (from 200 nm – 420 nm wavelength).

30 The FSR ink may therefore be printed directly onto a plastic surface such as polyester and then brought into contact with UV radiation. The printed FSR ink may have high resistance in the steady state and the resistance may drop with pressure touch sufficiently to allow activation of a control circuit.

The FSR ink may show resistance drops in-line with insulation resistance.

35 The FSR ink may show resistance drops proportionally with activation resistance

The FSR ink may show that the resistance changes proportionally with force and that that force change is suitable to allow fine voltage control such as in a hand held device or console such as in a car or touch screen.

The said FSR ink can be integrated in 3 different states:

- 5 a. Adhere FSR ink sensor circuit onto a sheet of ThermoPlastic Elastomer (TPE)
- b. 2D TPE can over mould as FSR ink sensor circuit
- c. 3D TPE can over mould as FSR sensor circuit

10 The FSR ink may be suitable for printing with a range of processes including but not restricted to: screen; flexographic; lithographic; gravure; ink jet; letterpress; intaglio; rotogravure and rotary screen.

The conductive particles may be in a variety of forms including any one of or a mixture of any of the following: graphite; graphene; graphene oxide; modified graphene; metal oxides; carbon black; carbon nanotubes both single walled and multi-walled; PEDOT:PSS and PEDOT-TMA.

15 The conductive particles may have a sub-micron size.

Typically, the conductive particles may have a size of about 0.1 – 500 nm; 0.1 – 200 nm; 0.1 – 100 nm or 0.1 – 50 nm.

The photoinitiator may be capable of initiating crosslinking in the curable photopolymer.

20 The photoinitiator may initiate the crosslinking of the material and may be selected from any one of or combination of the following: 1-hydroxy-cyclohexyl-phenylketone; 2-hydroxy-2-methyl-1-phenyl-1-propanone; 2-hydroxy-1-[4-(2-hydroxyethoxy)phenyl]-2-methyl-1-propanone; alpha-dimethoxy-alpha-phenylacetophenone; 2-benzyl-2-(dimethylamino)-1-[4-(4-morpholinyl)-1-butanone]; 2-methyl-1-[4-(methylthio)phenyl]-2-(4-morpholinyl)-1-propanone; diphenyl(2,4,6-trimethylbenzoyl)-phosphine oxide; phosphine oxide; phenyl bis(2,4,6-trimethyl benzoyl); phosphine oxide iodonium and (4-methylphenyl)[4-(2-methylpropyl)phenyl]- hexafluorophosphate.

25 The photoinitiators may initiate the crosslinking of the material and may be selected from any one of or combination of the following: 2,4,6- triorganobenzoyldiarylphosphine oxides; 2,4,6-trimethylbenzoyldiphenylphosphine oxide; 2,4,6-triethylbenzoyldinaphthylphosphineoxide; 2,4,6-triorganobenzoyl diorganophosphonates, such as, 2,4,6-trimethylbenzoyl diethylphosphonate and 2,4,6- triethylbenzoyl diphenylphosphonate; 2,4,6-triorganobenzoyldiarylphosphine sulfides, such as 2,4,6-trimethylbenzoyldiphenylphosphine sulfide commercially available under the Irgacure or Darocur trademarks from BASF; mixed arylsulfonium hexafluoroantimonate salts; mixed arylsulfonium hexafluorophosphate salts, commercially available under the Cyracure trademark from Dow Chemical; benzophenone; 4-phenyl benzophenone; 4-methyl benzophenone; 2-isopropyl thioxanthone; 2-chlorothioxanthone; 2,4-diethylthioxanthone; commercially available under the Omnirad trademark from IGM resins.

The curable photopolymer may be included in the curable photopolymer to initiate the crosslinking of the material and are selected from any one of or combination of the following: 2- dimethylamino-ethylbenzoate; ethyl-4-(dimethylamino)benzoate; 2-ethyl-4-(dimethylamino)benzoate; isoamyl 4-(N,N-dimethylamino)benzoate commercially available from under the Omnirad trademark from IGM resins.

The photoinitiators may be present in the range of about 0.1% to about 15% or about 0.1% to about 1.5% weight on weight of the composition for cationic coatings and preferably in the range of about 8.0% to about 10.0% weight on weight of the composition for free radical coatings.

The at least one additive may comprise a wetting agent and may be capable of providing any one of or combination of the following: humidity resistance; surface wetting and levelling properties which enables the curable photopolymer to be evenly spread onto a surface where imaging is to occur.

The additive may also comprise an adhesive agent.

The adhesive agent may be capable of providing adhesion for the bonding of the curable photopolymer to various substrates including metals, glass and plastics.

The additive may be present in an amount from 0.1% and 2.5% by weight; 0.1% and 2% by weight; 0.1% and 1% by weight; 0.1% and 0.5% by weight.

The curable photopolymer may be all solids or substantially all solids and is therefore solvent free or substantially solvent free with no volatile organic content.

The curable photopolymer may comprise less than about 1% solvent, less than about 3% solvent, less than about 10% solvent or less than about 15% solvent curable photopolymer.

The curable photopolymer may be cured with energy of about 0 - 20 mJ, about 0 - 50 mJ, about 50 - 500 mJ or about 100 - 1,000 mJ.

The curable photopolymer may be cured with a very low energy radiation in the range of about 0.5 - 20 mJ or about 1.5 mJ - 2.0 mJ.

The curable photopolymer may be cured with energy of wavelength from about 200 nm to about 500 nm, about 365 nm to about 415 nm or about 395nm to about 405nm.

The curable photopolymer may have good adhesion to copper, polyester, FR4, glass and polyimide substrates.

The curable photopolymer may also comprise any one of or combination of the following: UV or visible light or IR photoinitiator(s); UV curable resin(s); acrylate and/or methacrylate monomer(s); UV stabilizers; rheology modifier(s); adhesive promoter(s) and/or self-levelling agent(s).

The curable photopolymer may also comprise aromatic ketones (e.g. Methylbenzoyl formate and 1-Hydroxycyclohexyl phenyl ketone).

The curable resin may be present in an amount of 5% to 60% by weight or 10% to 30% by weight of the curable photopolymer.

The curable resins may be selected from any one of or combination of the following: aliphatic linear polyether urethane acrylate; aliphatic polyester urethane acrylate; and polyester acrylated monomer blends with fast cure characteristics.

The curable resins may be UV curable resins selected from any one of or combination of the following: pentaerythritol tri/tetra-acrylate (PETA); trimethylolpropane triacrylate (TMPTA); trimethylolpropane ethoxy triacrylate (TMPEOTA); hexamethylene diacrylate (HDDA); Dipropylene glycol diacrylate (DPGDA); tripropylene glycol diacrylate (TPGDA); Isobornyl acrylate (IBOA) and Hexylethyl acrylate (HEA).

The curable resins may be selected from any one of or combination of the following: isobornyl acrylate; cyclohexyl acrylate; tert-butyl acrylate; 2-ethylhexyl acrylate; dicyclopentenyl acrylate; tetrahydrofurfuryl acrylate; cyclic trimethylolpropane formal acrylate and vinyl caprolactam.

The curable resins may be selected from acrylate monomers which are monofunctional and multifunctional acrylates e.g. methacrylate monomers which are monofunctional and multifunctional methacrylates.

The curable photopolymer may also comprise any one of or combination of the following to improve adhesion to metal or glass surfaces: Acrylic acid; CEA; Epoxy Silane and Trifunctional acid esters.

The curable photopolymer may also comprise any one of or combination of the following wetting agents in the range of about 0.1% to about 5% w/w:

- a. a blend of acrylate copolymers;
- b. polyether modified polydimethylsiloxane;
- c. polyether modified dimethylsiloxane;
- d. polyether modified polydimethylsiloxane;
- e. polyether modified dimethylsiloxane;
- f. polymeric dispersant;
- g. polymeric dispersant; and
- h. polyether amino acid polyamine derivative;

The curable photopolymer may also comprise any one of or combination of the following:

- a. surfactants;
- b. antioxidants;
- c. thixotropes;
- d. dilatants;
- e. reinforcement materials;
- f. silane functional perfluoroether;
- g. phosphate functional perfluoroether;

- h. silanes;
- i. titanates;
- j. wax;
- k. air release agents;
- l. flow additives;
- m. adhesion promoters;
- n. rheology modifiers;
- o. surfactants; and
- p. spacer beads

The curable photopolymer may further comprise the following:
resins in the amount of 10% to 60% by weight e.g. acrylate and/or methacrylate monomers;

photoinitiators 2% to 12% by weight;
levelling agents 0.3% to 1% by weight; stabilizers 0.1% to 0.5% by weight;
adhesion promoters 5% to 10% by weight;
rheology modifiers 0.1% to 5.0% by weight; and
wetting agents 0.01% to 0.5% by weight.

The curable photopolymer may comprise:

about 1 w/w% to 60 w/w% of an acidic acrylate monomer;
about 1 w/w% to 50 w/w% of a urethane acrylate monomer;
about 25 w/w% to 90 w/w% of di-, tri- and hexa-acrylate monomer consisting essentially of a mixture of about 20 w/w% to 90 w/w% of hexanediol diacrylate; and about 10 w/w% to 80 w/w% of a mono-functional branched or carbocyclic acrylate; and about 1 w/w% to 15 w/w% of a photoinitiator or blend of photoinitiators.

According to a second aspect of the present invention there is provided a cured photopolymer as described in the first aspect in a control circuit, hand held device or console such as in a car or touch screen.

A user may press and apply pressure to the cured photopolymer to change the resistance of the force sensing resistor and thereby change the operation of the device.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example only, with reference to the following Figures:

Figure 1 relates to a radiation curable photopolymer which is capable of functioning as a pressure sensitive force sensing resistor when coated directly onto the electrode arrangement according to an embodiment of the present invention;

Figure 2 relates to a radiation curable photopolymer which is capable of functioning as a pressure sensitive force sensing resistor when coated directly onto the electrode arrangement according to a further embodiment of the present invention;

Figures 3 relates to inks which were coated using a lab screen printer with mesh using the template of Figure 1 according to an embodiment of the present invention;

Figure 4 relates to inks which were coated using a lab screen printer with mesh using the template of Figure 2 according to a further embodiment of the present invention; and

Figure 5 relates to FSR Sensor arrangements where pressure was brought to bear on the FSR using an Instron 3342 increasing step by step the pressure from 0N to 100N.

BRIEF DESCRIPTION

There is herein described a UV curable photopolymer which is capable of functioning as a pressure sensitive force sensing resistor in the form of a sensor.

The force-sensing resistor consists of a conductive polymer, which changes resistance in a predictable manner following application of force to its surface. The conductive polymer comprises both electrically conducting and non-conducting particles suspended in a matrix.

The particles are sub-micron such as in the nanometre range in size, and may be formulated to reduce the temperature dependence, improve mechanical properties and increase surface durability.

Applying a force to a surface of the sensor causes particles to touch conducting electrodes, changing the resistance of the force sensing resistor.

The UV curable ink used to form the curable photopolymer also inherently shows a wide variation of electrical resistance upon mechanical deformation allowing the use of 2D and 3D force sensors and sensor matrices on both rigid and flexible substrates to be used for example in embedded sensor applications or touch interactive surfaces or even printed strain gauges and other sensing equipment. The UV curable photopolymer of the present invention may therefore be described as a Force Sensitive Resistor ink.

The FSR ink is printed separately on a plastic substrate e.g. polyester and then brought into contact with UV radiation.

The UV curable FSR ink is printed directly onto a sensor arrangement.

The UV curable FSR ink has high resistance in the steady state. The resistance drops with pressure touch sufficiently to allow activation of a control circuit.

The UV curable FSR ink is essentially 100% solids and cures with any UV combination of light sources (from 200 nm – 420 nm wavelength).

The FSR ink is therefore be printed directly onto a plastic surface such as polyester and then brought into contact with UV radiation.

The FSR ink shows resistance drops in-line with insulation resistance.

The FSR ink shows resistance drops proportionally with activation resistance

The FSR ink shows that the resistance changes proportionally with force and that that force change is suitable to allow fine voltage control such as in a hand held device or console such as in a car or touch screen.

The said FSR ink can be integrated in 3 different states:

- a. Adhere FSR ink circuit onto a sheet of ThermoPlastic Elastomer (TPE)
- b. 2D TPE can over mould as FSR ink circuit
- c. 3D TPE can over mould as FSR circuit

The FSR ink may be suitable for printing with a range of processes including: screen; flexographic; lithographic; gravure; ink jet; letterpress; intaglio; rotogravure and rotary screen.

The conductive particles may be in a variety of forms including any one of or a mixture of any of the following: graphite; metal oxides; carbon black; carbon nanotubes both single walled and multi-walled; PEDOT:PSS and PEDOT-TMA.

Figure 1 relates to an interdigitated sensor electrode 10. The interdigitated sensor electrode 10 comprises an enclosed area 14 within which there is the FSR print area 12. The radiation curable photopolymer is therefore capable of functioning as a pressure sensitive force sensing resistor when coated directly onto the electrode arrangement.

Figure 2 relates to a spiral sensor electrode 20. The spiral sensor electrode 20 comprises an enclosed area 124 within which there is the FSR print area 22 in a spiral form. The radiation curable photopolymer is therefore capable of functioning as a pressure sensitive force sensing resistor when coated directly onto the electrode arrangement.

Whilst specific embodiments of the present invention have been described above, it will be appreciated that departures from the described embodiments may still follow within the scope of the present invention. For example, any suitable type of UV curing may be used along with any suitable mix of conductive and non-conductive particles.

TEST RESULTS AND EXAMPLE FORMULATIONS

EXAMPLE FORMULATIONS

Low concentration nanotube formula vs graphene formula

30	Raw material	A1	A2	A3
	Trifunctional monomer	10.0	10.0	10.0
	Hexafunctional monomer	5.0	5.0	5.0
	Difunctional monomer	7.5	7.5	7.5
	Monofunctional monomer	25.3	24.3	24.4
35	Resin 1	30.0	30.0	N/A
	Resin 2	N/A	N/A	30.0
	Photoinitiator	8.0	8.0	8.0
	Graphene	N/A	1.2	1.1

	Carbon NT	0.2	N/A	N/A
	Filler	10.0	10.0	10.0
	Levelling agent	1.0	1.0	1.0
	Defoamer	1.0	1.0	1.0
5	Anti-cratering	2.0	2.0	2.0

Inks A1, A2 and A3 were coated using a lab screen printer with 24 mesh using the templates as laid out in Fig 3 and Fig 4. The ink was cured using a Natgraph Air Force Combination drier model 90-22201R with 2 UV lamps at full power, belt speed @ 6m/min.

10

Resistance measurements were taken using a Kewtech KT117 Multimeter (Auto).

RESULTS

15	Sample A1 Film		Starting	Resisitance
	Fig 3	thickness (um)	Resistance kΩ	with pressure Ω
	1	79	30 – 50	400 - 420
	2	79	30 – 50	400 - 420
	3	78	30 – 40	80 - 100
20	4	81	30 – 40	80 - 100
	5	81	10 – 20	50 - 70
	6	83	35 – 50	390 - 410
	7	82	35 – 50	390 - 410
	8	85	20 – 25	160 – 170

25

	Sample A1 Film		Starting	Resisitance
	Fig 4	thickness (um)	Resistance kΩ	with pressure Ω
	1	79	60 – 70	450 - 500
	2	79	50 – 60	450 - 500
30	3	78	30 – 40	80 - 100
	4	77	30 – 40	80 - 100
	5	76	30 – 40	50 - 70
	6	82	35 – 40	90 - 110
	7	82	40 – 50	90 - 110
35	8	83	20 – 25	60 - 70
	9	81	10 – 20	50 - 70
	10	77	45 – 60	90 - 110
	11	82	45 – 50	90 - 110

12 83 35 – 40 55 - 65

	Sample A2 Film		Starting	Resisistance
	Fig 3	thickness (um)	Resistance MΩ	with pressure kΩ
5	1	81	2.5 – 3.0	100 -200
	2	81	2.5 – 3.0	100 - 200
	3	77	1.5 – 2.0	80 - 160
	4	77	1.5 – 2.0	80 - 160
	5	81	5.0 – 6.0	50 - 200
10	6	87	5.0 – 6.0	130 - 200
	7	83	3.0 – 4.0	130 - 180
	8	78	4.5 – 5.0	150 - 200

	Sample A2 Film		Starting	Resisistance
	Fig 4	thickness (um)	Resistance MΩ	with pressure kΩ
15	1	77	2.5 – 3.0	100 - 200
	2	81	2.5 – 3.0	100 - 200
	3	81	1.5 – 2.0	100 - 180
	4	77	1.5 – 2.0	100 - 180
20	5	82	1.0 – 1.5	50 - 120
	6	80	1.0 – 1.5	50 - 120
	7	86	4.0 – 5.0	130 - 210
	8	83	4.5 – 5.0	120 - 200
	9	83	3.5 – 4.0	140 - 240
25	10	81	2.5 – 3.0	100 - 200
	11	93	1.5 – 2.0	100 - 180
	12	85	1.5 – 2.0	100 – 180

	Sample A3 Film		Starting	Resisistance
	Fig 3	thickness (um)	Resistance MΩ	with pressure kΩ
30	1	77	2.0 – 2.5	120 -220
	2	77	2.0 – 2.5	120 - 200
	3	76	1.0 – 2.0	140 - 160
	4	76	1.0 – 2.0	140 - 160
35	5	83	3.5 – 4.5	150 - 180
	6	87	3.5 – 4.5	130 - 180
	7	83	2.0 – 3.0	130 - 140
	8	86	2.5 – 3.0	180 - 220

	Sample A3 Film		Starting	Resisitance
	Fig 4	thickness (um)	Resistance MΩ	with pressure kΩ
5	1	77	1.5 – 2.0	80 - 120
	2	77	1.5 – 2.0	80 - 120
	3	83	1.5 – 2.0	70 - 100
	4	83	1.5 – 2.0	80 - 110
	5	84	2.5 – 3.0	150 - 220
10	6	84	2.5 – 3.0	150 - 200
	7	83	4.0 – 5.0	100 - 110
	8	86	4.5 – 5.0	120 - 180
	9	86	3.5 – 4.0	100 - 200
	10	88	2.5 – 3.0	140 - 180
15	11	92	2.5 – 3.5	140 - 180
	12	93	3.5 – 5.0	180 - 250

CONCLUSIONS

20 The sample prepared using the carbon nano tubes (CNT) was significantly more conductive than the samples prepared using graphene. As we are seeking to have a very low resting conductivity in the MΩ range the CNT sample would not be suitable.

25 It is surprising to find that there is very little overall difference in performance between the 7mm and 10mm sensor arrangements as we thought that the relatively larger surface area of the smaller electrodes would allow more current to pass. It seems reasonable to conclude then that the FSR ink itself is responsible for the initial resistance reading rather than the sensor filament interdigitated track size as the readings are within a reasonable tolerance for both 7mm and 10mm sensors.

30 Interdigitated spiral sensors were more sensitive than interdigitated lines dropping to a lower kΩ figure when pressed.

Examination of varying Pressure on the FSR

35 FSR Sensor arrangements were set up as in Figures 1 and 2.

Pressure was then brought to bear on the FSR using an Instron 3342 increasing step by step the pressure from 0N to 100N.

Pressure (N)		Resistance (k Ω)				
		S1	s2	s3	s4	s5
5	0	20000	1800	28390	17380	21230
	2	16700	1387	19870	12340	17000
	4	1987	212	2310	1682	1329
	6	1012	121	1176	832	934
10	8	488	54	692	512	476
	10	273	32	382	297	285
	12	131	18	199	172	151
	14	72	10	98	92	62
15	16	31	8	62	49	52
	18	13	6	28	31	18
	20	9	4	17	19	12
	25	1.8	2	12	8	7
20	30	0.4	0.7	6	3	2
	35	0.18	0.3	1.9	0.9	0.06
	40	0.03	0.06	0.19	0.5	0.01
	45	0.006	0.02	0.05	0.2	0.003
25	50	0.002	0.004	0.01	0.03	0.001
	60	0.00045	0.0076	0.0024	0.0018	0.00031
	70	0.00018	0.0031	0.0008	0.0003	0.00013
	80	0.00007	0.0007	0.0002	0.0002	0.00008
	100	0.000009	0.0001	0.00004	0.00002	0.000009

These results are shown in Figure 5.

CLAIMS

1. A radiation curable photopolymer comprising:
A radiation curable resin(s) present in an amount of 10% to 80% by weight;
a mix of conductive particle(s) between 0.2% and 30% by weight;
5 a spacer material(s) in an amount between 1% and 15% by weight
at least one photoinitiator between 1% and 12% by weight;
at least one additive between 0.1% and 2.5% by weight;
wherein the curable photopolymer is capable of being cured with energy of less than
about 1,000 mJ and where there is no pre-drying prior to curing or imaging in a photoimaging
10 process.
2. A radiation curable photopolymer according to any preceding claim, wherein the curable
photopolymer is printed directly onto a sensor arrangement.
- 15 3. A radiation curable photopolymer according to claim 1, wherein the curable ink is printed
directly onto an electrode located on a plastic surface such as polyester and then brought into
contact with UV radiation.
4. A radiation curable photopolymer according to claim 1, wherein the cured photopolymer
20 forms a cured photopolymer which is capable of functioning as a pressure sensitive force
sensing resistor when applied to a sensor arrangement.
5. A radiation curable photopolymer according to any of claims 1 or 2, wherein the cured
photopolymer forms force-sensing resistors which change resistance in a predictable manner
25 following application of force to its surface when in direct contact with electrodes.
6. A radiation curable photopolymer according to any preceding claim, wherein conductive
particles are in the form of a conductive polymer which comprises both electrically conducting
and non-conducting particles suspended in a matrix of radiation curable photopolymers.
- 30 7. A radiation curable photopolymer according to any preceding claim, wherein the UV
curable photopolymer is printed directly on top an electrode array such as a copper or silver
on a polyester sheet and then brought into contact with UV radiation.
- 35 8. A radiation curable photopolymer according to any preceding claim, wherein the radiation
curable photopolymer has high resistance in the steady state when printed directly onto a
sensor electrode and drops with pressure touch sufficiently to allow activation of a control

circuit.

9. A radiation curable photopolymer according to any preceding claim, wherein the radiation curable ink is essentially 100% solids and cures with any radiation combination of energy sources (from 100 nm – 1120 nm wavelength).

10. A radiation curable photopolymer according to any preceding claim, wherein the cured photopolymers when printed directly onto a sensor electrode show resistance drops proportionally with activation resistance and the resistance changes proportionally with force and that that force change is suitable to allow fine voltage control such as in a hand held device or console such as in a car or touch screen.

11. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer can be integrated in 3 different states after printing directly onto a sensor electrode:

- a. Adhere FSR ink circuit onto a sheet of ThermoPlastic Elastomer (TPE)
- b. 2D TPE can over mould as FSR ink circuit
- c. 3D TPE can over mould as FSR circuit.

12. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer is suitable for printing with a range of processes including but not restricted to: screen; flexographic; lithographic; gravure; ink jet; letterpress; intaglio; rotogravure and rotary screen.

13. A radiation curable photopolymer according to any preceding claim, wherein conductive particles in the curable photopolymer includes any one of or a mixture of any of the following: graphite; graphene; graphene oxides; modified graphene; metal oxides; carbon black; carbon nanotubules both single walled and multi-walled; PEDOT:PSS and PEDOT-TMA.

14. A radiation curable photopolymer according to any preceding claim, wherein the photoinitiator is capable of initiating crosslinking in the curable photopolymer.

15. A curable photopolymer according to any preceding claim, wherein the photoinitiator initiates the crosslinking of the material and is selected from any one of or combination of the following: 1-hydroxy-cyclohexyl-phenylketone; 2-hydroxy-2-methyl-1-phenyl-1-propanone; 2-hydroxy-1-[4-(2-hydroxyethoxy)phenyl]-2-methyl-1-propanone; alpha-dimethoxy-alpha-phenylacetophenone; 2-benzyl-2-(dimethylamino)-1-[4(4-morpholinyl)-1-

butanone); 2- methyl-1-[4-(methylthio)phenyl]-2-(4-morpholinyl)-1-propanone;diphenyl(2,4,6-trimethylbenzoyl)-phosphine oxide; phosphine oxide; phenyl bis(2,4,6-trimethyl benzoyl); phosphine oxide iodonium and (4-methylphenyl)[4-(2-methylpropyl)phenyl]-hexafluorophosphate.

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16. A curable photopolymer according to any preceding claim, wherein the photoinitiator initiates the crosslinking of the material and is selected from any one of or combination of the following: 2,4,6- triorganobenzoyldiarylphosphine oxides; 2,4,6-trimethylbenzoyldiphenylphosphine oxide; 2,4,6-triethylbenzoyldinaphthylphosphineoxide; 2,4,6-triorganobenzoyl diorganophosphonates, such as, 2,4,6-trimethylbenzoyl diethylphosphonate and 2,4,6- triethylbenzoyl diphenylphosphonate; 2,4,6-triorganobenzoyldiarylphosphine sulfides, such as 2,4,6-trimethylbenzoyldiphenylphosphine sulfide commercially available under the Irgacure or Darocur trademarks from Ciba Specialty Chemicals; mixed arylsulfonium hexafluoroantimonate salts; mixed arylsulfonium hexafluorophosphate salts, commercially available under the Cyracure trademark from Dow Chemical; benzophenone; 4-phenyl benzophenone; 4-methyl benzophenone; 2-isopropyl thioxanthone; 2-chlorothioxanthone; 2,4-diethylthioxanthone; commercially available under the Omnirad trademark from IGM resins.

17. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer is included in the curable photopolymer to initiate the crosslinking of the material and are selected from any one of or combination of the following: 2- dimethylamino-ethyl benzoate; ethyl-4-(dimethylamino) benzoate; 2-ethyl-4-(dimethylamino) benzoate; isoamyl 4-(N, N-dimethylamino) benzoate commercially available from under the Omnirad trademark from IGM resins.

18. A radiation curable photopolymer according to any preceding claim, wherein the photoinitiators are present in the range of about 0.1% to about 15% or about 0.1% to about 1.5% weight on weight of the composition for cationic coatings and preferably in the range of about 8.0% to about 10.0% weight on weight of the composition for free radical coatings.

19. A radiation curable photopolymer according to any preceding claim, wherein at least one additive comprises a wetting agent and is capable of providing any one of or combination of the following: humidity resistance; surface wetting and levelling properties which enables the curable photopolymer to be evenly spread onto a surface where imaging is to occur.

20. A radiation curable photopolymer according to any preceding claim, wherein the at least

one additive also comprises an adhesive agent.

21. A radiation curable photopolymer according to claim 20, wherein the adhesive agent is capable of providing adhesion for the bonding of the curable photopolymer to various substrates including metals, glass and plastics.

22. A radiation curable photopolymer according to any of claims 20 to 21, wherein the additive is present in an amount from 0.1% and 2.5% by weight; 0.1% and 2% by weight; 0.1% and 1% by weight; 0.1% and 0.5% by weight.

23. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer is all solids or substantially all solids and is therefore solvent free or substantially solvent free with no volatile organic content.

24. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer comprises less than about 1% solvent, less than about 3% solvent, less than about 10% solvent or less than about 15% solvent curable photopolymer.

25. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer is cured with energy of about 0 – 20 mJ, about 0 – 50 mJ, about 50 – 500 mJ or about 100 – 1,000 mJ.

26. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer is cured with a very low energy radiation in the range of about 0.5 – 20 mJ or about 1.5 mJ – 2.0 mJ.

27. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer is cured with energy of wavelength from about 100 nm to about 500 nm, about 365 nm to about 415 nm or about 395nm to about 405nm or about 400nm to about 1200nm.

28. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer has good adhesion to copper, polyester, FR4, glass and polyimide substrates.

29. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer also comprises any one of or combination of the following: UV or visible light photoinitiator(s); UV curable resin(s); acrylate and/or methacrylate monomer(s); UV stabilizers; rheology modifier(s); fillers for spacing; adhesive promoter(s) and/or self-levelling agent(s).

30. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer may also comprise aromatic ketones (e.g. Methylbenzoyl formate and 1-Hydroxycyclohexyl phenyl ketone).

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31. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer(s) is/are present in an amount of 5% to 60% by weight or 10% to 30% by weight of or 20% to 80% the curable photopolymer.

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32. A radiation curable photopolymer according to any preceding claim, wherein resins in the curable photopolymer are selected from any one of or combination of the following: aliphatic linear polyether urethane acrylate; aliphatic polyester urethane acrylate; and polyester acrylated monomer blends with fast cure characteristics.

15

33. A radiation curable photopolymer according to any preceding claim, wherein the curable resins are radiation curable resins selected from any one of or combination of the following: pentaerythritol tri/tetra-acrylate (PETA); trimethylolpropane triacrylate (TMPTA); trimethylolpropane ethoxy triacrylate (TMPEOTA); hexamethylene diacrylate (HDDA); Dipropylene glycol diacrylate (DPGDA); tripropylene glycol diacrylate (TPGDA); Isobornyl acrylate (IBOA) and Hexylethyl acrylate (HEA).

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34. A radiation curable photopolymer according to any preceding claim, wherein the curable resins are selected from any one of or combination of the following: isobornyl acrylate; cyclohexyl acrylate; tert-butyl acrylate; 2-ethylhexyl acrylate; dicyclopentenyl acrylate; tetrahydrofurfuryl acrylate; cyclic trimethylolpropane formal acrylate and vinyl caprolactam.

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35. A radiation curable photopolymer according to any preceding claim, wherein the curable resins are selected from acrylate monomers which are monofunctional and multifunctional acrylates e.g. methacrylate monomers which are monofunctional and multifunctional methacrylates.

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36. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer may also comprise any one of or combination of the following to improve adhesion to metal or glass surfaces: Acrylic acid; CEA; Epoxy Silane and Trifunctional acid esters.

35

37. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer may also comprise any one of or combination of the following wetting agents

in the range of about 0.1% to about 5% w/w:

- a. a blend of acrylate copolymers;
- b. polyether modified polydimethylsiloxane;
- c. polyether modified dimethylsiloxane;
- 5 d. polyether modified polydimethylsiloxane;
- e. polyether modified dimethylsiloxane;
- f. polymeric dispersant;
- g. polymeric dispersant; and
- h. polyether amino acid polyamine derivative.

10

38. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer also comprises any one of or combination of the following:

- a. surfactants;
- b. antioxidants;
- 15 c. thixotropes;
- d. dilatants;
- e. reinforcement materials;
- f. silane functional perfluoroether;
- g. phosphate functional perfluoroether;
- 20 h. silanes;
- i. titanates;
- j. wax;
- k. fillers
- l. air release agents;
- 25 m. flow additives;
- n. adhesion promoters;
- o. rheology modifiers;
- p. surfactants; and
- q. spacer beads.

30

39. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer further comprises the following:

resins in the amount of 10% to 60% by weight e.g. acrylate and/or methacrylate monomers;

35

photoinitiators 2% to 12% by weight;
levelling agents 0.3% to 1% by weight; stabilizers 0.1%
to 0.5% by weight;

filler spacing material 1% - 15% by weight
adhesion promoters 5% to 10% by weight;
rheology modifiers 0.1% to 5.0% by weight; and
wetting agents 0.01% to 0.5% by weight.

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40. A radiation curable photopolymer according to any preceding claim, wherein the curable photopolymer comprises:

about 1 w/w% to 60 w/w% of an acidic acrylate monomer;

about 1 w/w% to 50 w/w% of a urethane acrylate monomer;

10

1 w/w% to 15% of a spacer filler material;

about 25 w/w% to 90 w/w% of di-, tri- and hexa-acrylate monomer

consisting essentially of a mixture of about 20 w/w% to 90 w/w% of a mix of monomers hexanediol diacrylate, GPTA, CTFA, DPHA, IBOA; and about 10 w/w% to 80 w/w% of a mono-functional branched or carbocyclic acrylate; and about 1 w/w% to 15 w/w% of a

15

photoinitiator or blend of photoinitiators.

41. A radiation cured photopolymer FSR sensor arrangement according to any preceding claim moulded in the form of a hand held device or console such as in a car or touch screen.

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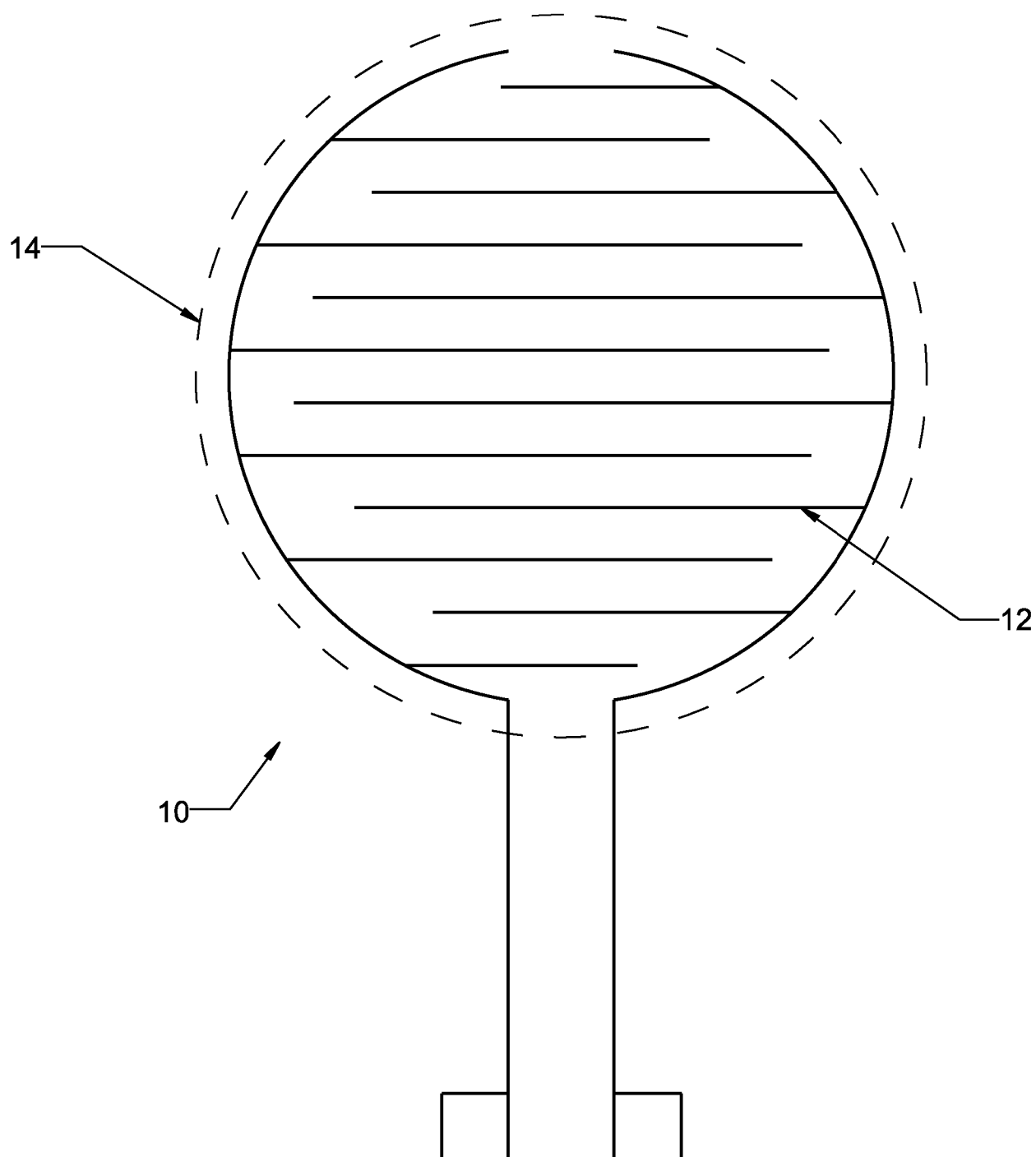


FIG. 1

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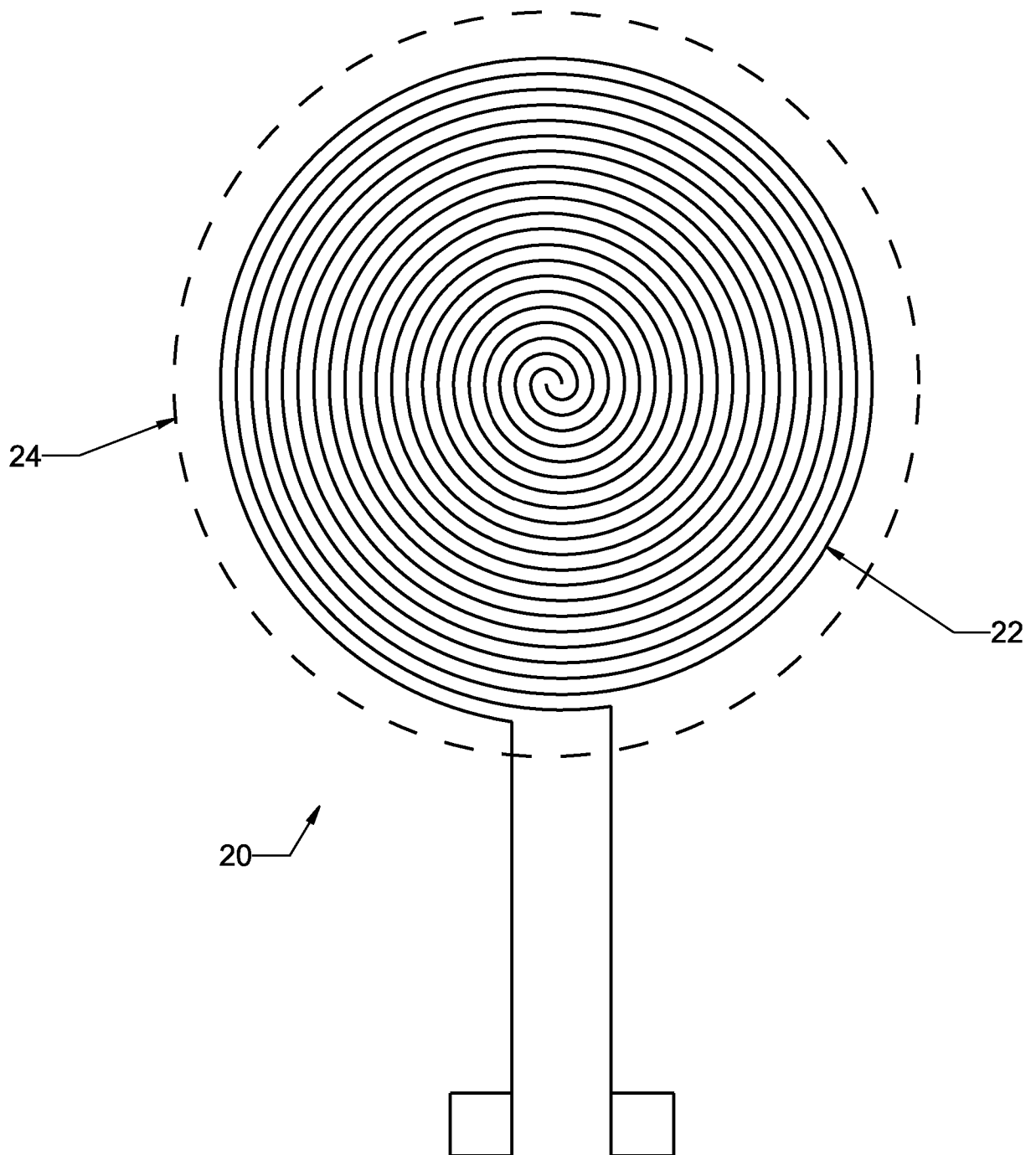
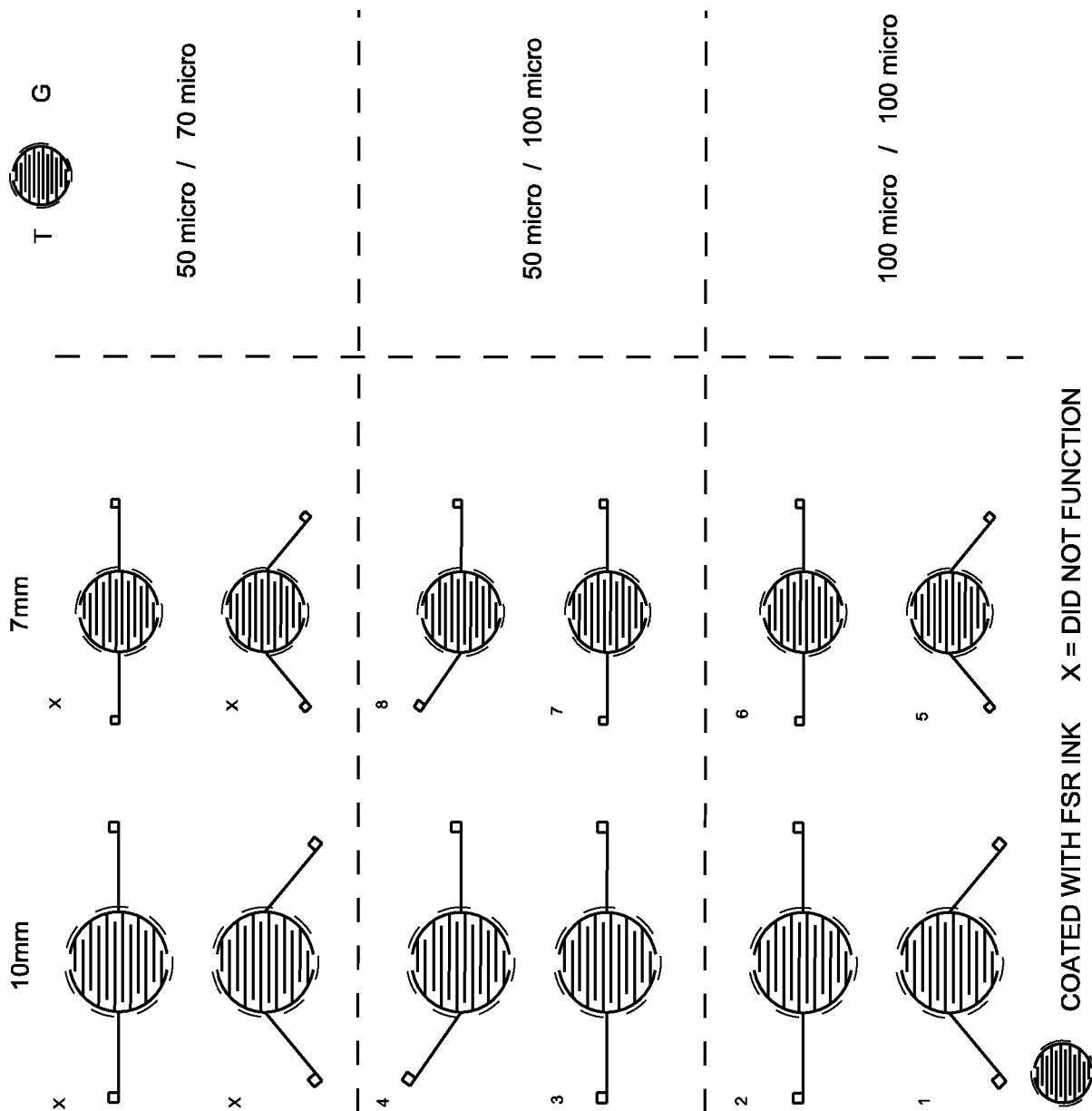
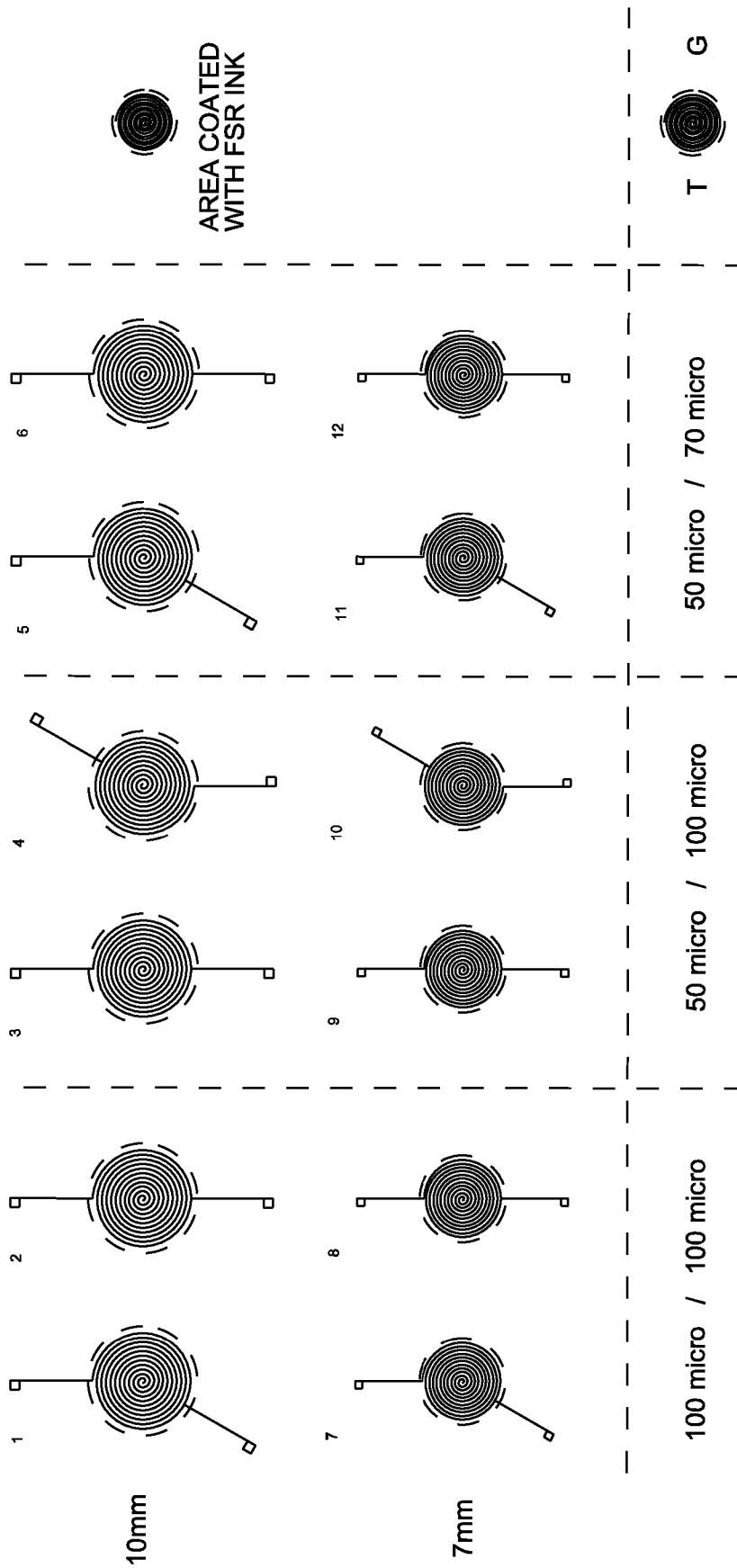


FIG. 2





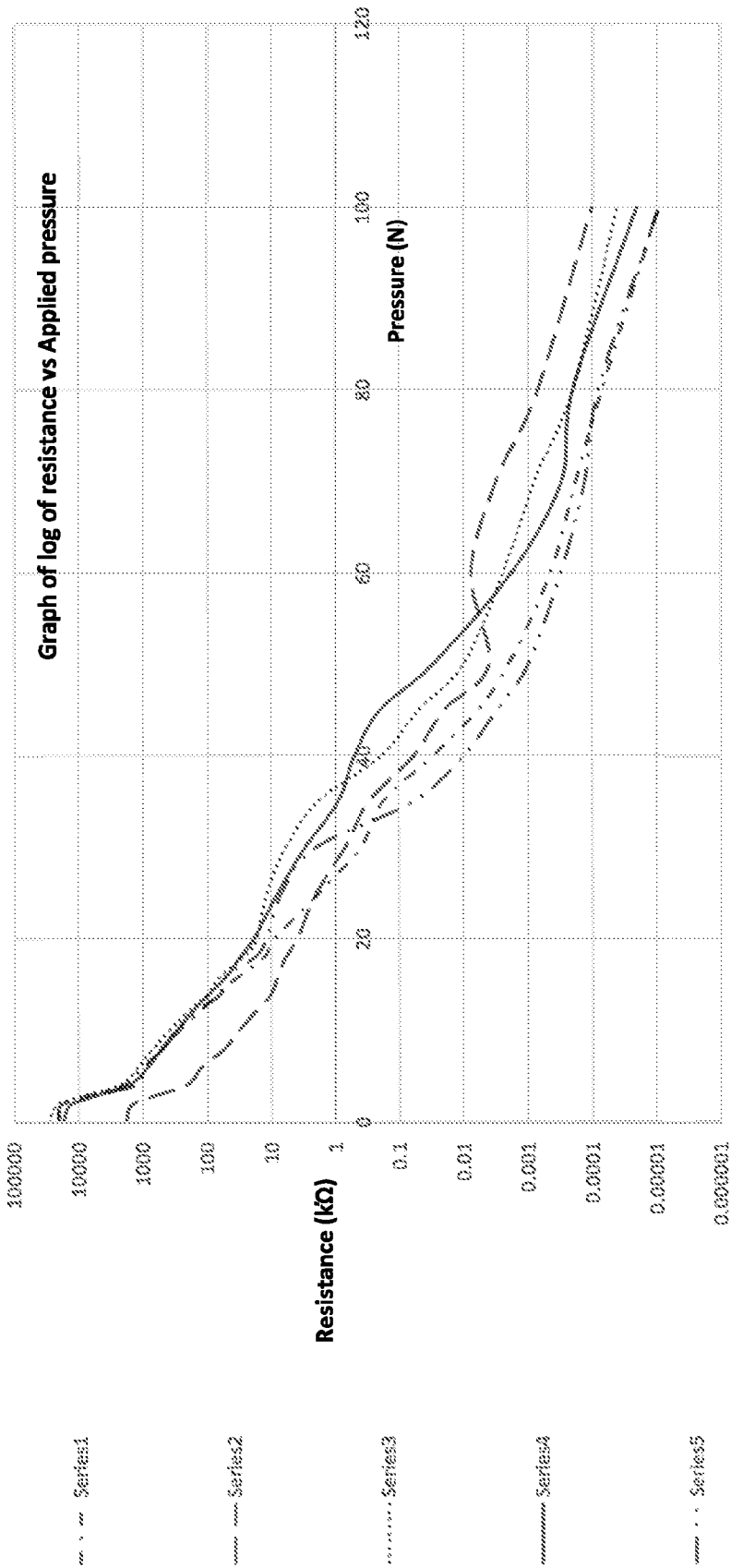


FIG.5

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	<u>S1</u>	<u>s2</u>	<u>s3</u>	<u>s4</u>	<u>s5</u>
<u>0</u>	<u>20000</u>	<u>1800</u>	<u>28390</u>	<u>17380</u>	<u>21230</u>
<u>2</u>	<u>16700</u>	<u>1387</u>	<u>19870</u>	<u>12340</u>	<u>17000</u>
<u>4</u>	<u>1987</u>	<u>212</u>	<u>2310</u>	<u>1682</u>	<u>1329</u>
<u>6</u>	<u>1012</u>	<u>121</u>	<u>1176</u>	<u>832</u>	<u>934</u>
<u>8</u>	<u>488</u>	<u>54</u>	<u>692</u>	<u>512</u>	<u>476</u>
<u>10</u>	<u>273</u>	<u>32</u>	<u>382</u>	<u>297</u>	<u>285</u>
<u>12</u>	<u>131</u>	<u>18</u>	<u>199</u>	<u>172</u>	<u>151</u>
<u>14</u>	<u>72</u>	<u>10</u>	<u>98</u>	<u>92</u>	<u>62</u>
<u>16</u>	<u>31</u>	<u>8</u>	<u>62</u>	<u>49</u>	<u>52</u>
<u>18</u>	<u>13</u>	<u>6</u>	<u>28</u>	<u>31</u>	<u>18</u>
<u>20</u>	<u>9</u>	<u>4</u>	<u>17</u>	<u>19</u>	<u>12</u>
<u>25</u>	<u>1.8</u>	<u>2</u>	<u>12</u>	<u>8</u>	<u>7</u>
<u>30</u>	<u>0.4</u>	<u>0.7</u>	<u>6</u>	<u>3</u>	<u>2</u>
<u>35</u>	<u>0.18</u>	<u>0.3</u>	<u>1.9</u>	<u>0.9</u>	<u>0.06</u>
<u>40</u>	<u>0.03</u>	<u>0.06</u>	<u>0.19</u>	<u>0.5</u>	<u>0.01</u>
<u>45</u>	<u>0.006</u>	<u>0.02</u>	<u>0.05</u>	<u>0.2</u>	<u>0.003</u>
<u>50</u>	<u>0.002</u>	<u>0.004</u>	<u>0.01</u>	<u>0.03</u>	<u>0.001</u>
<u>60</u>	<u>0.00045</u>	<u>0.0076</u>	<u>0.0024</u>	<u>0.0018</u>	<u>0.00031</u>
<u>70</u>	<u>0.00018</u>	<u>0.0031</u>	<u>0.0008</u>	<u>0.0003</u>	<u>0.00013</u>
<u>80</u>	<u>0.00007</u>	<u>0.0007</u>	<u>0.0002</u>	<u>0.0002</u>	<u>0.00008</u>
<u>100</u>	<u>9E-06</u>	<u>0.0001</u>	<u>0.00004</u>	<u>0.00002</u>	<u>9E-06</u>

FIG.6

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2018/050940

A. CLASSIFICATION OF SUBJECT MATTER INV. G03F7/004 C09D11/101 C09D11/52 G03F7/029 G03F7/031 G03F7/09 ADD. According to International Patent Classification (IPC) or to both national classification and IPC																										
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) G03F C09D G01L 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 practicable, search terms used) EPO-Internal, WPI Data																										
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Category*</th> <th style="width: 70%;">Citation of document, with indication, where appropriate, of the relevant passages</th> <th style="width: 20%;">Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">X</td> <td>EP 1 980 597 A1 (NAT STARCH CHEM INVEST [US]) 15 October 2008 (2008-10-15)</td> <td style="text-align: center;">1-40</td> </tr> <tr> <td style="text-align: center;">Y</td> <td>paragraphs [0001] - [0013]; claims 1-20; examples 1,2; tables 1,2</td> <td style="text-align: center;">41</td> </tr> <tr> <td style="text-align: center;">X</td> <td>WO 2015/179341 A2 (SUN CHEMICAL CORP [US]) 26 November 2015 (2015-11-26)</td> <td style="text-align: center;">1-40</td> </tr> <tr> <td style="text-align: center;">Y</td> <td>paragraphs [0015] - [0040], [0045]; table 1</td> <td style="text-align: center;">41</td> </tr> <tr> <td style="text-align: center;">X</td> <td>WO 2005/021665 A1 (NATOCO CO LTD [JP]; TERANISHI SHIGEKAZU [JP]; DOI MICHIO [JP]; SAKAI Y) 10 March 2005 (2005-03-10)</td> <td style="text-align: center;">1-40</td> </tr> <tr> <td style="text-align: center;">Y</td> <td>paragraphs [0008] - [0027], [0064] - [0086]; claims 1-13; examples 1-13</td> <td style="text-align: center;">41</td> </tr> <tr> <td></td> <td style="text-align: center;">-/--</td> <td></td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	EP 1 980 597 A1 (NAT STARCH CHEM INVEST [US]) 15 October 2008 (2008-10-15)	1-40	Y	paragraphs [0001] - [0013]; claims 1-20; examples 1,2; tables 1,2	41	X	WO 2015/179341 A2 (SUN CHEMICAL CORP [US]) 26 November 2015 (2015-11-26)	1-40	Y	paragraphs [0015] - [0040], [0045]; table 1	41	X	WO 2005/021665 A1 (NATOCO CO LTD [JP]; TERANISHI SHIGEKAZU [JP]; DOI MICHIO [JP]; SAKAI Y) 10 March 2005 (2005-03-10)	1-40	Y	paragraphs [0008] - [0027], [0064] - [0086]; claims 1-13; examples 1-13	41		-/--	
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Date of the actual completion of the international search 27 June 2018		Date of mailing of the international search report 06/07/2018																								
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Mingam, Claudie																								

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2018/050940

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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