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(71) Applicant: **Agfa-Gevaert naamloze vennootschap
2640 Mortsel (BE)**

(72) Inventors:
• **Strijckers, Hans, c/o Agfa-Gevaert N.V.
2640 Mortsel (BE)**
• **Dierksen, Karsten
S 1107 Köln (DE)**
• **Overmeer, Robert, c/o Agfa-Gevaert N.V.
2640 Mortsel (BE)**
• **Kaerts, Eric, c/o Agfa-Gevaert N.V.
2640 Mortsel (BE)**

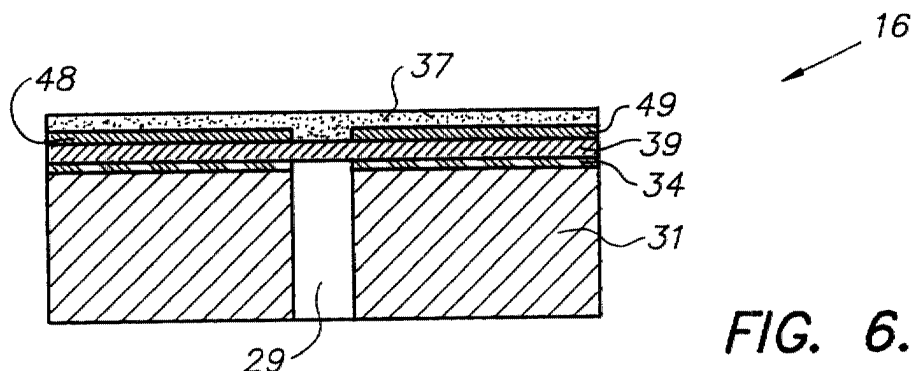
(54) **Thermal head**

(57) A thermal head comprising a heatsink (31), heating elements (39) made of a heating material (36), electrodes (48, 49), and optionally additional layers, wherein the heating elements are optically transparent by having, within wavelengths ranging from 350 to 1200 nm, a transparency higher than 70 %.

The heating material is selected from a group con-

sisting of In_2O_3 optionally doped; SnO/O_2 optionally doped; ZnO optionally doped; Cd_2SnO_4 , or CdSnO_3 ; Bi_2O_3 ; MoO_3 ; TiO_2 ; WO_2 ; RhO_2 ; ReO_2 ; Na_xWO_3 ; Zn_2SnO_4 , and V_2O_5 .

Alternatively, the heating material is a conductive polymer. Also disclosed is the use of a such a thermal head in e.g. thermography and in photothermography.



Description

FIELD OF THE INVENTION

[0001] The present invention relates to a device operable for applying thermal energy to a recording medium, the device comprising a thermal head having energisable heating elements which are individually addressable. In particular, the recording medium is a thermographic material, and the head relates to thermal imaging, generally called thermography.

BACKGROUND OF THE INVENTION

[0002] Thermal imaging or thermography is a recording process wherein images are generated by the use of imagewise modulated thermal energy. Thermography is concerned with materials which are not photosensitive, but are sensitive to heat or thermosensitive and wherein imagewise applied heat is sufficient to bring about a visible change in a thermosensitive imaging material, by a chemical or a physical process which changes the optical density.

[0003] Referring to figure 1, there is shown a global principle schema of a thermal printing apparatus 10 that can be used in accordance with the present invention (known from e.g. EP 0 724 964, in the name of Agfa-Gevaert). This apparatus is capable of printing lines of pixels (or picture elements) Pi on a thermographic recording material m, comprising thermal imaging elements or (shortly) imaging elements, often symbolised by the letters le. As an imaging element le is part of a thermographic recording material m (which will be explained later on), both are indicated in the present specification by a common reference number 3. The thermographic recording material m comprises on a support a thermosensitive layer comprising an organic silver salt, which generally is in the form of a sheet. The imaging element 3 is mounted on a rotatable drum 15, driven by a drive mechanism (not shown) which continuously advances (see arrow Y representing a so-called slow-scan direction) the drum 15 and the imaging element 3 past a stationary thermal print head 16. This head 16 presses the imaging element 3 against the drum 15 and receives the output of the driver circuits (not shown for the sake of greater clarity). The thermal print head 16 normally includes a plurality of heating elements equal in number to the number of pixels in the image data present in a line memory. The imagewise heating of the heating element is performed on a line by line basis, the "line" may be horizontal or vertical depending on the configuration of the printer, with the heating resistors geometrically juxtaposed each along another and with gradual construction of the output density. Each of these resistors is capable of being energised by heating pulses, the energy of which is controlled in accordance with the required density of the corresponding picture element. As the image input data have a higher value, the output energy increases and so the optical density of the hardcopy image 17 on the imaging element 3. On the contrary, lower density image data cause the heating energy to be decreased, giving a lighter picture 17.

[0004] In input data block 22, first a digital signal representation is obtained; then, the image signal is applied via a digital interface to a storing means (not shown) of the thermal printer 10.

[0005] In the processing unit 24, the digital image signal is processed. Next the recording head 16 is controlled so as to produce in each pixel the density value corresponding with the processed digital image signal value. After processing electrical current may flow through the associated heating elements. In this way a thermal hardcopy 17 of the electrical image data is recorded. By varying the heat applied by each heating element to the carrier, a variable density image pixel is formed.

[0006] Figure 3 (known from e.g. EP 0 627 319, in the name of Agfa-Gevaert) is a detailed cross-section of a flat thermal head TH, indicated as part 16 in the present drawings.

[0007] This head comprises at least an insulating substrate 34 (e.g. a ceramic such as glass filled e.g. with alumina Al_2O_3 , with a relatively high thermal conductivity of e.g. $40 \cdot 10^{-3}$ cal/cm.sec °C; thickness between 1 and 60 μm), a protrusion 35 (e.g. a layer, composed of glass or the like, with a positioning bulb having a circular or sectional configuration; with a low thermal conductivity of e.g. $2 \cdot 10^{-3}$ cal/cm.sec.°C), a heating element 36 of electrically resistive material (e.g. 1 μm thick tungsten W, chromium oxide CrO_2 , tantalum nitride Ta_2N , tantalum silicate TaSi or TaSiO , ruthenium oxide RuO_2 , CrSiO , or the like), a protective layer 37 (e.g. of glass or siliciumnitride having 5 to 10 μm thickness) and electrodes 48, 49 (e.g. 0,7 μm thickness, composed of a metal as Al or Cu). The protective layer 37 itself may be composed of an oxidant-resistant layer of about 2 μm SiO_2 and a wear-resistant layer of about 8 μm of Ta_2O_5 or the like.

[0008] Generally, the head further comprises also a heatsink 31 (at least 1 mm thickness), a temperature sensor 32, and a bonding layer 33.

[0009] Figure 4, not necessarily to scale, is a detailed cross-section of another type of a thermal head 16 known from prior art (e.g. US 5,635,974 of Kyocera). Herein reference number 34 denotes an electrically insulating substrate comprising a ceramic substrate 34a and a glaze layer 34b; a heating element 36, electrodes 48 and 49 (made of Al, Au, Cu or the like), and a protective layer 37 (e.g. filler-containing-glass).

[0010] Actually, there are still many problems with respect to the use of thermal heads. Some of these problems will be discussed hereinafter.

[0011] First, in direct thermography, it is known, e.g. from EP 0 654 355 (in the name of Agfa-Gevaert) that ... "it appears to be difficult to obtain a neutral black tone image... Furthermore, it appears to be difficult to obtain a desired number of grey levels which may be required for some application, in particular if the image is to be used for medical diagnostic purposes." (For the sake of conciseness, only the relevant passages of the indicated references are reproduced here; not the whole paragraphs.) According to the same patent EP 0 654 355, a solution is disclosed comprising "the steps of: preheating each heating element ..., selecting a pulse duty cycle ..., retrieving pro individual pixel ... an individual writing time with respect to a desired density on the imaging element;" and energising the heating elements with the selected gradient pulse duty cycle for a time with respect to the retrieved individual writing time". It is obvious that it would be advantageous in many aspects if the equipment for implementing the solution of EP 0 654 355 could be compact.

[0012] Second, in photothermography, it is also known, e.g. from EPA 96.200.689.6 (of Agfa-Gevaert N.V.) that ... "it is desirable to increase the photosensitivity of photosensitive thermally developable photographic materials ..." According to the same invention "a method of increasing the photosensitivity of a photosensitive thermally developable photographic material is provided, characterised in that the photosensitive thermally developable photographic material is on one and the same holding or guiding means during both the information-wise exposure step and the heating step; the heating step is carried out before and/or during the information-wise exposure step." Furthermore, as indicated in EP-A 96.200.689.6, "it is also desirable to achieve such an increase in photosensitivity, while enabling the simplification of photothermographic processing equipment, for example as disclosed in DE 196 36 235A1 or WO 98/10333 (both in the name of Agfa - Gevaert). Once again, it would be advantageous in many aspects if the equipment for implementing the solution of EP-A 96.200.689.6 could be compact.

OBJECTS OF THE INVENTION

[0013] It is an object of the present invention to provide a thermal head which brings a solution to the above indicated problem of a compact equipment.

[0014] Other objects and advantages of the present invention will become clear from the further description, examples and drawings.

SUMMARY OF THE INVENTION

[0015] The above mentioned objects are realised by a thermal head having the characteristics defined in claim 1. Specific features for preferred embodiments of the invention are disclosed in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The invention will be described hereinafter with reference to the accompanying drawings (not necessarily to scale), which are not intended to restrict the scope of protection of the present invention.

[0017] Herein,

Fig. 1 shows the basic functions of a direct thermal printer;

Fig. 2 shows the basic functions of a thermal printer which uses a protective ribbon or a donor ribbon containing a reducing agent, or of a ribbon containing consumables which can be thermally sublimated;

Fig. 3 shows a cross-section of a thermal head according to prior art;

Fig. 4 shows a cross-section of another thermal head according to prior art;

Fig. 5 shows a recording method using a transparent thermal head according to the present invention;

Fig. 6.1 shows a cross-section of one embodiment of a transparent thermal head according to the present invention;

Fig. 6.2 shows a cross-section of another embodiment of a transparent thermal head according to the present invention;

Fig. 6.3 shows a plan-view of an embodiment of a transparent thermal head according to the present invention;

Fig. 7 shows a plan-view of a portion of a thermal head illustrating a plurality of heating elements $H_i = \{H_1, H_2, H_3 \dots\}$;

Fig. 8 shows a plan-view of a portion of a thermal head and some components for rendering a plurality of pixels $P_i = \{A, B, C \dots\}$;

Fig. 9 is a diagram showing the optical transmission of ITO with respect to the wavelength of measurement, suitable for use according to the present invention;

Fig 10 is a diagram showing the optical transmission of ORGACON-EL with respect to the wavelength of meas-

urement, suitable for use according to the present invention;

Fig 11 is a diagram showing the optical transmission, the absorption and the reflectance of ORGACON-EL with respect to the wavelength of measurement, suitable for use according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0018] The description given hereinafter mainly comprises six sections, namely (i) terms and definitions used in the present application, (ii) preferred embodiments of a transparent thermal head, (iii) heating materials suitable for use according to the present invention, (iv) use of a thermal head according to the present invention, (v) use of a thermal head according to the present invention combined with a laser, and (vi) further use of a thermal head according to the present invention.

[0019] More information about methods using a transparent thermal head according to the present invention can be found in co-pending application entitled "IMPROVED METHOD FOR THERMAL RECORDING", filed on a same date and incorporated herein by reference.

(i) Explanation of terms used in the present description

[0020] For the sake of clarity, the meaning of some specific terms applying to the specification and to the claims are explained before use.

[0021] The term "thermographic material" (being a thermographic recording material, hereinafter indicated by symbol m) comprises both a thermosensitive imaging material and a photothermographic imaging material (being a photosensitive thermally developable photographic material).

[0022] For the purposes of the present specification, a thermographic imaging element le is a part of a thermographic material m (both being indicated by ref. nr. 3).

Hence, symbolically: $m \ni le$.

[0023] By analogy, a thermographic imaging element le , comprises both a (direct or indirect) thermal imaging element and a photothermographic imaging element. In the present application the term thermographic imaging element le will mostly be shortened to the term imaging element.

[0024] By the term "heating material" (hereinafter indicated by symbol hm) is meant a layer of material which is electrically conductive so that heat is generated when it is activated by an electrical power supply.

[0025] In the present specification, a heating element Hi is a part of the heating material hm .

Hence, symbolically: $hm \ni Hi$.

[0026] A heating element Hi (as e.g. $H1$, $H2$, $H3$...) being a part of the heating material hm is conventionally a rectangular or square portion defined by the geometry of suitable electrodes.

[0027] According to the present specification, a heating element is also part of a heating system, which system further comprises a power supply, a data capture unit, a processor, a switching matrix, leads, etc.

[0028] An "original" is any hardcopy or softcopy containing information as an image in the form of variations in optical density, transmission, or opacity. Each original is composed of a number of picture elements, so-called "pixels". Further, in the present application, the terms pixel and dot are regarded as equivalent.

[0029] Furthermore, according to the present invention, the terms pixel and dot may relate to an input image (known as original) as well as to an output image (in softcopy or in hardcopy, e.g. known as print).

[0030] It is known, and put to intensive commercial use (e.g. DrystarTM, of Agfa-Gevaert N.V.), to prepare both black-and-white and coloured half-tone images by the use of a thermal printing head, a heat-sensitive receiving material (in case of so-called one-sheet thermal printing) or a combination of a heat-sensitive donor material and a receiving (or acceptor) material (in case of so-called two-sheet thermal printing), and a transport device which moves the receiving material or the donor-acceptor combination relative to the thermal printing head. The thermal head usually consists of a one-dimensional array of heating elements arranged on a ceramic substrate which is itself mounted on a heat-dissipating base element or heatsink hs . In the next paragraphs, a thermal head according to the present invention and a working method will be explained in depth.

(ii) Preferred embodiments of a transparent thermal head according to the present invention

[0031] According to the present invention, a thermal head TH is optically transparent. The description which follows in the instant section, comprises three subsections: (ii-a) a description of global characteristics common to different embodiments of the invention, (ii-b) a description of some preferred embodiments of the invention and focused on cross-sectional views, and (ii-c) a description of the electrodes and of the heating elements, being focused on planviews of a thermal head.

(ii-a) A characteristic common to the different embodiments of the invention, is a transparent thermal head using a transparent conducting layer as heating material hm.

[0032] In a first preferred embodiment the heating material hm is e.g. indium-tin-oxide ITO. A process for producing a transparent thermal head now will be described, although other processes could also be used. A conducting layer as heating material hm is applied by sputtering, by chemical vapor deposition, spraying followed by pyrolysis, metal evaporation followed by oxidation, etc, to a transparent substrate which is preferentially glass (e.g. Baltron 255, Balzers). Thereafter, the completely coated substrate can be structured by removing the conduction layer spatially selectively. This can be done e.g. by using a tape as mask and later removing the ITO on untaped locations by means of lithographic techniques.

[0033] The area of ITO that is not covered with adhesive tape is then removed from the glass substrate e.g. by etching. For example, a pinch of zinc powder is applied to and spread over the area to be etched away by using a spatula. Next, a few drops of semiconcentrated hydrochloric acid are pipetted on the zinc powder by using a disposable pipette. The hydrochloric acid is poured off the substrate and any residual zinc removed by rinsing with a few drops of hydrochloric acid. The substrates are immersed in a beaker containing water, rinsed with water and rubbed dry with paper. After the etching process the adhesive tape is peeled off and the substrate is cleaned first with acetone, then with ethanol and finally with distilled water. This cleaning operation is repeated until all traces of adhesive have been removed from the surface.

[0034] In a last step the heating material hm is connected with a conducting layer, such as silver ($R < 1 \Omega / \square$), to produce electrodes. A central area is not covered, which is the heating element Hi (see figures 6.1 - 6.3 e.g.; to be explained below). Now the electrodes are electrically connected with wires and a voltage can be applied. The resistance of this system is e.g. between 5 and 25 $\Omega / \square$, e.g. about 8 to 10 $\Omega / \square$.

[0035] In one of our experimental examples, the size of the thermal head was 50 mm x 50 mm. Although there is no limitation in the number and size (cf. spatial resolution expressed in dpi) of the structure, in one experiment a 3 mm x 50 mm wide ITO structure in the centre of a substrate was used.

(ii) As to a description of a further preferred embodiment of the invention, reference is made to Figs. 6.1 and 6.2 which show a cross-section and to Fig. 6.3 which shows a plan-view of embodiments of a transparent thermal head according to the present invention.

[0036] From these drawings and from the instant description it is clear that a flat-type thermal head according to the present invention comprises at least a heatsink 31, heating elements 39, electrodes 48, 49, and optionally additional layers, wherein at least the heating elements are optically transparent. More specifically, the heating elements 39 are part of a heating material 36, especially a transparent heating material.

[0037] Figs. 6.1 and 6.2 represent two exemplary embodiments according to the present invention. Figs. 6.1 illustrates a heatsink 31 which is thermally conductive and optically transparent (e.g. made from glass, a flexible glass, polycarbonate, or polyacrylonitrile, optionally comprising a filler), a transparent conducting layer as heating material hm (e.g. made from an ITO-layer) comprising transparent heating elements 39 (e.g. 39a, 39b, 39c...), electrodes 48-49 and preferably a transparent protective layer 37.

[0038] Figs. 6.2 illustrates a heatsink 31 which is thermally conductive but not necessarily optically transparent (e.g. made from aluminium) and which has locally a sufficiently open zone (see ref. nr. 29), a transparent conducting layer as heating material hm (e.g. made from an ITO-layer) comprising transparent heating elements 39 (e.g. 39a, 39b, 39c ...), electrodes 48-49, preferably a transparent protective layer 37, and optionally an insulating substrate 34.

[0039] Depending on the resistivity characteristics of the heating material hm, different cases can be differentiated:

(i) heating material hm having surface conductance, or (ii) heating material hm having a bulk conductance.

In case (i) of a heating material hm having surface conductance and a resistive bulk, the non-conducting side of the heating material hm may be in direct contact with the heatsink hs, even if the heatsink is made of an electrically conducting material (such as aluminium). In case (ii) of a heating material hm having bulk, the heating material hm only may be in direct contact with the heatsink hs, if the heatsink is made of an electrically non-conducting material (e.g. made from glass, a flexible glass, polycarbonate, or polyacrylonitrile, optionally comprising a filler). Clearly, the heating material hm may not be in direct contact with the heatsink hs, if the heatsink is made of an electrically conducting material (such as aluminium), and here an additional insulating layer is needed between heating elements 39 and the heatsink 31 (see e.g. insulating substrate 34 in Fig. 6.2). In case of a heatsink hs made of aluminium, such insulating layer may be given by providing a oxide-layer, generally a thin oxide-layer, being both electrically insulating and thermally sufficient conductive.

[0040] Also with regard to the heatsink 31, different embodiments can be differentiated. So, if the heatsink hs has electrically insulating characteristics, no additional insulating layer is needed between heating elements 39 and heatsink 31 (which case is illustrated e.g. in Fig. 6.1.). Alternatively, if the heatsink hs has no electrically insulating characteristics

(such as e.g. aluminium) an additional insulating layer is needed between heating elements 39 and heatsink 31 (which case is illustrated e.g. in Fig. 6.2).

[0041] Insulating substrate 34 may comprise a ceramic such as glass or glass filled with alumina Al_2O_3 , with a relatively high thermal conductivity of e.g. $40 \cdot 10^{-3} \text{ cal/cm.sec.}^\circ\text{C}$ ($= 2 \cdot 10^{-3} \text{ W.m}^{-1}.\text{K}^{-1}$); thickness about 30 to 60 μm . Other materials suitable for providing such an insulating substrate 34 may comprise siliconnitride (optionally being doped), AlN, or diamond-like thin film coating such as DylynTM, etc.

DylynTM is a trademark of Advanced Refractory Technologies Inc., USA; the product is available in Europe from Bekaert Dymonics, Belgium. A few technical characteristics comprise e.g. the following: thickness between 0,01 and 10 μm ; thermal stability up to 400°C (or 673 K); dielectric breakdown strength $> 10^6 \text{ V/cm}$; electrical resistivity being controllable between 10^{14} and $10^{-2} \Omega \text{ cm}$, thermal conductivity about 70 W/m.K .

[0042] From another point of view, optionally an additional layer may be introduced between the heating element 39 and the heatsink 31 in order to reduce possible transition resistance of heat. For example, Fisher Elektronik commercialises e.g. (i) silicon thermal transfer compounds comprising silicon oil and inorganic fillingmaterial (e.g. metal oxides), and (ii) siliconfree thermal transfer compounds comprising a synthetic liquid without silicon and inorganic fillingmaterial (e.g. metal oxides). These materials have interesting characteristics such as thermal conductivities up to 1 W/mK , a dielectric strength up to 40 kV/mm , a specific resistance greater than $10^{12} \Omega.\text{cm}$, an operating temperature range up to $+ 250^\circ\text{C}$ (or 523 K), etc. (cf. Data sheets from Fischer Elektronik & Dau).

[0043] It has to be remarked that, in usual practice, the temperature of the insulating substrate 34 rarely exceeds $+ 100^\circ\text{C}$ (or 373 K), generally even not $+ 70^\circ\text{C}$ (or 343 K). The temperature of the heatsink 31 rarely exceeds $+ 60^\circ\text{C}$ (or 333 K).

[0044] A more general overview of eight different embodiments (indicated as I. to VIII.) of a transparent thermal head according to the present invention, is schematically summarised in Table 1. In preparing that table, it has been supposed that in case of a heating material hm with surface conductivity, the electrical conductive side was in contact with the electrodes (48, 49) and hence, not in contact with the heatsink hs (31). If on a horizontal row named 'action' a cross 'x' is mentioned, no special construction precaution has to be undertaken; if no cross is mentioned, a particular precaution in designing the thermal head is necessary (such as e.g. introducing an opening 29 or an insulating substrate 34). Although all embodiments of Table 1 are protected by the instant patent application, for the sake of conciseness only two drawings (e.g. Figs. 6.1 and 6.2) are enclosed (respectively corresponding with embodiments III. and VI.).

heating material (39) hm ↓	heatsink (31) hs			
hm = surface conductive	hs el conductive		hs el non- conductive	
	I. hs transpar.	II. hs non- transpar.	III. hs transpar.	IV. hs non- transpar.
	actions	x	x	x
	⇒	x	opening 29	x
Fig	-	-	Fig. 6.1	-
hm = bulk conductive	hs el conductive		hs el non- conductive	
	V. hs transpar.	VI. hs non- transpar.	VII. hs transpar.	VIII. hs non- transpar.
	actions	insulat. 34	insul. 34	x
	⇒	x	opening 29	x
Fig	-	Fig. 6.2	-	-

Table I

(ii-c) Definitions of the electrodes and of the heating elements.

[0045] According to a preferred embodiment of the present invention, the abovementioned optionally additional layers, comprise a protective layer 37 and optionally at least one bonding layer. In a further preferred embodiment, the protective layer 37 comprises glass or siliconnitride or is composed of an oxidant-resistant layer of SiO₂ and a wear-resistant layer of Ta₂O₅.

According to a preferred embodiment of the present invention, a thermal head further also comprises a temperature sensor.

[0046] In a the thermal head TH according to the invention, the heats'ink 31, the bonding layer 33, the insulating substrate 34 and the additional layers (e.g. 37) are optically transparent, at least at zones corresponding to the heating elements.

[0047] The illustrated embodiment has discontinuous areas of heating material hm (see e.g. ref. nrs.. 39a, 39b, etc.).

[0048] The thermal print head 16 typically comprises an array of individually addressable, electrically resistive heating elements. These individually energisable juxtaposed heating elements 39 for image-wise heating the thermosensitive layer are energised by the application of voltage to produce heat as current flows therethrough. The heat produced by a heating element is applied to a localised pixel area on the imaging element in contact with the energised element to activate the dye and produce a visible pixel therein.

[0049] Figs. 6.1 and 6.2 illustrate a heatsink hs (ref 31) which is transparent by being made of optical transparent material (see Fig. 6.1), or by having locally a sufficient open zone (see ref 29 in Fig. 6.2). Further, Figs. 6.1 and 6.2 show a transparent conducting layer as heating material 39 (e.g. made from ITO-layer), with discontinue heating elements 39a, 39b, 39c; leads or lead wires with signal electrodes 48a, 48b, 48c ...and counter electrodes 49a, 49b, 49c ...

[0050] Any individual heating element H in the linear array may be energised simply by applying voltage between its corresponding electrodes. Indeed, when an energising voltage, typically in the range of 12 to 18 volts, is applied between electrodes 48a and 49a, it causes a current to flow through the rectangular portion 39a of heating material in between, designated element H1. The current through the resistive material hm of heating element H1 generates thermal energy which heats up the pixel area of the imaging element in contact with heating element H1 causing the image-forming thermographic system to change colour once a threshold temperature is exceeded. The next element H2 in the array may be energised by applying voltage between its corresponding electrodes 48b and 49b. Likewise, the next successive element H3 may be energised by impressing voltage between 48c and 49c,... etc.

Another type of a preferred embodiment of a thermal print head 16 according to the present invention comprises a continuous strip of heating material hm and is diagrammatically shown in dual Figs. 7 and 8. For the sake of greater clarity, it is indicated that Fig. 7 mainly and concisely illustrates the heating elements $H_i = \{H1, H2, H3 \dots\}$ of the heating material hm, whereas Fig. 8 focuses on the printed pixels $P_i = \{A, B, C \dots\}$ on the output print. Further, Fig. 8 also illustrates some components of the signal processing system (e.g. power supply and signal processor 44 and switching matrix 46).

[0051] Here, the thermal head comprises an elongated rectangular substrate 34 made of ceramic, glass or the like, a continuous elongated strip of heating material 36, extending along the length of substrate 34, formed of a film of electrically conductive-resistive heating material hm, and a plurality of equally spaced, interdigitated electrodes 48-49 which make electrical contact to heating material 36 (the technical term interdigitated here is nearly equivalent to interlocked or interpenetrated).

[0052] The signal electrodes 48 and the counter electrodes 49 serve to divide the continuous strip of heating material 36 into a serial array of individually addressable thermal heating elements H_i . When an energising voltage, typically in the range of 12 to 18 volts, is applied between electrodes 48a and 49x, it causes a current to flow through that portion, e.g. a rectangular portion, of heating material 36 therebetween, designated as heating element H1. The current through the resistive material of element H1 generates thermal energy or heat which impinges upon the pixel area of the imaging element in contact with element H1 causing the dye therein to react and change colour once the threshold temperature is exceeded. The next element H2 in the array may be energised by applying voltage between its corresponding electrodes 48b and 49x. Likewise, the next successive element H3 may be energised by impressing voltage between 48c and 49y, etc.

[0053] Any individual element H_i in the linear array may be energised simply by applying voltage between its corresponding electrodes. Leads or lead wires generally are connected to a matrix switching system which facilitates the application of energising voltage to selected electrodes. Through the switching system, any or all of the heating elements H_i may be energised simultaneously on response to appropriate data input signals.

[0054] As shown in Fig. 8, the print head 16 is of the line printing type and includes a laterally extending support member or substrate 34 made of electrically insulating material. Substrate 34 has an elongated laterally extending window 47, which is coextensive with the length of a line of the image to be recorded, into which the free ends of a plurality of signal electrodes 48a, 48b, 48c ... extend in interdigitated relationship with a plurality of corresponding spaced counter electrodes 49x, 49y, 49z ... The electrodes 48 and 49 are mounted on substrate 34 and each comprises a separate electrical contact having its end opposite the free end connected to a matrix switching device 46 which is operated by a print head signal processor and power supply 44.

The free ends of electrodes 48 and 49 are in engagement with a corresponding segment of heating element hm. To print a pixel in area A (also shortly indicated as "dot A" or "pixel A") between the first two electrodes, the recording signal V_s is applied to the first signal electrode 48a which is paired with the first counter-electrode 49x i.e.. The print head signal processor 44 operates the matrix switching device 46 so that voltage V_s is applied to electrode 48a and the counter-electrode 49x is lowered to a ground potential relative to V_s so that a current flow path I is established therebetween to generate heat in the corresponding pixel area section of the imaging element. To print selectively a pixel in the next area B, signal voltage V_s is applied to the second signal electrode 48b with this paired with the first counter-electrode 49x. A pixel is printed in the next adjacent area C by pairing the second signal electrode 48b with the next counter-electrode 49y ...etc. Additional electrode pairs are provided along the entire length of window 47. By the use of appropriate software and matrix switching techniques, electrode pairs corresponding to each of the pixel area sections in the line can be addressed individually.

[0055] In one preferred embodiment of the present invention, the electrodes 38 comprise "strictly" individual electrodes 48, 49 energising each of the heating elements 39 (as e.g. illustrated in Figs. 6.3, 7 and 8).

[0056] In another preferred embodiment of the present invention, the electrodes 38 comprise a common electrode (not shown) and an individual electrode (not shown) energising each of the heating elements.

[0057] It has to be indicated that according to a preferred embodiment of the present invention, the heating elements have a width smaller than 80 or even smaller than 70 μm . So, a spatial resolution of 320 dpi or even 360 dpi is attainable.

(iii) Heating materials suitable for being used according to the present invention

[0058] As mentioned before, in a first preferred embodiment the transparent heating material hm is e.g. indium-tin-oxide ITO.

[0059] However, other metal oxides may also be used in conductive layers, for example non-stoichiometric and doped oxides of tin, indium, cadmium, zinc and their alloys. Well known examples of the latter category include tin oxide (TO) doped with antimony (ATO) or fluorine (FTO), indium oxide (IO) doped with tin (ITO), and zinc oxide doped with indium (IZO). These metal oxides exhibit high transmittance in the visible spectral region, and nearly metallic conductivity. The electrical as well as the optical properties of these materials can be tailored by controlling the deposition conditions and other process steps.

Reformulated in a survey, usable transparent heating materials comprise:

In_2O_3 optionally doped with O_2 , Sn, Ti, Pb, F;

SnO/O_2 optionally doped with O_2 , Sb, F, Cl, Br, I, P, As, In, Th, Te, W;

ZnO optionally doped with O_2 , In, Al;

Cd_2SnO_4 or CdSnO_3 or mixtures thereof (as e.g. Cadmium stannate);

$\text{Bi}_2\text{O}_3\text{MoO}_3$; TiO_2 ; WO_2 ; RhO_2 ; ReO_2 ; Na_xWO_3 ; Zn_2SnO_4

[0060] Fig. 9 is a diagram showing the optical transmission of an ITO as a function of the wavelength which is suitable for use according to the present invention. I.e ref. nr. 81 gives the transmittance curve of a heating material hm ITO.

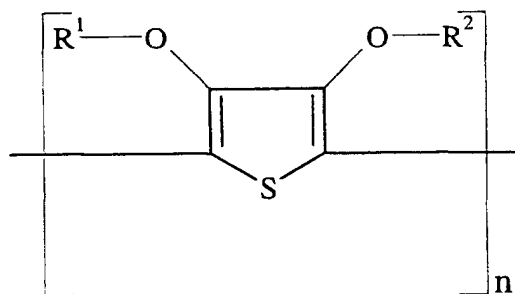
[0061] According to the present invention, the heating material hm applied in the thermal head is optically transparent by having, in the wavelength range from 350 to 1200 nm, a transparency higher than 70 %.

More preferably, the heating material hm is optically transparent by having in the wavelength range from 700 to 1100 nm a transparency higher than 80%.

[0062] A preferred thermal head TH according to the present invention, has heating material hm selected from In_2O_3 optionally doped with oxygen, Sn, Ti, Pb, F; SnO/O_2 optionally doped with oxygen, Sb, F, Cl, Br, I, P, As, In, Th, Te, W; ZnO optionally doped with oxygen, In, Al; Cd_2SnO_4 , or CdSnO_3 , or mixtures thereof (as cadmium stannate); Bi_2O_3 ; MoO_3 ; TiO_2 ; WO_2 ; RhO_2 ; ReO_2 ; Na_xWO_3 ; Zn_2SnO_4 ; V205.

[0063] In a further preferred embodiment of the present invention, the transparent (e.g. ITO being Indium-Tin oxide) layer is replaced by transparent conductive organic polymers e.g. polyacetylene, polypyrrole, polyaniline (PANI), polythiophene e.g. polydioxylthiophene (PEDT), etc. The advantage of this replacement resides in the increased flexibility and lower brittleness of such layers compared with ITO so that the life-time of the device can be prolonged.

[0064] In a particularly further preferred embodiment of the present invention, the transparent conductive layer is prepared by applying a mixture containing (a) a polythiophene with the formula



wherein each of R1 and R2 independently represents hydrogen or a C1-4 alkyl group or together represent an optionally substituted C1-4 alkylene group or a cycloalkylene group, preferably an ethylene group, an optionally alkyl-substituted methylene group, an optionally C1-12 alkyl- or phenyl-substituted 1,2-ethylene group, a 1,3-propylene group or a 1,2-cyclohexylene group,

(b) a polyanion compound and

(c) an organic compound containing 2 or more OH and/or COOH groups or amide or lactam groups.

Such conductive polymers have been described in EP-A-686 662 (in the name of Bayer) and in European unpublished application N°. 99.201.645.1 (in the name of Agfa - Gevaert).

[0065] A commercial conductive and transparent foil comprising a heat-stabilised polyester film carrying a water based transparent conductive coating polymer is known as ORGACON (registered tradename of Agfa-Gevaert), e.g. type ORGACON-EL.

[0066] Fig 10 is a diagram showing the optical transmission of ORGACON-EL with respect to the wavelength, suitable for use according to the present invention. Ref. nr. 82a is the transmittance curve of the heating material.

[0067] Fig 11 is a diagram showing the optical transmission, the absorption and the reflectance of ORGACON-EL with respect to the wavelength, suitable for use according to the present invention. Ref. nr. 82b is the transmittance curve of a heating material ORGACON-EL, ref. nr. 83 the absorption curve and ref. nr. 84 the reflection curve of the same heating material ORGACON-EL. It has to be noticed that, especially in the range above 350 nm, both the absorption and the reflection of the heating material hm are very low.

[0068] All values of resistivity presented in this document are measured according to the following method. A sample of the heating material hm is cut to obtain a strip having e.g. a length of 275 mm and a width of 35 mm. Electrodes are applied over the width of the strip at a distance of 100 mm from each other. The electrodes are made e.g. of a conductive polymer, ECCOCOAT CC-2 available from Emerson & Cumming Speciality polymers, or of another material assuring good electrical contacts (e.g. Ag). A constant potential is then applied over the electrodes and the current flowing through the circuit is measured e.g. on a Pico-ammetermeter KEITHLEY 485.

(i) The resistance R of the heating material hm is the ratio of the applied voltage over the current flowing through the conductive layer.

(ii) Considering a mean thickness of the conductive layer (e.g. of $t \mu\text{m}$), the specific resistivity ρ (expressed in $\Omega \cdot \text{cm}$) equals R multiplied by a first geometry factor g_1 (taking into account the geometry of the tested sample).

(iii) The specific conductivity σ (expressed in S/cm) can be obtained by mathematically inverting the specific resistivity.

(iv) The surface resistivity SR can be derived from the specific resistivity multiplied by a second geometrical parameter g_2 (also taking into account the geometry of the tested sample): $\text{SR} = R \times g_2$ (expressed in $\Omega/\square$).

(v) Optionally, a surface conductivity σ can be obtained by mathematically inverting the surface resistivity.

[0069] In a preferred embodiment of the present invention the heating material hm has a surface resistivity (SR) between 5 and $3000 \Omega/\square$.

[0070] In another preferred embodiment of the present invention, the heating material hm has a specific resistivity ρ between $10^{-5} \Omega \cdot \text{cm}$ and $1 \Omega \cdot \text{cm}$ or a specific conductivity σ between 1 and 10^5 S/cm , or between 1 and 10^4 S/cm , or even between 1 and 10^3 S/cm .

[0071] Such specific conductivity σ thus ranges from semi-metallic to near-metallic conductivity.

(iv) Applicability of a thermal head according to the present invention

[0072] It will be clear for people skilled in the art, that several thermal heads according to the present invention may be connected to one another in a longitudinal direction (so-called butting or staggering) in order to achieve a larger thermal head.

In another preferred embodiment of the present invention, a thermal head TH scans in X-direction (the so-called fast-scan direction) over the heating material m from one side of a printing line to the other side (so-called shuttling), in order to attain pagewide-heating.

[0073] Although line-type print heads having a one dimensional array have been referred to, the present invention can also make use of two dimensionally arranged print head arrays.

[0074] Depending on production requirements and facilities, a thermal head TH according to the present invention can be realised by a so-called thick-film technique (such as lithography, screen-printing; with heating elements of e.g. $20 \mu\text{m}$ thickness) or by a so-called thin-film technique (such as vapour deposition or sputtering; with heating elements of e.g. $0,1 \mu\text{m}$ thickness). For more information, reference may be given to review paper "Transparent conductors - a status review", of authors Chopra, Major and Pandya, in "Electronics and optics - Thin Solid Films", 102 (1983) p. 1-46, ed. Elsevier Sequoia.

[0075] From the instant disclosure, it may be clear that a thermal head TH according to the present invention can be used advantageously e.g. in thermography and in photothermography. Further, the head is applicable in various machines such as printers, plotters, facsimiles, copiers, output terminals such as CAD systems, etc.

[0076] One type of a thermographic material m suitable for application within the present invention comprises on a support a thermosensitive layer incorporating an organic silver salt and a reducing agent contained in said thermosensitive layer and/or in (an) other optional layer(s). A cross-section of such a thermographic material m is disclosed in co-pending application entitled "IMPROVED METHOD FOR THERMAL RECORDING", filed on a same date and incorporated herein by reference. Further details about the composition of such a thermographic material m may be read in EP 0 692 733 (in the name of Agfa-Gevaert).

[0077] It may be remarked that such a thermal print head can be used for uniform heating, e.g. in thermography. This results in a method for uniform heating an imaging element (m), comprising the steps of: providing an imaging element (m), and a thermal head (TH) having energisable heating elements (H_i), activating each heating element such that an equal temperature (T_0) in the imaging element is reached. Alternatively, a non-transparent thermal head can

be used for uniform heating, e.g. in cases of so-called preheating or in cases of so-called postheating.

[0078] Moreover, uniform heating by means of a thermal head TH, being transparent or being non-transparent, may be used advantageously in an imaging or recording apparatus. For example, sheets fed through a recording apparatus may be subjected to a drying operation prior to imaging, in order to reduce the moisture content, e.g. below 60 %.
 5 Indeed, a lower moisture content may be favourable for jamfree transport of the sheet and/or for the quality of imaging. Such paper conditioning or dehumidifying means can incorporate a thermal head according to the present invention.

[0079] In addition to the imaging apparatus and methods, uniform heating by means of a thermal head, being transparent or being non-transparent, also can be used in other applications, such as electrophotography (e.g. for fixing a powder image), in drying wet-processed photographic materials (such as microfilms, medical prints, printing plates ...),
 10 in heating ink-jet images, etc.

(v) Applicability of a transparent thermal head combined with a laser

[0080] As mentioned above, more information about methods using a transparent thermal head TH according to the present invention, especially of a transparent thermal head combined with a laser, can be found in co-pending application entitled "IMPROVED METHOD FOR THERMAL RECORDING", filed on a same date and incorporated herein by reference.

[0081] As an example of such use, attention may be focused on present Fig. 5, which shows a recording method using a transparent thermal head according to the present invention combined with a laser.

[0082] Such method for recording an image on a thermal imaging element le comprises the steps of providing (e.g. by means of a rotatable drum 15) a thermographic material m (ref. 3) having a thermal imaging element le, a transparent thermal head TH (ref. 16) having energisable heating elements (Hi), and a radiation beam L (ref. 41), capturing input data (see input data block 22), processing (in processing unit 24) the digital image signals, activating heating elements of said thermal head and imagewise and scanwise exposing said imaging element by means of said radiation beam,
 20 wherein said imagewise and scanwise exposing is carried out by passing said radiation beam through transparent parts of said thermal head.

[0083] Several advantages of the instant invention may be indicated. For the sake of conciseness, no redundant description is repeated in the instant specification. Yet, it is indicated that, an important advantage of a transparent thermal head comprises the possibility of e.g. directing a density control through the thermal head, e.g. for controlling a density while it is formed on a the thermographic material. Because pixel formation is not obscured by the head 16,
 25 it can be easily monitored with a photocell detector.

(vi) Further applicability of a thermal head according to the present invention

[0084] The method of the present invention is applicable for a wide variety of printing techniques. Reference is made to Figure 2 which schematically shows the basic functions of a thermal printer which uses a reductor (donor) ribbon. As many elements of Fig. 2 are similar in structure and in operation to the correspondingly numbered structural elements described in relation to Fig. 1, a full description of Fig. 2 is not necessary here.

[0085] Reduction ribbon printing uses a thermal print head 16, which can be a thick or a thin film thermal print head, to selectively heat specific portions of the donor element 2 in contact with a receiving element 1. Supply roller 13 and take-up roller 14 are driven by variable speed motor 18 with a predetermined tension in the web or ribbon of the donor element 2.
 40

[0086] A thermal head TH according to the present invention also may be used in a method for recording an image on a thermal imaging element (m) comprising the steps of providing a thermographic material having a thermal imaging element, and providing at least two thermal heads (TH₁ and TH₂) each having energisable heating elements (Hi), activating heating elements of the first thermal head such that a preheat temperature (T_o) in the imaging element is reached which is below the conversion temperature (T_c) of the imaging element, imagewise exposing the imaging element by means of the second thermal head having a level of energy corresponding to a gradation (optionally also standing for e.g. density, colour, etc.) of the image to be recorded on the imaging element, wherein at least one of the thermal heads is transparent.
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[0087] In such an embodiment, the energy is supplied in two steps: first providing a uniform situation, and secondly a fine-adjusted tuning to the precise end-situation, wherein the second step is as small, and hence as accurate, as possible.

[0088] If e.g. a final temp of 125°C (or 398 K) were to be desired, a preheating from ambient temperature up to 80°C (or 353 K) would be less favourable than a preheating from ambient temperature up to 110 °C (or 383 K).

[0089] More information about embodiments using at least two thermal heads according to the present invention can be found in co-pending application entitled "IMPROVED METHOD FOR THERMAL RECORDING", filed on a same date and incorporated herein by reference. In particular reference is made to drawing Fig. 6 of the co-pending appli-

cation, and even more in particular to ref. nrs. 71, 74, 91, 94 and 96 as indicated and disclosed in the co-pending application. For the sake of conciseness, no redundant description is repeated in the instant specification.

[0090] While the present invention has been described in connection with preferred embodiments thereof, it will be understood that it is not intended to limit the invention to those embodiments. Moreover, having described in detail preferred embodiments of the current invention, it will now be apparent to those skilled in the art that numerous modifications can be made therein without departing from the scope of the invention as defined in the appending claims.

[0091] Some exemplary modifications could comprise the following:

(i) The print head 16 may include a 'horizontally' extending array of elements that spans the width of the paper for printing a line at a time, or it may include a smaller matrix of elements and be mounted for horizontal movement back and forth across the paper to print characters serially.

(ii) Although line-type print heads having a one dimensional array have been referred to here, the present invention can also make use of two dimensionally arranged print head arrays.

[0092] Thermal imaging can be used for both the production of transparencies and reflection type prints. In the hard copy field recording materials on white opaque base are used, whereas in the medical diagnostic field black imaged transparencies find wide application in inspection techniques operating with a light box.

[0093] The present invention clearly can also be applied in the case of coloured images, in the case of which the electrical image signals corresponding to different colour selections are sequentially subjected to typical corresponding transformation lookup tables such that the diagnostic visual perception of the coloured hardcopy reaches an optimum.

[0094] Having described in detail preferred embodiments of the current invention, it will now be apparent to those skilled in the art that numerous modifications can be made therein without departing from the scope of the invention as defined in the appending claims.

Parts list

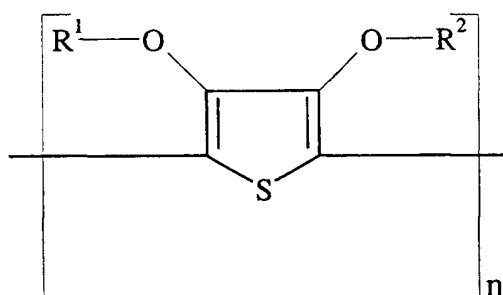
[0095]

- 1 receiving element
- 2 donor element
- 3 thermographic material m / thermographic imaging element le
- 10 thermal printer
- 13 supply roller
- 14 take-up roller
- 15 drum
- 16 thermal print head TH
- 17 hardcopy image
- 18 motor
- 22 input data
- 24 processing unit
- 29 opening
- 31 heatsink hs
- 32 temperature sensor
- 33 bonding layer
- 34 insulating substrate
- 35 protrusion
- 36 heating material hm
- 37 protective layer
- 39 heating element Hi
- 41 laser beam
- 44 power supply & processor
- 47 window
- 46 switching matrix
- 48 signal electrodes
- 49 counter electrodes
- 81 transmittance curve of heating material ITO
- 82 transmittance curve of heating material ORGACON-EL
- 83 absorption curve of heating material ORGACON-EL

84 reflection curve of heating material ORGAICON-EL

Claims

1. A thermal head TH (16) comprising a heatsink (31), heating elements (39), and electrodes (48, 49), characterised in that said heating elements are optically transparent.
2. The thermal head TH according to claim 1, wherein said heating elements (39) are part of a heating material hm (36).
3. The thermal head according to claim 2, wherein said heating material hm is optically transparent by having a transparency higher than 70 % in the wavelength range of 350 to 1200 nm.
4. The thermal head according to claim 2, wherein said heating material hm is optically transparent by having a transparency higher than 80% in the wavelength range of from 700 to 1100 nm.
5. The thermal head according to claim 2, wherein said heating material hm is selected from the group consisting of In_2O_3 optionally doped with oxygen, Sn, Ti, Pb, F; SnO/O_2 optionally doped with oxygen, Sb, F, Cl, Br, I, P, As, In, Th, Te, W; ZnO optionally doped with oxygen, In, Al; Cd_2SnO_4 , or CdSnO_3 , mixtures thereof (as cadmium stannate); Bi_2O_3 ; MoO_3 ; TiO_2 ; WO_2 ; RhO_2 ; ReO_2 ; Na_xWO_3 ; Zn_2SnO_4 ; and V2O5.
6. The thermal head according to claim 2, wherein said heating material hm is a conductive polymer.
7. The thermal head according to claim 6, wherein said conductive polymer is polypyrrole, polyaniline or polythiophene.
8. The thermal head according to claim 6, wherein said polythiophene has formula



in which, each of R^1 and R^2 independently represents hydrogen or a C1-4 alkyl group or together represent an optionally substituted C1-4 alkylene group or a cycloalkylene group, preferably an ethylene group, an optionally alkyl-substituted methylene group, an optionally C1-12 alkyl- or phenyl-substituted 1,2-ethylene group, a 1,3-propylene group or a 1,2-cyclohexylene group.

9. The thermal head according to claim 2, wherein said heating material hm has a surface resistivity (SR) between 5 and $3000 \Omega / \square$
10. The thermal head according to claim 2, wherein said heating material hm has a specific resistivity ρ between $10^{-5} \Omega \cdot \text{cm}$ and $1 \Omega \cdot \text{cm}$ or a specific conductivity σ between 1 and 10^4 S/cm .
11. The thermal head according to claim 1, wherein said heating elements have a width smaller than $70 \mu\text{m}$.
12. Use of a thermal head according to any one of the preceding claims in thermography or in photothermography.
13. Imaging method according to claim 12, wherein a thermographic material m comprises on a support a thermosensitive layer incorporating an organic silver salt and a reducing agent contained in said thermosensitive layer and/

or in another optional layer.

14. A method for uniform heating an element,
comprising the steps of:

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- providing said element and a heating means,
- energising said heating means such that an equal temperature (T_0) in the element is reached,

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characterised in that said energising said heating means comprises activating energisable heating elements (H_i)
of a transparent thermal head (TH).

15. A method for recording an image on a thermographic material (m) comprising the steps of

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- providing said thermographic material (m) having a thermal imaging element (Ie), and providing at least two thermal heads (TH₁ and TH₂) each having energisable heating elements (Hi),
- activating heating elements of said first thermal head such that a preheat temperature (T_0) in the imaging element is reached which is below the conversion temperature (T_c) of the imaging element,
- imagewise exposing said imaging element by means of said second thermal head having a level of energy corresponding to a gradation of the image to be recorded on said imaging element, wherein at least one of said thermal heads is transparent.

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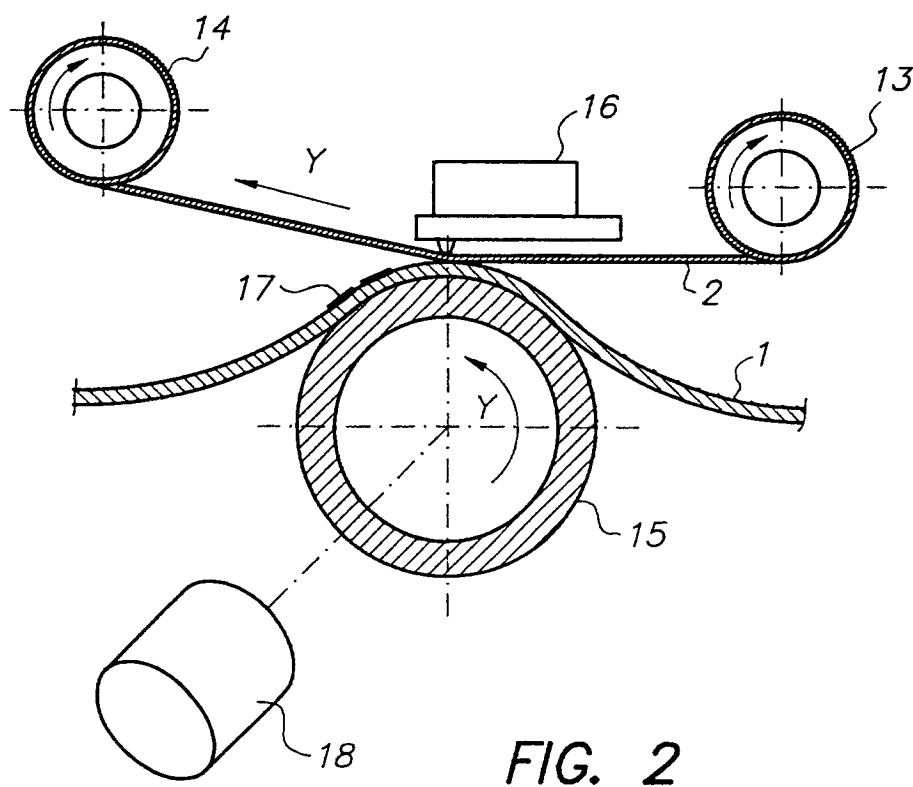
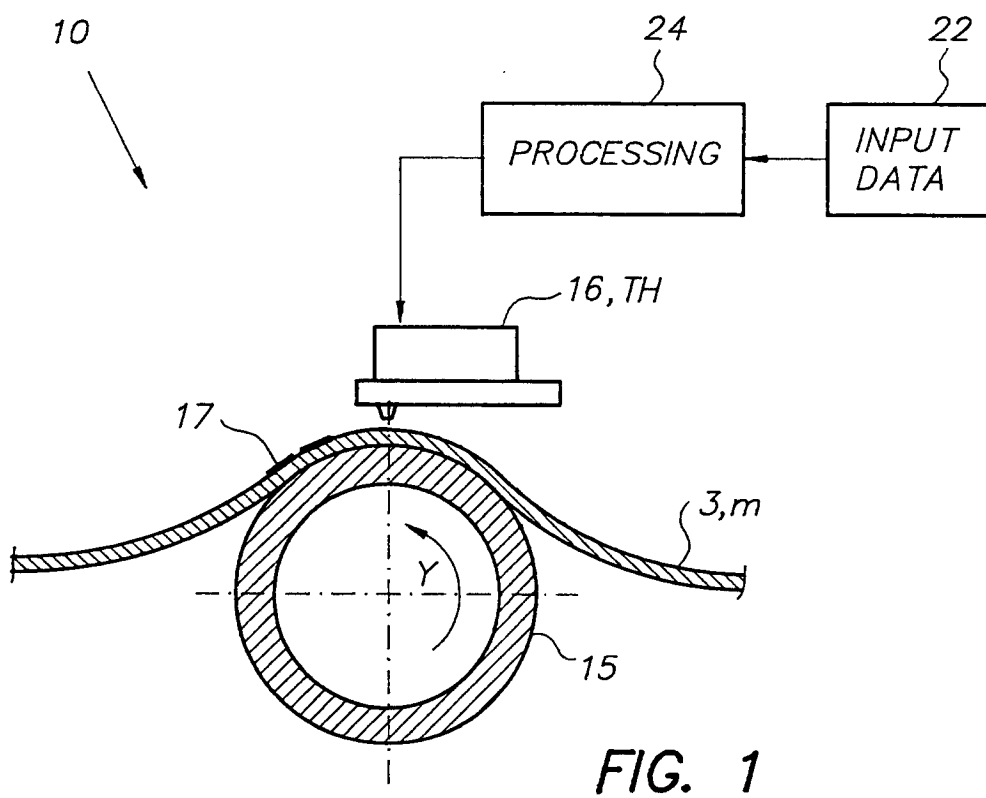
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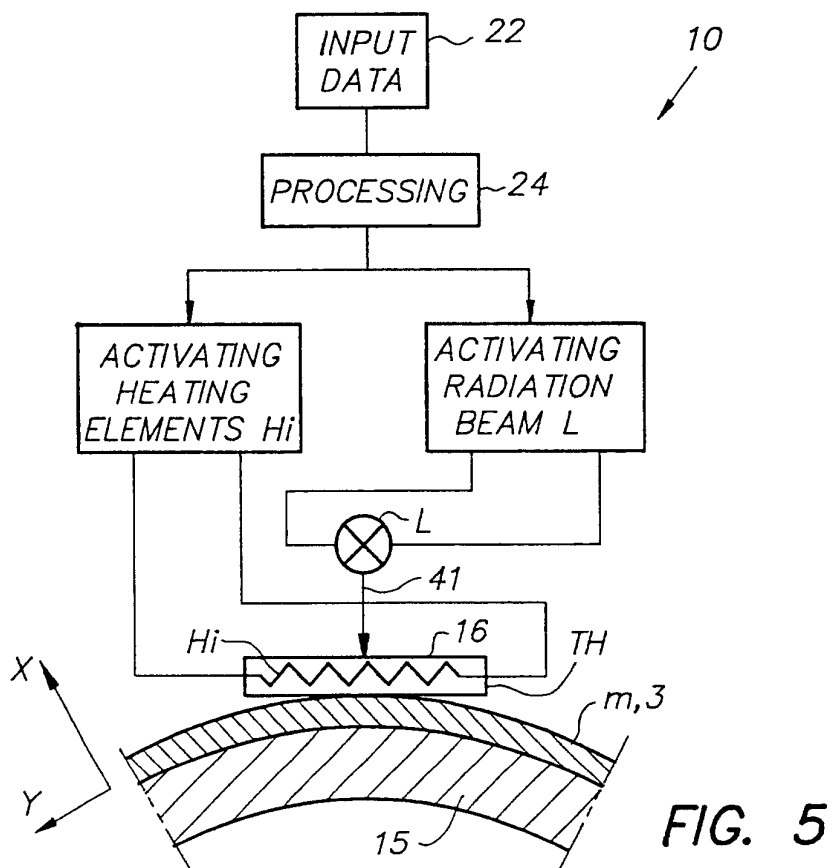
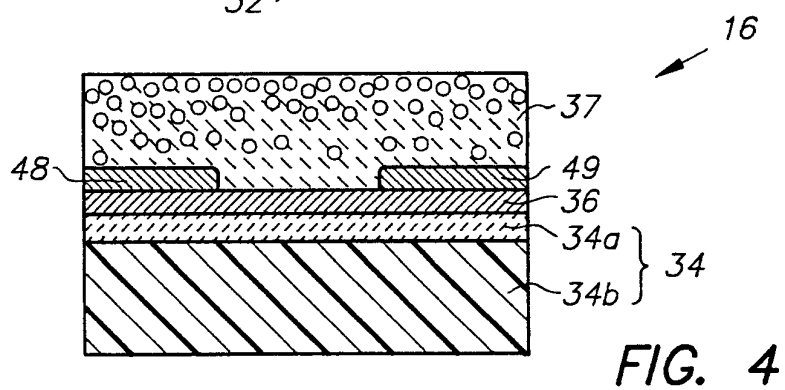
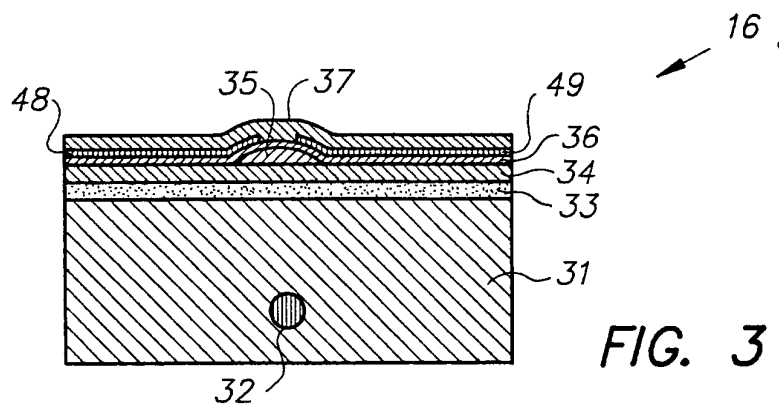
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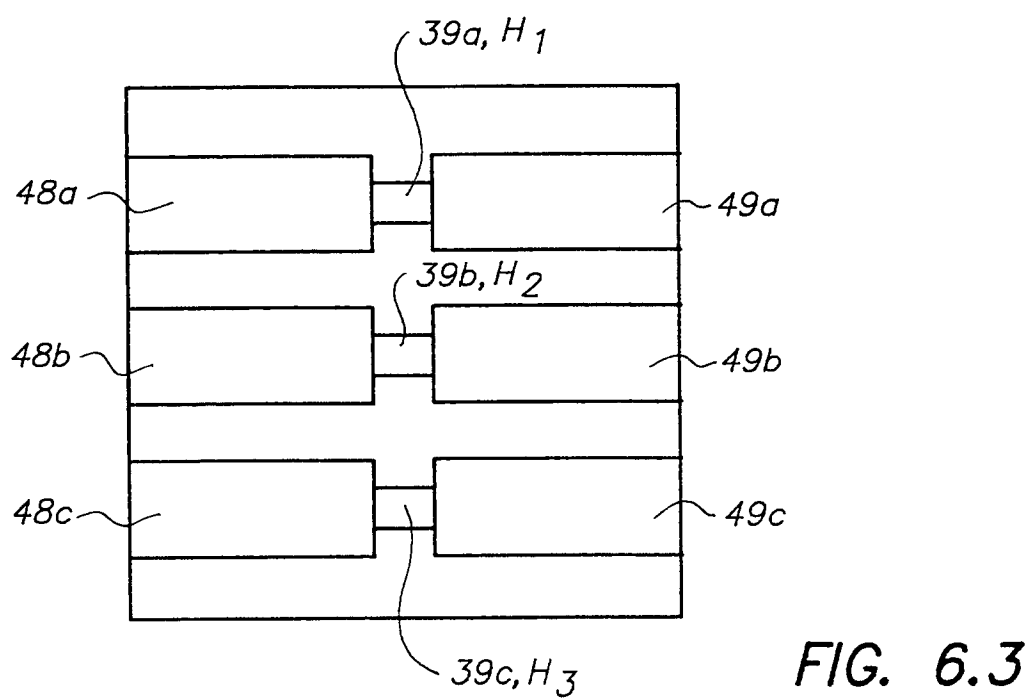
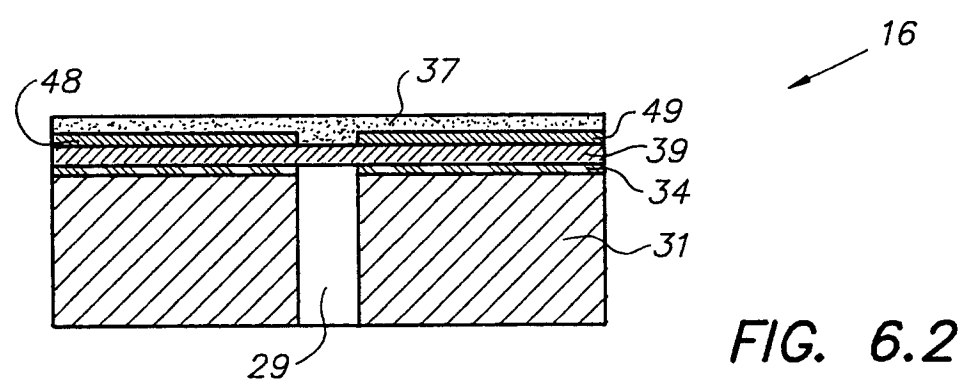
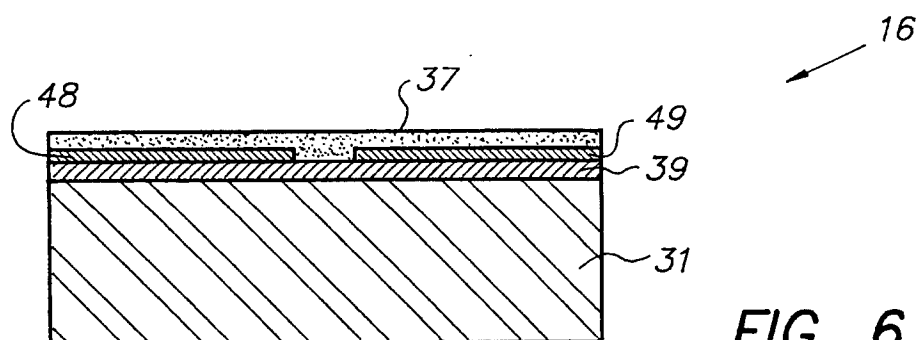
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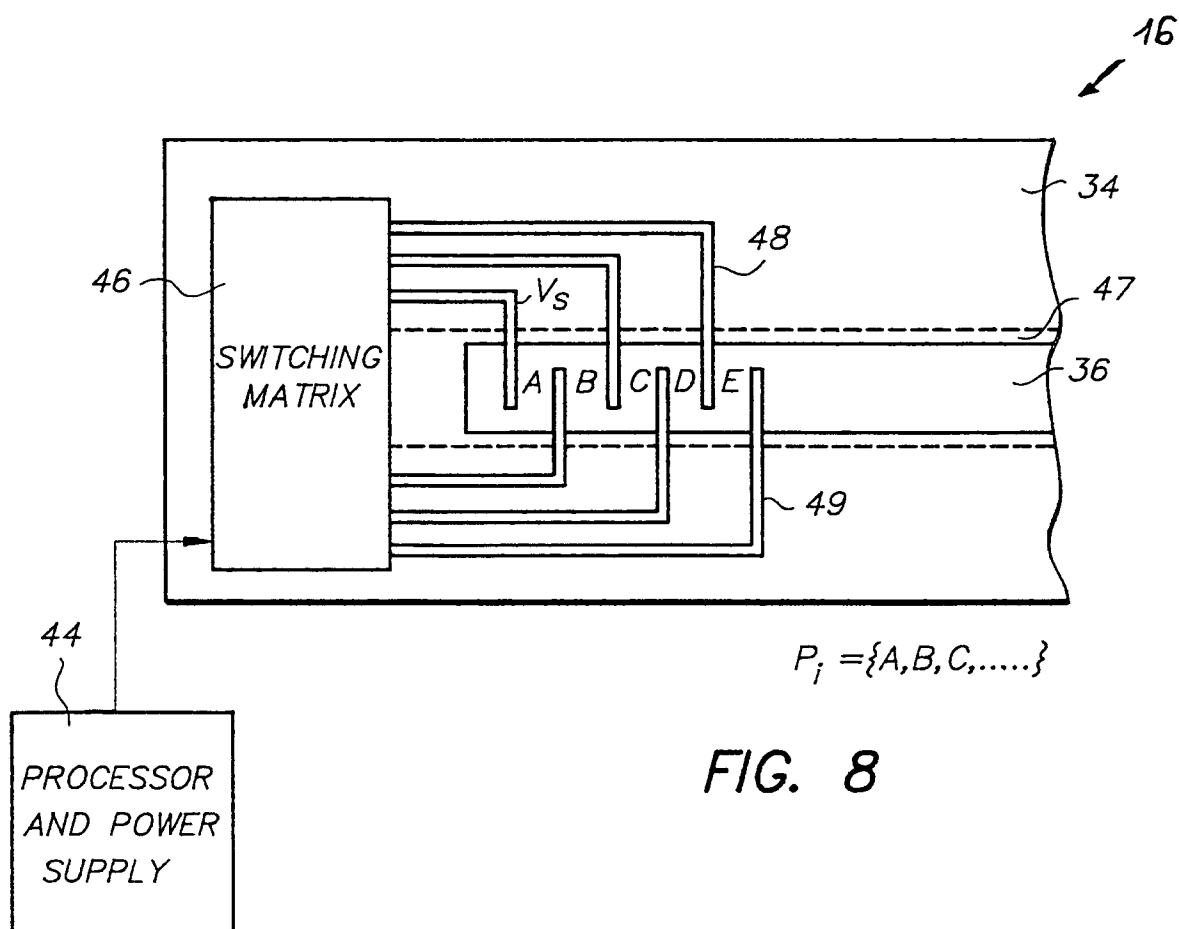
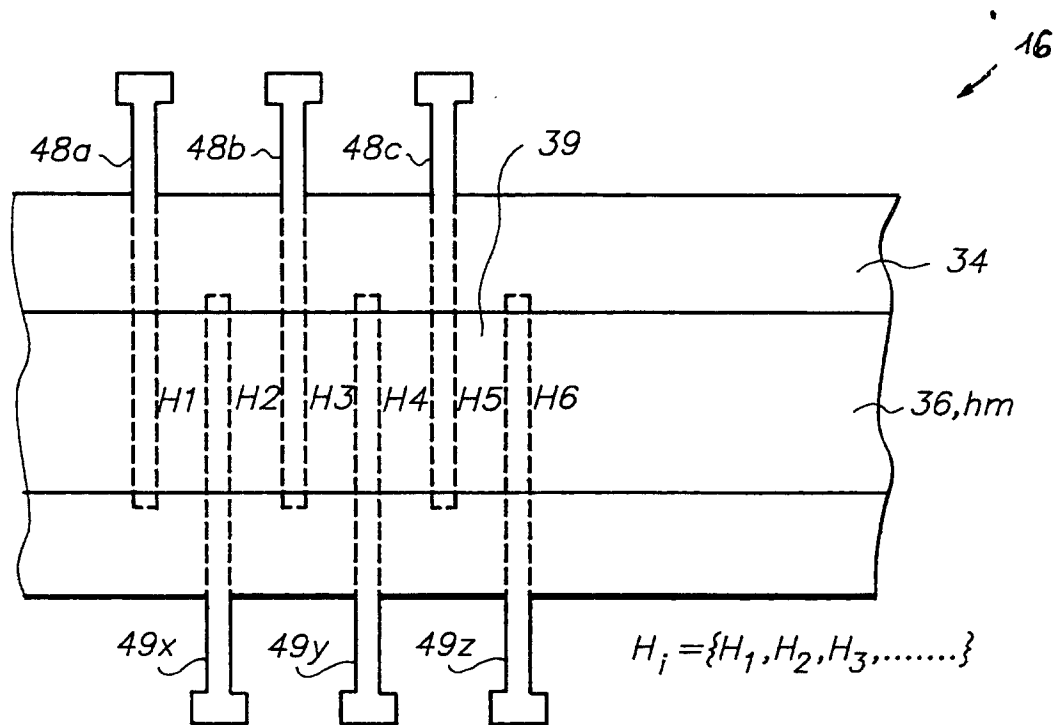
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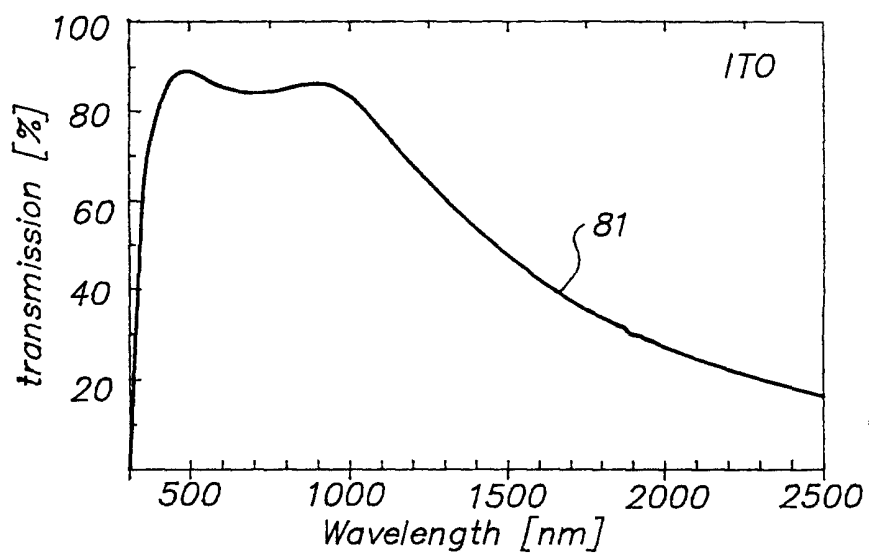


FIG. 9

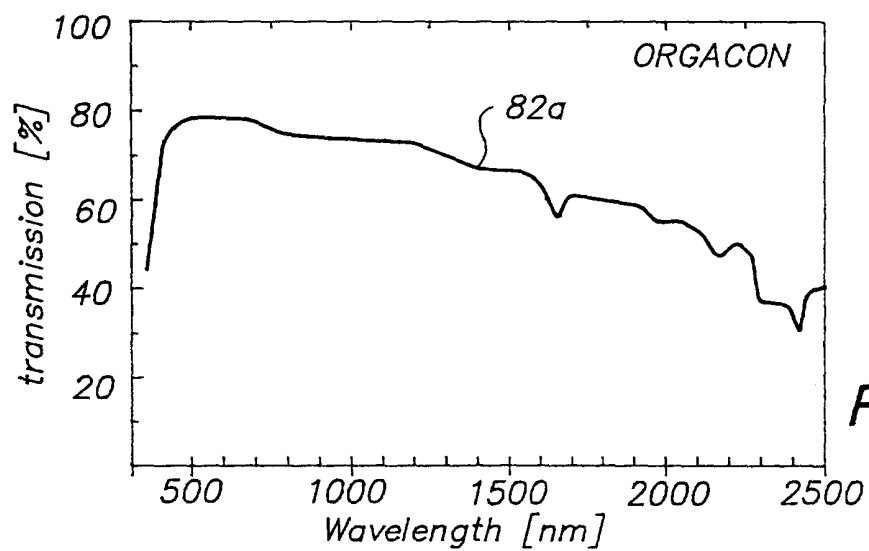


FIG. 10

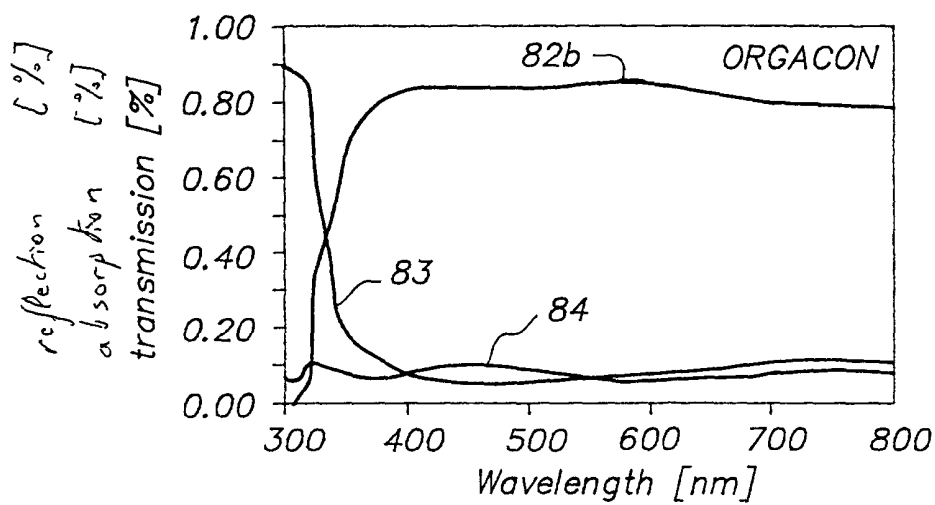


FIG. 11



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 20 4069

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 28 April 2000	Examiner Didenot, B
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 99 20 4069

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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28-04-2000

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82