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(71) Applicant: **Siemens-Elema AB**
171 95 Solna 1 (SE)

(72) Inventor: **Slettenmark, Bruno**
17569 Järfälla (SE)

(54) Packaging comprising a phase changes temperature moderator

(57) Packaging for thermally sensitive material comprises a temperature moderator (9) locatable in heat exchange relationship with the material and with a variable temperature space, the moderator (9) being adapted to maintain the thermally sensitive material within a temperature range defined by a minimum temperature and a maximum temperature **characterised in that** the moderator (9) is adapted to undergo a first phase change at the minimum temperature and a second phase change at the maximum temperature to maintain the temperature sensitive material within the temperature range when the temperature of the variable temperature space lies outside the range. The moderator (9) may usefully be included within a container for the thermally sensitive material comprising (3,4) formed of thermally insulating material (2) to further improve the thermal protection offered by the packaging (1).

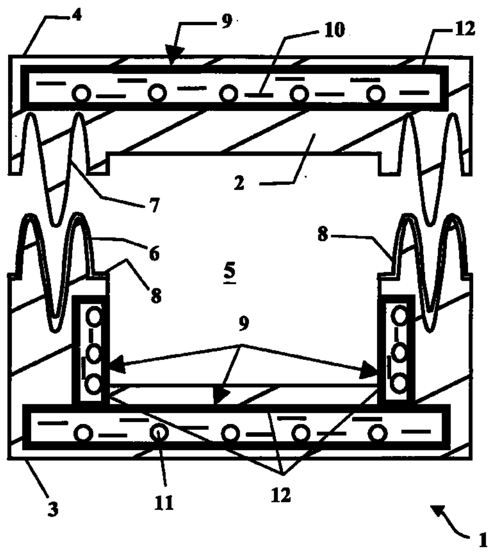

FIG. 1

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Description

[0001] The present invention relates to packaging and in particular to packaging for thermally sensitive material.

[0002] Thermally sensitive material, for example perishable foodstuffs and electronic components or devices, such as charge-coupled device (CCD) cameras, exhibit a sensitivity to temperature in a manner that could cause irreparable damage to the material should its temperature fall outside a safe temperature range, which may typically be for example 0°C to +45°C for a CCD camera. Whereas it is relatively simple to control the use of the component or device to ensure that it only is exposed to temperatures within its safe range it is more difficult to control the temperatures it may be exposed to during transport or storage. Transport as air cargo and storage in cargo bays that are exposed to strong sunlight may respectively result in the thermally sensitive material being subjected to ambient external temperatures ranging from extremes of -40°C to +60°C. However, packaging has been developed protect the thermally sensitive material from similar temperature extremes.

[0003] Known packaging, such as for example is described in US 5,435,142, generally includes a container of insulating material configured to provide a inner space. A temperature moderator comprising a freezable substance is placed around the walls of the inner space and frozen to form a cooled chamber in which the thermally sensitive material is held during transport and storage. In particular US 5,435,142 describes a temperature moderator using two types of substance, one frozen to -20°C and the other chilled to +4°C. These substances co-operatively transfer heat to the thermally sensitive material in a manner that enables the temperature of the latter to be maintained between +2°C and +10°C for several hours, even if the temperature of the space outside the container reaches extreme high or low values (for example -20°C or +38°C).

[0004] One problem with this known type of packaging is that the thermal protection requires "priming" by freezing of at least one component of the temperature moderator to a temperature below the minimum temperature of the safe range. This means that the protection starts from the moment the frozen substance is exposed to external temperatures higher than its initial temperature, irrespective of whether or not the external temperature is within the limits of the safe temperature range for the thermally sensitive material. This has the disadvantage that the protection offered will have a limited life-time, determined by the rate at which the substance melts, which is used up even if the outside temperature is within the safe temperature range of the temperature sensitive material. A further disadvantage is that in order to maximise this protective life-time freezing facilities will usually have to be provided in physical proximity to the packaging area, even if the ambient temperature is within the material's safe temperature range.

[0005] It is an aim of the present invention to provide packaging for thermally sensitive material that may at least alleviate one or more of the disadvantages associated with the known packaging.

[0006] This is achieved by the packaging of the present invention as described in and characterised by claim 1. With this arrangement the temperature of the temperature moderator initially lies within the safe temperature range and the material undergoes a change of phase due to the temperature of the variable temperature space, for example ambient air in cargo holds or storage facilities, falling below the minimum temperature or exceeding the maximum temperature of a safe temperature range. When undergoing this phase change the temperature moderator maintains a substantially constant temperature and thereby moderates the temperature that the thermally sensitive material will be exposed to. The thermal protection thus provided by the moderator of the present invention is not activated until external temperatures require it, that is to say, until external temperatures fall outside the safe temperature range of the thermally sensitive material.

[0007] Advantageously, the temperature moderator may comprise two chemically distinct materials, a first material selected to undergo a suitable phase change at the minimum temperature, for example liquid to solid, and a second material at the maximum temperature, for example solid to liquid.

[0008] In circumstances where the minimum and maximum temperatures lie within the limits of between 0°C and 60°C, particularly where the thermally sensitive material comprises electronic components, phase change materials such as water; elaidic acid ($C_{18}H_{34}O_2$); paraffins, "paraffin-like" substances such as n-Tetradecane, n-Hexadecane, n-Octadecane, n-Nonadecane; waxes; olefins or other known materials compatible with the function and purpose of the present invention, as disclosed herein, may be employed. Indeed, by adding impurities, such as for example salt to the water, the phase change temperatures of the above materials may be readily adapted to suit the intended use, for example salt-water may be usefully employed as the first material where the minimum allowable temperature is lower than 0°C. Such materials also have the advantage that they are "safe" in so far as they are basically non-toxic and present no corrosion or explosion risk under normally expected conditions of usage.

[0009] Most usefully the packaging also comprises thermally insulating container fabricated from, for example, expanded polystyrene foam and formed to provide an inner space for receiving the thermally sensitive material. The container is preferably arranged so that at least part of its thickness will be disposed between the variable temperature space and the temperature moderator. This provides further thermal protection for the thermally sensitive material, a delayed activation of the temperature moderator and may also provide a degree of physical protection.

[0010] **Usefully**, the container may also include one or more layers adapted to limit thermal conduction between the variable temperature space and the inner space by the reflection of incident thermal energy.

[0011] Embodiments of the invention will now be described, by way of example only, with reference to the drawings of the accompanying Figures of which:

Figure 1 illustrates one embodiment of packaging comprising a container and temperature moderator arrangement according to the present invention.

Figure 2 illustrates a further embodiment of packaging comprising an alternative container and temperature moderator arrangement according to the present invention.

Figure 3 illustrates an alternative form of removable temperature moderator useable as packaging according to the present invention.

[0012] Considering now Figure 1, packaging 1 is provided comprising a container fabricated from a thermally insulating material 2, such as expanded polystyrene, and arranged with a body section 3 and a lid section 4. The body section 3 and lid section 4 when placed together define an inner space 5 in to which may be placed a temperature sensitive material that is to be protected (not shown). The material having a safe temperature range delimited by a maximum temperature and a minimum temperature, within which no thermal damage will be caused.

[0013] Opposing faces of the body 3 and the lid 4 are formed with structured mating surfaces 6,7 which co-operate to provide a long leakage path seal that, in use, results in a good thermal insulation between the inner space 5 and temperatures external the container 3,4. A thin compressible layer 8, such as may be formed using a sponge foam material, may be overlaid on one or both mating surfaces 6,7 in order to form a compressible seal which will limit any thermal leakage that may be caused by convention.

[0014] Both the body section 3 and the lid section 4 have a temperature moderator 9 disposed within their thicknesses. The moderator 9 comprises a liquid 10 and solid 11 mixture of two chemically unreactive materials. These materials 10,11 which act as a first and a second phase change material respectively, are selected to protect the temperature sensitive material against effects of the temperature outside the container 3,4 falling below the minimum temperature and rising above the maximum temperature in a manner that will be more fully discussed below. A holder 12 is provided to contain the moderator 9 and may be formed from a suitable plastic material.

[0015] Considering now Figure 2 in which items common to this Figure and Figure 1 are provided with the same reference numerals. Packaging 13 is provided which again is fabricated from a thermally insulating material 2, such as expanded polystyrene, but arranged with two, approximately equal, sections 14, 15 which when placed together define an inner space 5 in to which may be placed temperature sensitive material (not shown) mentioned in respect of Figure 1.

[0016] Opposing faces of the body sections 14,15 are formed with "step-like" structured mating surfaces 16,17 which again co-operate in use to provide a long leakage path seal.

[0017] A temperature moderator 18 is provided and comprises a liquid 19 and solid 20 mixture of two chemically unreactive materials, which may or may not be the materials 10,11 of Figure 1, to act as a first and a second phase change material selected to change phase at the minimum and at the maximum temperatures respectively.

[0018] The liquid 19 and the solid 20 are loosely sealed separately within pouches 21 which themselves are removably locatable within the inner space 5 to surround the temperature sensitive material.

[0019] Additionally, one or mare layers 22a-c of thermally reflective material, such as the metal foil or metallised plastic foil, may be placed around and or within the container 14,15 to further improve the thermal insulation capacity of the packaging. Such layers, 22a and 22b, can act to reflect thermal radiation back to the variable temperature space. The layers 22c can also act to inhibit the conduction of thermal energy from the inner space 5, particularly when placed against the inner walls of the container 14,15 that define the inner space 5. It will be appreciated by those skilled in the art that a similar construction may also be used with the container 3,4 of Figure 1 in order to achieve the same advantages.

[0020] Figure 3 shows a further removable arrangement of a temperature moderator according to the present invention. Two sheets 23,24 of "bubble pack" are provided, each sheet 23,24 having "bubbles" or pockets 25,26, formed in a manner known in the art, on one face 27,28 of the respective sheets 23,24 and are joined at the opposite faces 29,30 thereof. All bubbles 25 on one sheet 23 contain a liquid 31 selected to change phase to a solid at the minimum temperature and all bubbles 26 on the other sheet 24 contain a solid 32 selected to change phase to a liquid at the maximum temperature. The temperature moderator 33 formed from the combined sheets 23,24 of bubble pack can then, in use, be packed or wrapped around the temperature sensitive material (not shown) and may even be used independently of any container 14,15 if expected conditions of transport and storage allow it or in addition to the fixedly located moderator 9 exemplified in the embodiment of Figure 1.

[0021] It will be appreciated by those skilled in the art that a similar technique may be used to provide a sheet having a mixture of bubbles where each bubble contains only either the solid or only the liquid compound or a sheet where each bubble contains a mixture of the solid and the liquid component.

[0022] Considering the packaging 1, 13 of Figures 1 and 2 examples of suitable materials for use as the phase change components of the temperature moderators 9,18,33 and their performance under typical conditions will now be described:

[0023] When protecting an electronic device, such as a CCD camera, a suitable safe temperature range will lie between 0°C and +45°C so that at typical ambient temperatures of around +20°C no thermal moderation will be required of the temperature moderator 9,18,33. With the above safe temperature range a suitable choice of liquid 10,19,31 will be water (phase change to a solid at a temperature T_P = 0°C) and a suitable choice of solid 11,20,32 will be elaidic acid (phase change to a liquid at a temperature T_P = +44.4°C).

[0024] In use the temperature of temperature moderator 9,18,33 will follow the sensed variations in the temperature of the variable temperature space with a time constant proportional to its thermal mass for as long as the temperature of the moderator 9,18,33 lies within the safe temperature range. These variations will be transmitted to the thermally sensitive material, which will tend to be in thermal equilibrium with the moderator 9,18,33 because of the relatively good heat exchange arrangement between the two elements. In this temperature range no thermal protection is required and the moderator 9,18,33 remains "inactive".

[0025] As the temperature of the variable temperature space and transmitted to the moderator 9,18,33 falls outside the safe temperature range the moderator 9,18,33 becomes "active", in a manner dependent on the transmitted temperature, to moderate the temperature that the thermally sensitive component is exposed to. This keeps the electronic device within the safe temperature range for a period of time. Thus, as the transmitted temperature falls below the minimum temperature the liquid 10,19,31 component of the moderator becomes "active" and undergoes a phase change to a solid. During the change of phase the temperature of the moderator 9,18,33 remains substantially constant at the phase change temperature, T_P (0°C) to keep the device within the safe temperature range, that is to say substantially at 0°C. As the temperature rises above the minimum temperature the solidified liquid returns to its liquid phase and the moderator 9,18,33 becomes "inactive".

[0026] Similarly, as the transmitted temperature of the variable temperature space moves above the maximum temperature the solid 11,20,32 component of the moderator 9,18,33 will become "active" by undergoing a phase change to a liquid. During this phase change the temperature of the moderator 9,18,33 again remains substantially constant but at the phase change temperature, T_P (+44.4°C) of the solid 11,20,32 to keep the device within the safe temperature range, that is to say substantially at +44.4°C. As the temperature falls below the maximum temperature the liquefied solid returns to its solid phase and the moderator 9,18,33 becomes "inactive".

[0027] It will be appreciated that the temperature moderator 9,18,33 of the present invention will be able to undergo very many temperature cycles of the variable temperature space between temperatures within the safe temperature range and those outside the range and still be able to provide protection for the sensitive component. Moreover, the moderator 9,18,33 will be able to provide protection for the device even if the device has stood for an indefinite period in ambient temperatures within the safe temperature range.

[0028] The maximum single period of protection that may be provided by the moderator 9,18,33 depends on the temperature of the variable temperature space and the amount of moderator 9,18,33 available for phase change. This period may be readily calculated using standard thermodynamic considerations.

[0029] Using the present example of a safe temperature range of between 0°C and +45°C and taking, for simplicity, a cubic container having typical outer dimensions of 70cm x 70cm x 70cm which defines a cubic inner space of 30cm x 30cm x 30cm then each wall of the container will have a thickness, W = 20cm and an average wall length, L = 50cm ((70+30)÷2). It is also assumed that expanded polystyrene is used as the insulating material 2 and this has a thermal conductivity, λ, of approximately 0.033 W $°C^{-1}$ m^{-1}.

[0030] With the temperature of the variable temperature space Tv = -40°C and a temperature of the inner space of the container, $T_S = T_P$ (water) = 0°C the transfer of thermal energy through the six walls of the container (cooling the inner space) in a time, t may be calculated from:

$$(t \times \lambda \times (|T_V - T_S|) \times 6 \times L^2) \div (W) \qquad (1)$$

which gives an hourly transfer of

$$(3600 \times 0.033 \times 40 \times 6 \times (0.5)^2) \div (0.2) \approx 36 \text{ kJ}$$

[0031] In converting 1 kg of water to ice approximately 334 kJ of latent heat is released.

[0032] Thus, in order to maintain the inner space at 0°C for 24 hours approximately 2.6 kg of water will be required to be used as the liquid component 10,19,31 in the moderator 9,18,33.

[0033] Similarly with the temperature of the variable temperature space, T_V = +60°C and a temperature of the inner space of the container, $T_S = T_P$ (acid) = +44.4°C the hourly transfer of thermal energy through the container walls (heating of the inner space) will be, from equation (1):

$$(3600 \times 0.033 \times 15.6 \times 6 \times (0.5)^2) \div (0.2) \approx 14 \text{ kJ}$$

[0034] In converting 1 kg of elaidic acid from solid to liquid approximately 218 kJ of latent heat is stored.

[0035] Thus, in order to maintain the inner space at +44.4°C for 24 hours approximately 1.6 kg of elaidic acid will be required to be used as the solid component 11,20,32 in the moderator 9,18,33.

[0036] Thus the overall weight of the moderator 9,18,33 sufficient to ensure adequate thermal protection for a single period of 24 hours when the ambient external temperature is at -40°C or at +60°C will therefore be 4.2 kg.

[0037] Of course materials other than those given in the example above may be chosen as the phase change materials provided that they have suitable physical properties such as a sufficiently high latent heat and phase change temperatures within the safe temperature range of the material to be protected. For example n-Octadecane, having a phase change from solid to liquid at a temperature, T_P of +28.2°C and a latent heat of 241.2 kJ kg^{-1} may replace the elaidic acid as the solid component 11,20,32 of the moderator 9,18,33.

[0038] It will also be appreciated by those skilled in the art that embodiments of the present invention may also be used to provide thermal protection for temperature sensitive materials having a safe temperature range that lies completely outside the normal room temperature of around +20°C.

[0039] If, for example, it was desired to protect a material having a safe temperature of around +30°C, perhaps in a range of between +28°C and +33°C then:

n-Octadecane (T_P = +28.2°C, 241.2 kJ kg^{-1}) and

n-Nonadecane (T_P = +32.1°C, 170.6 kJ kg^{-1})

may be used respectively as the liquid 10,19,31 and solid 11,20,32 component of the moderator 9,18,33. In this case the moderator would need to be activated before use by heating it sufficiently to melt only the n-Octadecane.

Claims

1. Packaging for thermally sensitive material comprising a temperature moderator (9,18,33) locatable in heat exchange relationship with the material and with a variable temperature space, the moderator (9,18,33) being adapted to maintain the thermally sensitive material within a temperature range defined by a minimum temperature and a maximum temperature **characterised in that** the moderator (9,18,33) is adapted to undergo a first phase change at the minimum temperature and a second phase change at the maximum temperature to maintain the temperature sensitive material within the temperature range when the temperature of the variable temperature space lies outside the range.

2. Packaging as claimed in claim 1 **characterised in that** the moderator (9,18,33) comprises a first material (10,19,31) selected to undergo the first phase change and chemically discrete second material (11,20,32) selected to undergo the second phase change.

3. Packaging as claimed in claim 2 **characterised in that** the first material (10,19,31) is adapted to change phase from liquid to solid at the minimum temperature and in that the second material (11,20,32) is adapted to change phase from solid to liquid at the maximum temperature.

4. Packaging as claimed in claim 3 **characterised in that** the phase change materials (10,19,31,11,20,32) are selected from a group comprising water, elaidic acid, paraffins, paraffin like hydrocarbons, waxes and olefins.

5. Packaging as claimed in claim 4 **characterised in that** the paraffin like hydrocarbons comprise the group n-Nonadecane, n-Octadecane, n-Hexadecane and n-Tetradecane.

6. Packaging as claimed in any previous claim **characterised in that** there is further provided a container (3,4; 14,15) comprising thermally insulating material (2) and having an inner space (5) for receiving the thermally sensitive material and a thickness (W), at least part of which is disposed between the variable temperature space and the temperature moderator (9,18,33).

7. Packaging as claimed in claim 6 **characterised in that** the temperature moderator (18,33) is removably locatable within the inner space (5) of the container (3,4; 14,15).

8. Packaging as claimed in claim 6 **characterised in that** the temperature moderator (9) is fixedly located within the thickness (W) of the thermally insulating material (2) to moderate a temperature gradient across the thickness of the material disposed between the moderator (9) and the inner space (5).

9. Packaging as claimed in any of the claims 6 to 8 **characterised in that** the container (14,15; 3,4) further comprises one or more layers (22a,22b,22c) adapted to moderate thermal conduction between the variable temperature space and the inner space (5) by reflection of incident thermal energy.

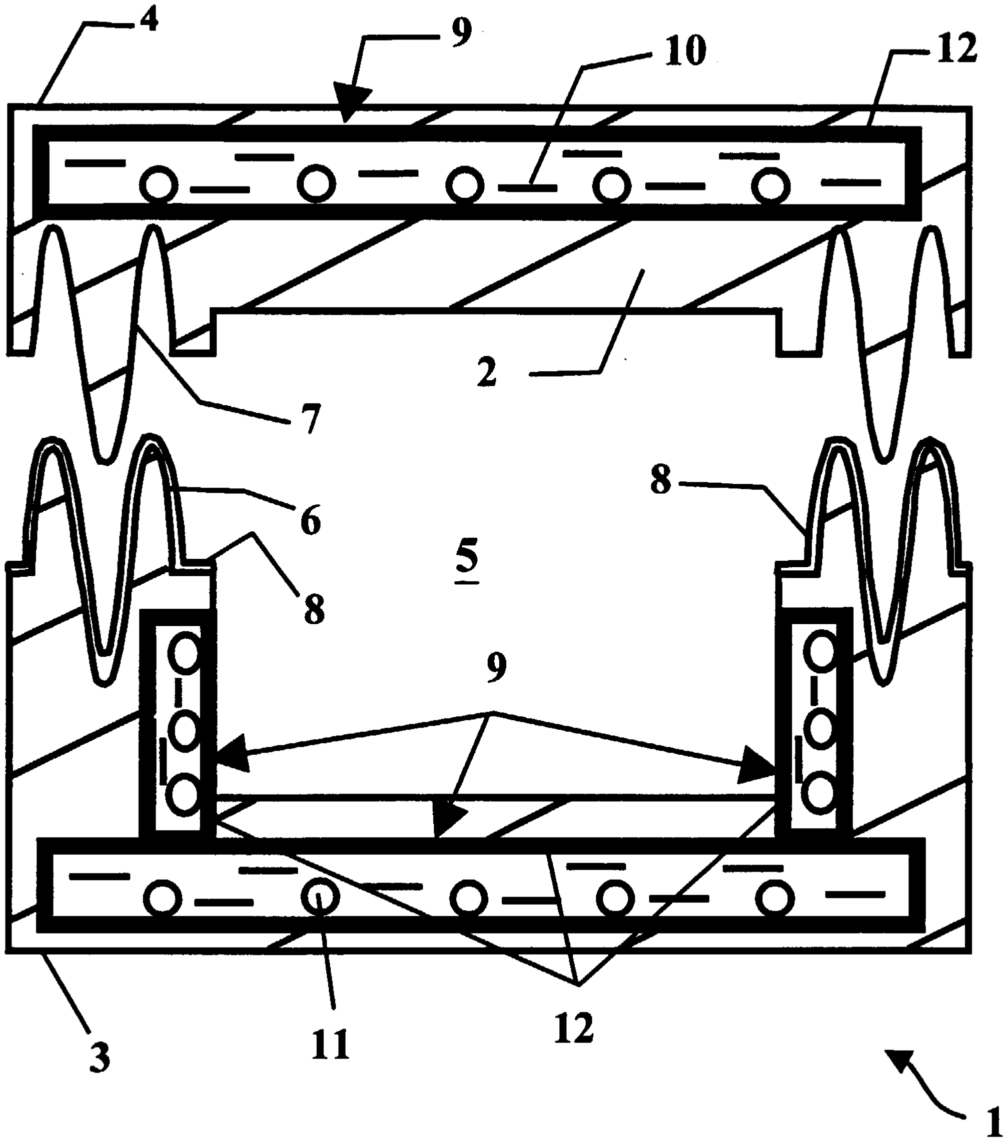

FIG. 1

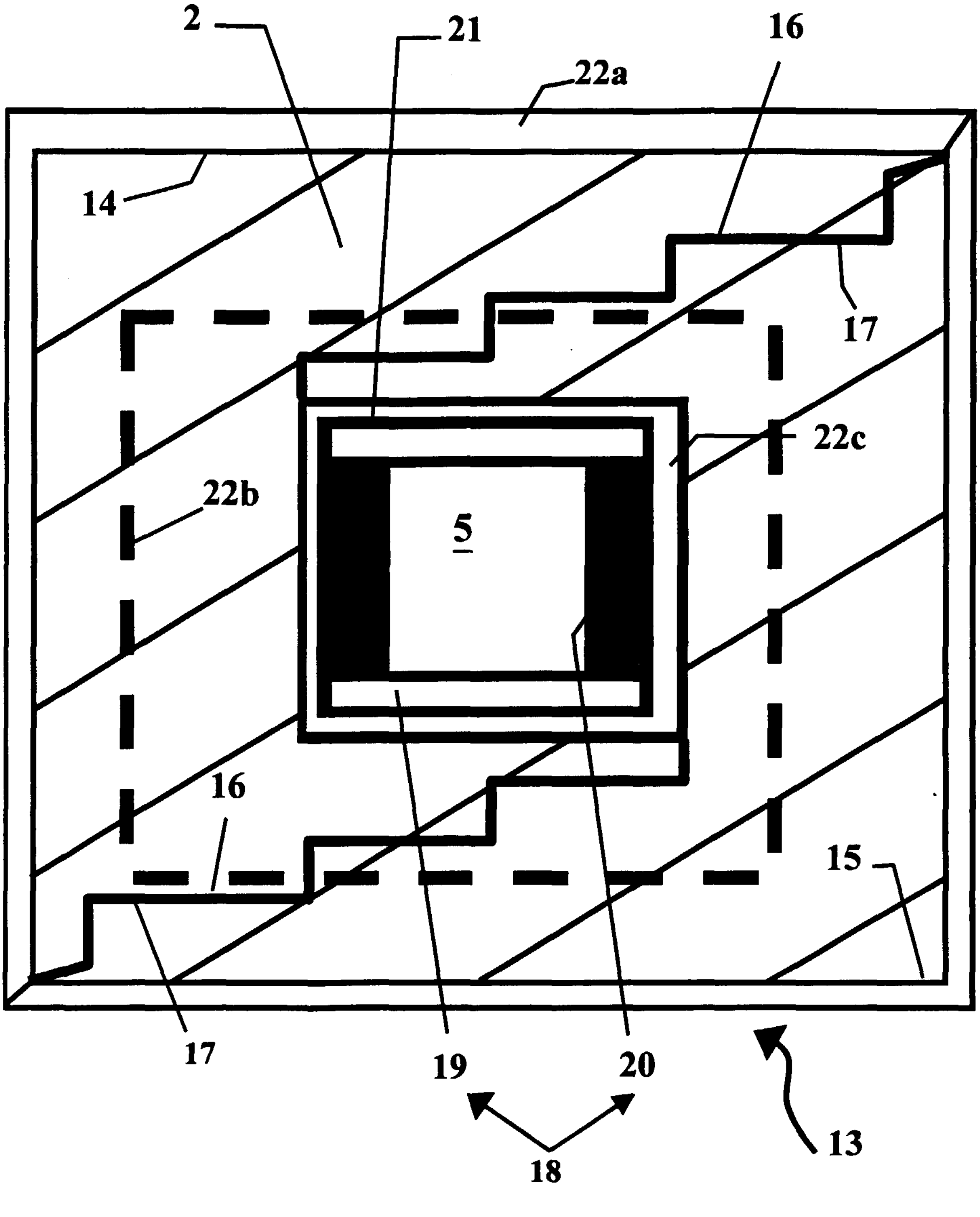

FIG. 2

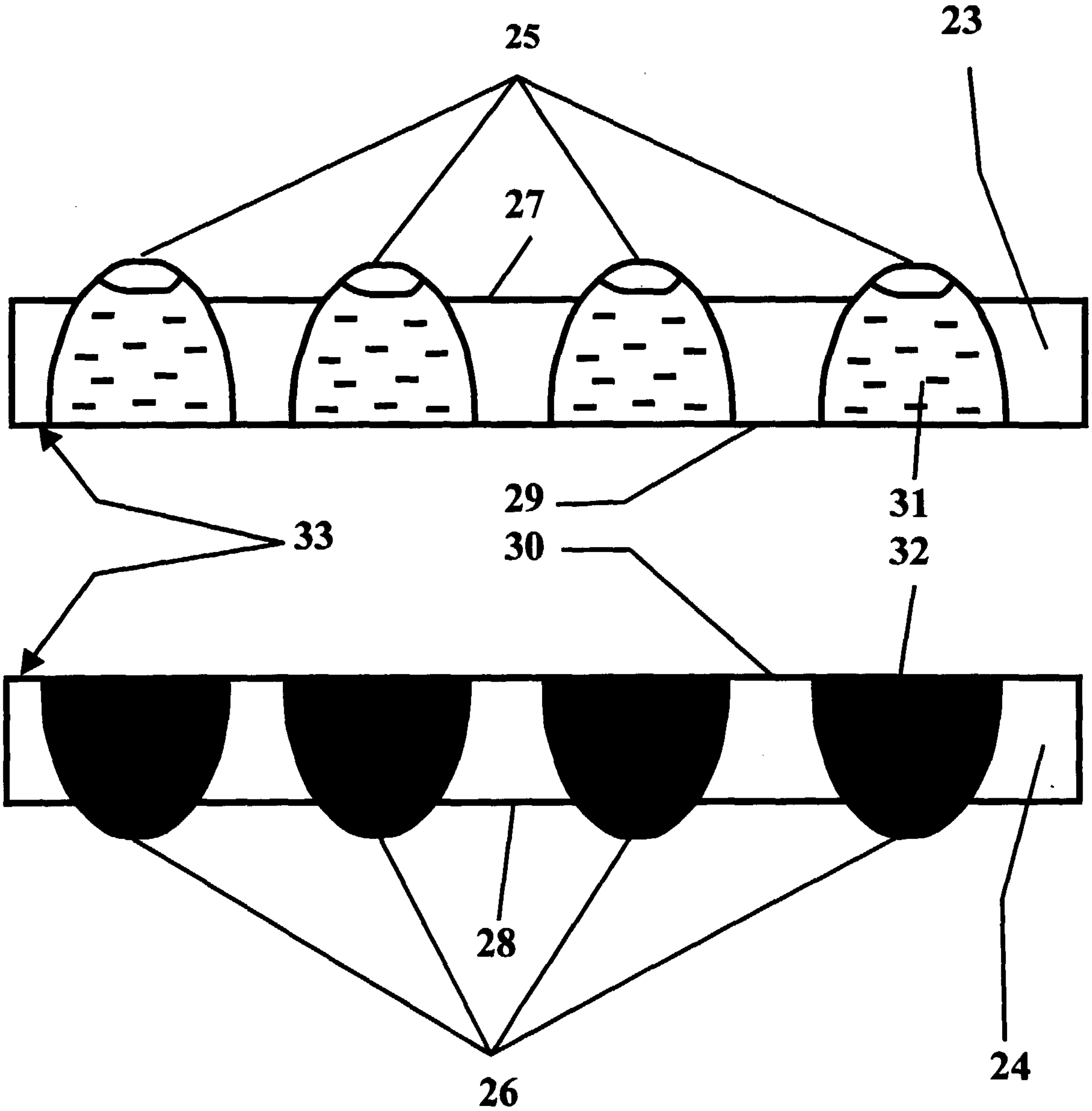

FIG. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 99 11 9635

DOCUMENTS CONSIDERED TO BE RELEVANT

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	Date of completion of the search	Examiner
BERLIN	29 February 2000	Spettel, J

CATEGORY OF CITED DOCUMENTS

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