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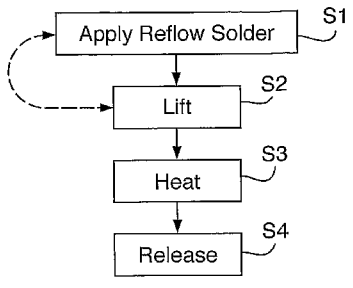
(54) Title: REFLOW SOLDERING IN AN APPARATUS COMPRISING AN SMA ACTUATOR ARRANGEMENT

Fig.1.



(57) Abstract: Reflow soldering between electrical terminals in an apparatus that comprises an SMA actuator arrangement is performed by applying reflow solder paste between the electrical terminals, moving a movable element relative to a support structure to reduce the stress in the SMA actuator arrangement, and whilst holding the movable element heating the reflow solder paste to electrically connect the electrical terminals. As the required high degree of heating is performed while the stress in an SMA actuator arrangement is reduced, the risk of damage to the SMA actuator arrangement is reduced.

Reflow Soldering in an Apparatus Comprising an SMA Actuator Arrangement

The present invention relates to the performing of reflow soldering between electrical terminals in an apparatus that comprises an SMA (shape memory alloy) actuator arrangement.

Such an apparatus may comprise a support structure, a movable element supported on the support structure, and an SMA actuator arrangement that is connected between the support structure and the movable element and arranged to drive movement of the movable element relative to the support structure. Such an apparatus is capable of precision controlled motion.

The present invention is generally applicable to any type of movable element but has particular application to actuation of a camera lens element, for example of the type used in a miniature camera which may be employed in a portable electronic device such as a mobile telephone or a mobile digital data processing and/or transmitting device. Miniature cameras of this the type are described in WO-2007/113478, WO-2008/099156 or WO-2009/056822. In a camera, the SMA actuator arrangement may provide various functions, such as movement along the optical axis to provide focussing or movement of the entire camera unit to provide optical image stabilisation.

There is ever-present pressure to reduce costs of manufacture of such an apparatus, particularly for application to mass-produced consumer electronic devices.

Part of the process of manufacturing such an apparatus includes creating the electrical connection between electrical terminals, for example between electrical terminals of the SMA actuator arrangement itself and electrical terminals of a circuit board, but equally between other electrical terminals. One process for making such electrical connection is hand soldering, but this process is labour intensive and thus time consuming and subject to yield issues.

In general, to reduce these issues, electrical connection between electrical terminals of surface mount electronic components is commonly performed by performing reflow soldering. In reflow soldering, reflow solder paste is applied between the electrical terminals, typically holding one component on another. The apparatus is then heated, for example by passage through a reflow oven, to make the

electrical connection by melting the reflow solder paste. This process greatly reduces or even eliminates the required degree of manual intervention, as compared to hand soldering. Thus, reflow soldering reduces labour costs and improves yield issues, thereby reducing overall manufacture costs. It would be desirable for such apparatuses to be compatible with reflow soldering techniques to reduce costs in this way.

By way of background, reflow soldering is not typically compatible with some competing actuator technologies, such as voice coil motors (VCM) and piezoelectric actuators. For example, in the case of a camera these competing actuator technologies are often used to provide focussing. The key reason that such competing actuator technologies are typically not compatible with reflow soldering is because of the materials used for some of their component parts. The reflow ovens reach high temperatures, for example of around 260°C, for sustained periods of time, for example of the order of a minute. Such conditions can produce damage, for example by the temperature exceeding the Curie temperature of the magnetic or piezolelectric material in the actuator, to the extent of significantly reducing the performance of the actuator.

SMA actuators have the potential to offer some important benefits over the competing technologies in terms of performance and manufacture cost. In this context, it would be beneficial for the apparatus to be compatible with reflow soldering to reduce downstream costs observed by end customers. However, there is an issue of the same nature as for the competing technologies of the temperatures required for reflow soldering damaging the SMA material of the SMA actuator arrangement. It should be noted that the temperatures observed within a reflow oven, for example of around 260°C, are significantly greater than the phase transition temperature of the SMA wire when electrically heated to provide contraction in normal operation, for example of around 80-100°C. Thus there remains the issue that its properties may be affected with the result of detrimental performance of the end product.

It would be desirable to perform reflow soldering of an apparatus comprising

an SMA actuator arrangement with a reduced risk of such damage.

According to the present invention, there is provided a method of performing reflow soldering between electrical terminals in an apparatus that comprises: a support structure; a movable element supported on the support structure; and an SMA actuator arrangement and a resilient biassing arrangement each connected between the support structure and the movable element, the SMA actuator arrangement being arranged to drive movement of the movable element relative to the support structure in a first direction on contraction, and the resilient biassing arrangement being arranged to bias the movable element relative to the support structure in a second, opposite direction, wherein the method comprises:

applying reflow solder paste between the electrical terminals;

before or after said step of applying reflow solder paste, moving the movable element relative to the support structure in the first direction to reduce the stress in the SMA actuator arrangement, and thereafter holding the movable element;

whilst so holding the movable element, heating the reflow solder paste to electrically connect the electrical terminals; and

releasing the movable element, thereby allowing the resilient biassing element to move the movable element in the second direction.

In the absence of moving the movable element in accordance with the invention, when the apparatus is exposed to the temperatures required for heating of the reflow solder paste, the SMA actuator arrangement will change phase and contract. This will move the movable element and deflect the resilient biassing arrangement, which in turn exposes the SMA wire to significant mechanical stress at the same time as exposure to significantly elevated temperatures, for example of around 260°C. Such temperatures being significantly greater than the phase transition temperature of the SMA material when electrically heated to provide contraction in normal operation, for example of around 80-100°C, this tends to detrimentally affect the properties of the SMA material, resulting in lowered performance of the final product.

However, it has been appreciated that such a detrimental affect to the

properties of the SMA material may be reduced by performing the required heating of the reflow solder paste whilst the SMA actuator arrangement is at a reduced stress, in particular by moving the movable element relative to the support structure in the first direction and thereafter holding the movable element whilst heating the reflow solder paste. Indeed, if subjected to low or no mechanical stress, for example in the case of SMA wire by moving the movable element until the SMA wire is slack, then the SMA material is typically insignificantly unaffected by exposure to the required temperatures for reflow soldering.

The present invention allows reflow soldering between electrical terminals in an apparatus including an SMA actuator arrangement to be performed with a reduced risk of damage to the SMA actuator arrangement. This in turn can render an apparatus including an SMA actuator arrangement compatible with reflow soldering, thus reducing manufacturing costs.

To allow better understanding, an embodiment of the present invention will now be described by way of non-limitative example with reference to the accompanying drawings. In the drawings:

Fig.1 is a flow chart of a method of performing reflow soldering;

Fig. 2 is a side view of a camera in the first step of the method;

Figs. 3 to 5 are schematic cross-sectional views of the camera in the first to third steps of the method; and

Fig. 6 is a side view of the apparatus in the fourth step of the method.

Fig. 1 shows a method of performing reflow soldering of camera 1 that is itself illustrated in Figs. 2 and 3.

There will first be described the structure of the camera 1, being designed for incorporation in a portable electronic device such as a mobile telephone, media player or portable digital assistant.

The camera 1 is shown schematically in Fig. 3. The camera 1 comprises a support structure 2 including a circuit board 3 on which there may be mounted an image sensor 4 (shown in dotted outline in Fig. 3) which may be CCD (charge-coupled device) or a CMOS (complimentary metal-oxide-semiconductor)

device. The support structure 2 further comprises an annular wall 5 protruding from the front side of the circuit board 3.

The camera 1 further comprises a lens element 6 which holds a lens system 7 consisting of one or more lenses 8, the optical axis O of the lens system 7 being perpendicular to the image sensor 4 to focus light onto the image sensor 4. By way of example, the lens system 7 is shown in Fig. 1 as consisting of two lenses 8 but in general there may be a single lens 8 or any number of lenses 8 as needed to provide the desired balance of optical performance and low cost. The camera 1 is a miniature camera with the lenses 8 of the lens system 7 typically having a diameter of at most 10mm.

The lens element 6 is suspended on the support structure 2 by a suspension system (not shown for clarity) that guides movement of the lens element 6 along the optical axis O. Such movement of the lens element 6 changes the focus of the image formed on the image sensor 4.

The camera 1 comprises an SMA actuator arrangement 10 which comprises plural lengths of SMA wire 11 that may be made of any suitable SMA material, for example Nitinol or another Titanium-alloy SMA material. SMA material has the property that on heating it undergoes a solid-state phase change which causes the SMA material to contract. At low temperatures the SMA material enters the Martensite phase. At high temperatures the SMA material enters the Austenite phase which induces a deformation causing the SMA material to contract. The phase change occurs over a range of temperatures due to the statistical spread of transition temperature in the SMA crystal structure. Thus heating of the lengths of SMA wire 11 causes them to decrease in length.

The lengths of SMA wire 11are connected in tension between the annular wall 5 of the support structure 2 and the lens element 6 at an angle to the optical axis O so that on contraction they apply a tensional force having a component along the optical axis O, in particular in a direction biassing the lens element 6 away from the image sensor 4. This contraction drives movement of the lens element 6 in a first direction X along the optical axis O.

The camera 1 further comprises a biassing element 12 connected between the support structure 2 and the lens element 6. The biassing element 12 comprises a resilient spring arranged in compression to provide a biassing force biassing the lens element 6 in the second, opposite direction Y along the optical axis O, thereby acting as a biassing means against the force applied by the SMA actuator arrangement 10.

The position of the lens element 6 relative to the support structure 2 along the optical axis O may be controlled by control of the temperature of the SMA actuator arrangement 10. In operation, heating of the SMA actuator arrangement 10 is provided by passing a current therethrough which provides resistive heating. Cooling is provided by ceasing the current and allowing the SMA actuator arrangement 10 to cool by conduction to its surroundings. The current is supplied by a control circuit 15 that is mounted on the circuit board 3.

The camera 1 may have the detailed construction of the camera described and shown in WO-2009/056822 which is incorporated herein by reference. As another alternative, the camera 1 may use the suspension system to act as a resilient biassing element, for example having the construction described and shown in WO-2007/113478 or WO-2008/099156 which are incorporated herein by reference. However, none of these detailed constructions are essential and in general the present invention may be applied to any kind of apparatus including any kind of SMA actuator arrangement for any kind of movable object requiring precision control, without limitation to cameras. Similarly, in the case of a camera, the SMA actuator arrangement could equally be adapted to drive movement of a lens element in other directions for example to provide optical image stabilisation.

To make an electrical connection between the SMA actuator arrangement 10 and the control circuit 15, as shown in Fig. 2 the support structure 2 includes electrical terminals 20 that are electrically connected to the SMA actuator arrangement 10 and the circuit board 3 includes electrical terminals 21 that are electrically connected to the control circuit 15. However, in general, the method may be applied to perform reflow solely between any terminals in the camera 1, not necessarily terminals that are electrically connected to the SMA actuator arrangement

10. The electrical terminals 20 and 21 are arranged in corresponding positions. The method of Fig. 1 is to perform reflow soldering between the electrical terminals 20 and 21 and will now be described in detail.

In step S1, reflow solder paste 22 is applied between the corresponding electrical terminals 20 and 21 as follows. The circuit board 3 and the remainder of the camera 1 including the support structure 2 are manufactured as separate components. The reflow solder paste 22 is applied to the electrical terminals 21 of the circuit board 3. Then the remainder of the camera 1 is placed on the circuit board 3 so the support structure 2 rests on the circuit board 3, the corresponding electrical terminals 20 of the support structure being positioned against the reflow solder paste 22.

In step S2, the lens element 6 is moved relative to the support structure 2 in the first direction X to reduce the stress in the SMA actuator arrangement 10, and thereafter held in this position. The lifting is performed by a lifting apparatus 30 as follows.

The lifting apparatus 30 includes a lifting member 31 that engages the lens element 6 and a base member 32 that engages the support structure 2, as shown in Fig. 3. The lifting member 31 moves relative to the base member 32 in the first direction X and thereby moves the lens element 6 relative to the support structure 2 in that first direction X, as shown in Fig. 3. This operation is performed whilst keeping the support structure 2 in good mechanical contact with the circuit board 3 so that the reflow solder paste 22 remains in place between the electrical terminals 20 and 21.

This movement reduces the stress in the SMA actuator arrangement 10 because biassing element 12 is compressed and the mechanical stress induced thereby is reduced. The distance of movement of the lens element is chosen such that the mechanical stress of the SMA wire is reduced even when the SMA wire 11 is contracted by being heated beyond its full phase transition temperature. Any reduction in stress will reduce damage to some degree, but for the greatest effect the movement is sufficiently great to make the SMA wire 11 slack, as shown in Fig. 4.

In the lifting apparatus 30 shown in the drawings, the lifting member 31 engages the lens element 31 by suction and the base member 32 engages the support structure 2 mechanically, but in general the lifting apparatus 30 may engage the camera 1 by any suitable means, including without limitation mechanical attachment, vacuum pressure, or magnetic attraction.

Thereafter, the lifting apparatus 30 holds the lens element 6 in the position shown in Fig. 3.

The lifting apparatus 30 may be arranged to operate on a plurality of cameras 1 together to provide batch processing.

In this method, step S2 is performed after step S1, although in principle step S2 could alternatively be performed before step S1.

In step S3, reflow solder paste 22 is heated to electrically connect the electrical terminals 20 and 21, in particular by placing the camera 1 inside a reflow oven 40 with standard reflow solder oven conditions to melt the reflow solder paste 22 and form an electrical connection between the electrical terminals 20 and 21. For example a typical internal temperature for the reflow oven is 260°C and a typical period of time is of the order of a minute.

Step S3 is performed with the lifting apparatus 30 continuing to hold the lens element 6 as shown in Fig. 3 so that the SMA actuator arrangement 10 remains in a state of reduced stress during the heating. As described above, this reduced stress, causes a reduction or avoidance of damage to the SMA wire 11, as compared to the heating being performed without reducing the stress.

After step S3 is complete and the camera 1 has been removed from the reflow oven 40, in step S4 the lens element 6 is released by removing the lifting apparatus from the camera 1. As a result, the lens element 6 is moved back in the second direction Y under the biassing of the biassing element 12 so that the camera 1 is in its rest state shown in Fig. 6, wherein the reflow solder paste 22 has been melted to become a reflow solder contact 23 providing the electrical connection between the electrical terminals 20 and 21.

Subsequently, the camera may be subjected to more processing, for example

to mount the image sensor 4 and control circuit 15, if not already mounted. The lifting apparatus 30 is re-used to process further cameras 1.

Claims

1. A method of performing reflow soldering between electrical terminals in an apparatus that comprises: a support structure; a movable element supported on the support structure; and an SMA actuator arrangement and a resilient biassing arrangement each connected between the support structure and the movable element, the SMA actuator arrangement being arranged to drive movement of the movable element relative to the support structure in a first direction on contraction, and the resilient biassing arrangement being arranged to bias the movable element relative to the support structure in a second, opposite direction, wherein the method comprises:

applying reflow solder paste between the electrical terminals;

before or after said step of applying reflow solder paste, moving the movable element relative to the support structure in the first direction to reduce the stress in the SMA actuator arrangement, and thereafter holding the movable element;

whilst so holding the movable element, heating the reflow solder paste to electrically connect the electrical terminals; and

releasing the movable element, thereby allowing the resilient biassing element to move the movable element in the second direction.

2. A method according to claim 1, wherein the SMA actuator arrangement comprises at least one SMA wire.

3. A method according to claim 2, wherein said step of moving the movable element comprises moving the movable element relative to the support structure in the first direction until the at least one SMA wire is slack.

4. A method according to any one of the preceding claims, wherein the SMA actuator arrangement comprises SMA material that is Nitinol.

5. A method according to any one of the preceding claims, wherein said step of

moving the movable element is performed after said step of applying reflow solder paste.

6. A method according to any one of the preceding claims, wherein said step of moving the movable element is performed by a lifting apparatus.

7. A method according to any one of the preceding claims, wherein said step of heating the reflow solder paste comprises placing the apparatus in a reflow oven.

8. A method according to any one of the preceding claims, wherein the movable element is a camera lens element.

9. A method according to claim 8, wherein the camera lens element includes one or more lenses having a diameter of at most 10mm.

10. A method according to claim 8 or 9, wherein the first and second directions are along the optical axis of the camera lens element.

11. A method according to any one of the preceding claims, wherein the electrical terminals between which reflow soldering is performed are on different components, the step of applying reflow solder paste comprises applying reflow solder paste on at least one electrical terminal on a first one of said components and then placing the second one of said components with at least one electrical terminal on the second component positioned against the reflow solder paste.

12. A method according to any one of the preceding claims, wherein the apparatus further comprises a circuit board, the electrical terminals between which reflow soldering is performed being at least one electrical terminal on the support structure and at least one electrical terminal on the circuit board.

13. A method according to claim 12, wherein the electrical terminals on the support structure are electrically connected to the SMA actuator arrangement.

Fig.1.

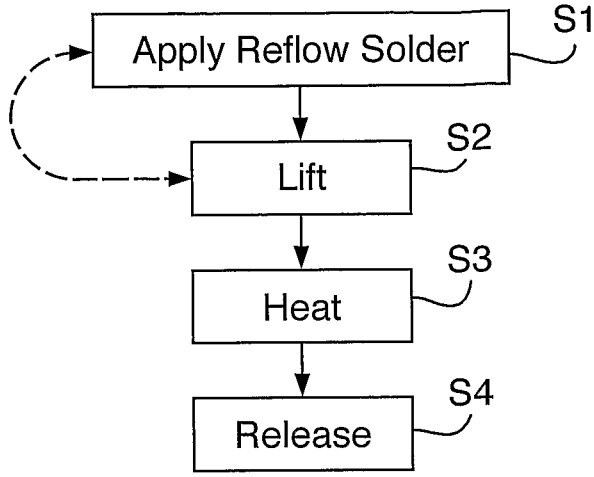


Fig.2.

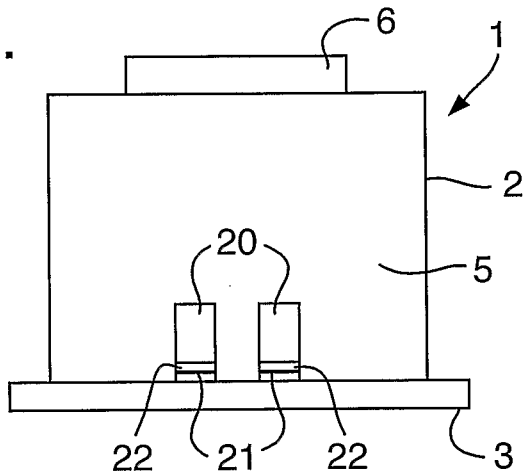


Fig.3.

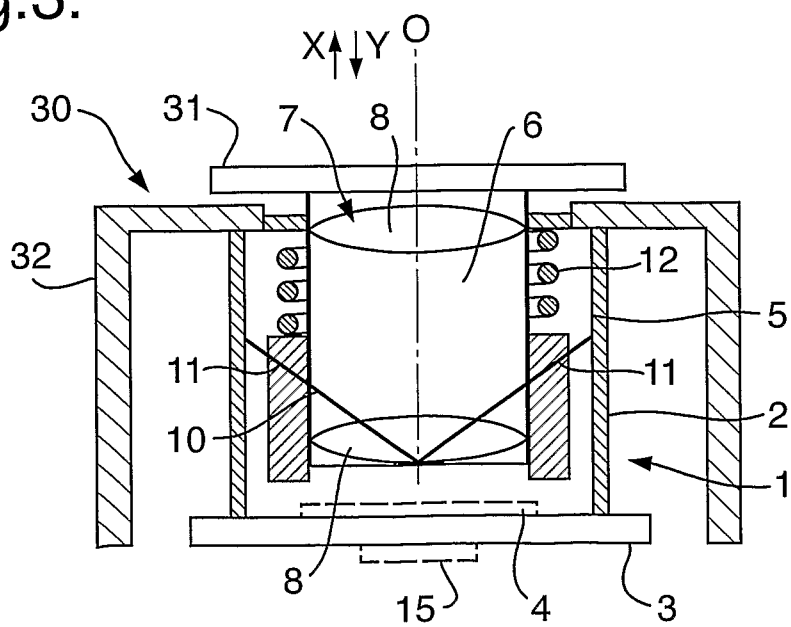


Fig.4.

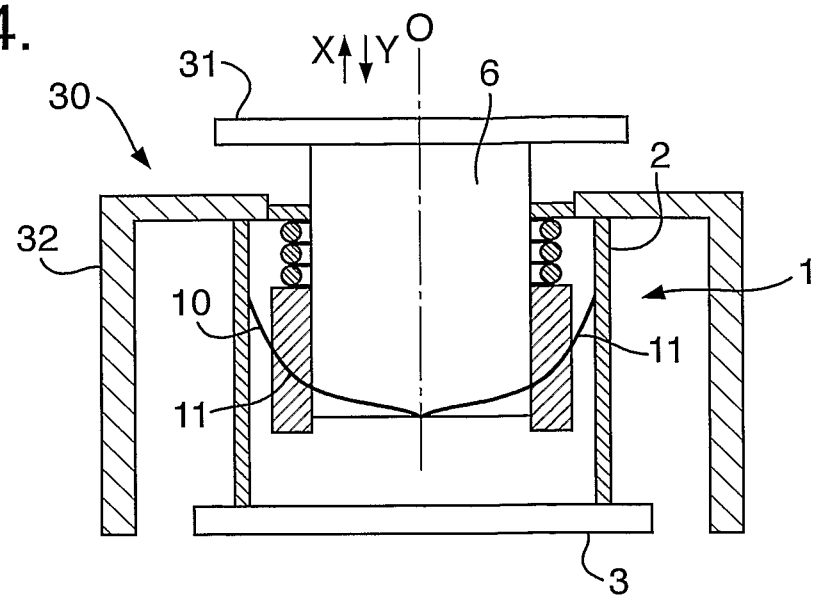


Fig.5.

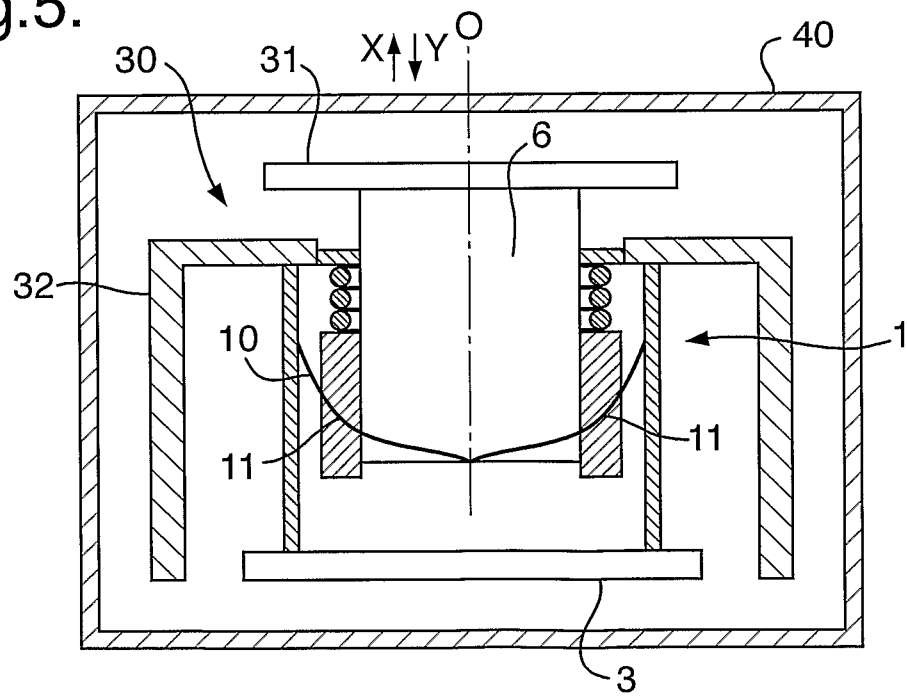
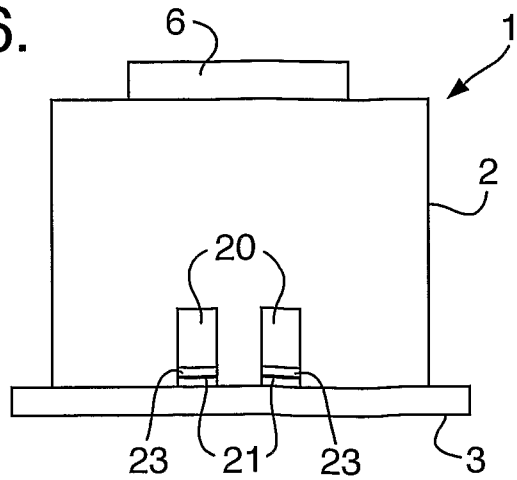


Fig.6.



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2010/000119

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05K3/34 B23K1/00 F03G7/06
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)
H05K B23K F03G

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2004/011557 A1 (COMBS CHRISTOPHER D [US] ET AL) 22 January 2004 (2004-01-22) paragraphs [0004], [0039], [0040]	1-13
Y	WO 2007/113478 A1 (1 LTD [GB]; TOPLISS RICHARD [GB]; LEVINGSTONE DAVID [GB]; LEEDHAM ROBE) 11 October 2007 (2007-10-11) cited in the application page 44, line 23 - page 45, line 12	1-13

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
19 April 2010	27/04/2010

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2010/000119

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATOOR E ET AL: "Shape memory alloys, Part I: General properties and modeling of single crystals" MECHANICS OF MATERIALS, AMSTERDAM, NL LNKD- DOI:10.1016/J.MECHMAT.2005.05.027, vol. 38, no. 5-6, 1 May 2006 (2006-05-01), pages 391-429, XP025072754 ISSN: 0167-6636 [retrieved on 2006-05-01] the whole document	1-13
A	LAGOUDAS D C ET AL: "Shape memory alloys, Part II: Modeling of polycrystals" MECHANICS OF MATERIALS, AMSTERDAM, NL LNKD- DOI:10.1016/J.MECHMAT.2005.08.003, vol. 38, no. 5-6, 1 May 2006 (2006-05-01), pages 430-462, XP025072755 ISSN: 0167-6636 [retrieved on 2006-05-01] the whole document	1-13
A	DAYANANDA G N ET AL: "Effect of strain rate on properties of superelastic NiTi thin wires" MATERIALS SCIENCE AND ENGINEERING A: STRUCTURAL MATERIALS:PROPERTIES, MICROSTRUCTURE & PROCESSING, LAUSANNE, CH LNKD- DOI:10.1016/J.MSEA.2007.09.006, vol. 486, no. 1-2, 15 July 2008 (2008-07-15), pages 96-103, XP022633340 ISSN: 0921-5093 [retrieved on 2008-04-29] the whole document	1-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2010/000119

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WO 2007113478 A1	11-10-2007	EP 1999507 A1	10-12-2008
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