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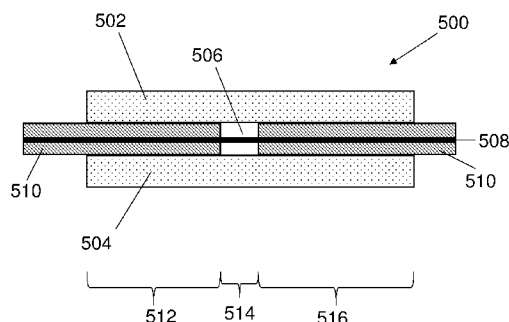


FIGURE 5

(57) Abstract: Broadly speaking, embodiments of the present techniques provide improved techniques for crimping a shape memory alloy (SMA) actuator wire to ensure that electrical connections between a crimp and SMA actuator wire are made in a controlled manner.



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Improved Crimping

The present application generally relates to improved techniques for crimping a shape memory alloy (SMA) actuator wire, and in particular to techniques for controlling where electrical connections are made between a crimp and an SMA actuator wire.

In a first approach of the present techniques, there is provided an actuation mechanism comprising: a static component; a moveable component that is moveable relative to the static component; at least one shape memory alloy (SMA) actuator wire, each SMA actuator wire comprising a first portion coupled to the static component and a second portion coupled to the moveable component; at least one crimp connected to the static component and arranged to electrically and mechanically connect the first portion of one SMA actuator wire to the static component, the crimp comprising a zone of electrical connection and at least one zone of electrical insulation where the SMA wire emerges from the crimp; at least one crimp connected to the moveable component and arranged to electrically and mechanically connect the second portion of one SMA actuator wire to the moveable component, the crimp comprising a zone of electrical connection and at least one zone of electrical insulation where the SMA wire emerges from the crimp; and an electrical connection forming mechanism for forming an electrical connection between the SMA actuator wire and the crimps in the zone of electrical connection; wherein an electrically insulating layer is selectively provided in each zone of electrical insulation.

For example, as will be explained in more detail below, the electrically insulating layer may be selectively provided in each zone of electrical insulation by selectively coating the SMA actuator wire (only) in locations corresponding to said zones and/or selectively coating the crimp (only) in said zones. By selectively providing the electrically insulating layer in this way, a selected portion of the SMA actuator wire can be brought into contact with the crimp in the zone of electrical connection, which is therefore defined in a more controlled manner.

In a second approach of the present techniques, there is provided a crimp for forming an electrical and mechanical connection with a shape memory alloy

(SMA) actuator wire, the crimp comprising a zone of electrical connection and at least one zone of electrical insulation where the SMA wire emerges from the respective edge of the crimp.

5 In a third approach of the present techniques, there is provided a strut element comprising: a sacrificial strut body; and at least two crimps, held apart by the sacrificial strut body, for holding at least one shape memory alloy (SMA) actuator wire by being folded and pressed over the at least one SMA actuator wire, each crimp comprising a zone of electrical connection and at least one zone of
10 electrical insulation where the SMA wire emerges from the crimp; wherein the sacrificial strut body is removable from the crimps.

 In a fourth approach of the present techniques, there is provided an actuation mechanism comprising: a static component; a moveable component
15 that is moveable relative to the static component; at least one shape memory alloy (SMA) actuator wire, each SMA actuator wire comprising a first portion coupled to the static component and a second portion coupled to the moveable component; at least one crimp connected to the static component and arranged to electrically and mechanically connect the first portion of one SMA actuator wire
20 to the static component, the crimp comprising a patterned inner surface for gripping the SMA actuator wire; and at least one crimp connected to the moveable component and arranged to electrically and mechanically connect the second portion of one SMA actuator wire to the moveable component, the crimp comprising a patterned inner surface for gripping the SMA actuator wire.

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 In a fifth approach of the present techniques, there is provided a crimp for forming an electrical and mechanical connection with a shape memory alloy (SMA) actuator wire, the crimp comprising a patterned inner surface for gripping the SMA
30 actuator wire.

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 In a sixth approach of the present techniques, there is provided a strut element comprising: a sacrificial strut body; and at least two crimps, held apart by the sacrificial strut body, for holding at least one shape memory alloy (SMA) actuator wire by being folded and pressed over the at least one SMA actuator wire,

each crimp comprising a patterned inner surface for gripping the SMA actuator wire; wherein the sacrificial strut body is removable from the crimps.

In a seventh approach of the present techniques, there is provided an actuation mechanism comprising: a static component; a moveable component that is moveable relative to the static component; at least one shape memory alloy (SMA) actuator wire, each SMA actuator wire comprising a first portion coupled to the static component and a second portion coupled to the moveable component; at least one crimp connected to the static component and arranged to electrically and mechanically connect the first portion of one SMA actuator wire to the static component, the crimp comprising a zone of electrical connection, at least one zone of electrical insulation where the SMA wire emerges from the crimp, and a patterned inner surface for gripping the SMA actuator wire; at least one crimp connected to the moveable component and arranged to electrically and mechanically connect the second portion of one SMA actuator wire to the moveable component, the crimp comprising a zone of electrical connection, at least one zone of electrical insulation where the SMA wire emerges from the crimp, and a patterned inner surface for gripping the SMA actuator wire; and an electrical connection forming mechanism for forming an electrical connection between the SMA actuator wire and the crimps in the zone of electrical connection.

In an eighth approach of the present techniques, there is provided a crimp for forming an electrical and mechanical connection with a shape memory alloy (SMA) actuator wire, the crimp comprising a zone of electrical connection, at least one zone of electrical insulation where the SMA wire emerges from the crimp, and a patterned inner surface for gripping the SMA actuator wire.

In a ninth approach of the present techniques, there is provided a strut element comprising: a sacrificial strut body; and at least two crimps, held apart by the sacrificial strut body, for holding at least one shape memory alloy (SMA) actuator wire by being folded and pressed over the at least one SMA actuator wire, each crimp comprising a zone of electrical connection, at least one zone of electrical insulation where the SMA wire emerges from the crimp, and a patterned inner surface for gripping the SMA actuator wire; wherein the sacrificial strut body is removable from the crimps.

In a tenth approach of the present techniques, there is provided a method of forming the actuation mechanism, comprising: a) selectively providing electrically insulating layer in the zone of electrical insulation; and b) forming electrical connection by an electrical connection forming mechanism between the SMA actuator wire and the crimps in the zone of electrical connection.

In a related approach of the present techniques, there is provided an apparatus comprising any of the actuation mechanisms, strut elements or crimps described herein. The apparatus may be any one of: a smartphone, a camera, binoculars, a foldable smartphone, a foldable image capture device, a foldable smartphone camera, an image capture device, a consumer electronics device, a mobile computing device, a laptop, a tablet computing device, a gaming system, an augmented reality system, a virtual reality system, a wearable device, a drone, a submersible, an aircraft, a spacecraft, a vehicle, an autonomous vehicle, a robotic device, a domotic device, and a home automation device. It will be understood that this is a non-exhaustive and non-limiting list of example apparatus.

Preferred features are set out in the appended dependent claims.

Implementations of the present techniques will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows an exploded view of SMA actuator wire arrangements in a camera;

Figure 2A shows a perspective view of a portion of an SMA actuator wire in a crimp;

Figures 2B and 2C are plan views of a strut element and an SMA actuator wire in successive stages of a method of assembly;

Figure 3 shows a known technique for forming a good electrical and mechanical connection between a crimp and an SMA actuator wire;

Figures 4A and 4B show, respectively, a cross-sectional view of a first technique for forming a good electrical and mechanical connection between a crimp and an SMA actuator wire without the wire and with the wire in the crimp;

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Figure 5 shows a cross-sectional view of a second technique for forming a good electrical and mechanical connection between a crimp and an SMA actuator wire; and

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Figure 6 shows a plan view of a third technique for forming a good electrical and mechanical connection between a crimp and an SMA actuator wire.

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Broadly speaking, embodiments of the present techniques provide improved techniques for crimping a shape memory alloy (SMA) actuator wire to ensure that electrical connections between a crimp and SMA actuator wire are made in a controlled manner.

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SMA actuator wires may be used to move components or elements in a variety of apparatus such as smartphones, cameras, and consumer electronics devices. Generally, an SMA actuator wire needs to be connected to a moveable component, and a component which the moveable component moves relative to (i.e. a static component). The SMA actuator wire is typically connected to the moveable and static components via crimps. The crimps electrically and mechanically connect the SMA actuator wire to the moveable and static components. Example techniques for holding an SMA actuator wire in a crimp are described below with respect to Figures 1 to 2C.

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Figure 1 shows an exploded view of a shape memory alloy (SMA) actuator wire arrangement 10 in a camera. The SMA actuator arrangement 10 includes a static part 5 that comprises a base 11 that is an integrated chassis and sensor bracket for mounting an image sensor, and a screening can 12 attached to the base 11. The SMA actuator arrangement 10 includes a moving part 6 that is a camera lens assembly comprising a lens carriage 13 carrying at least one lens (not shown).

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In this example, the SMA actuator arrangement 10 includes eight SMA wires 2 each attached between the static part 5 and the moving part 6. A pair of SMA wires 2 that cross each other are provided on each of four sides of the SMA actuator arrangement 10 as viewed along an optical axis. The SMA wires 2 are attached to the static part 5 and the moving part 6 in such a configuration that they are capable of providing relative movement of the moving part 5 with multiple degrees of freedom for providing both autofocus (AF) and optical image stabilisation (OIS).

Thus, in respect of each pair of SMA wires 2, the SMA wires 2 are attached at one end to two static mount portions 15, which are themselves mounted to the static part 5 for attaching the SMA wires 2 to the static part 5. The static mount portions 15 are adjacent one another but are separated to allow them to be at different electrical potentials.

Similarly, in respect of each pair of SMA wires 2, the SMA wires 2 are attached at one end to a moving mount portion 16 which is itself mounted to the moving part 6 for attaching the SMA wires 2 to the moving part 6. The moving part 6 further comprises a conductive ring 17 connected to each of the moving mount portions 16 for electrically connecting the SMA wires 2 together at the moving part 6.

The static mount portions 15 and the moving mount portions 16 comprise crimp tabs 23 which may be formed into crimps and used to hold the SMA wires 2. The moving mount portions 16 may comprise electrical connection tabs 31 for providing electrical connection to the conductive ring 17. Thus, in the example shown in Figure 1, the crimp tabs 23 that are formed into crimps are integral parts of the static and moving portions of the actuator arrangement 10. Methods for forming the crimps and trapping the SMA wires within the crimp tabs 23 are described in International Patent Publication No. WO2016/189314.

Figure 2A shows a perspective view of a portion of an SMA actuator wire 42 in a crimp 43. It is important to achieve good mechanical and electrical contact between the SMA actuator wire 42 and the crimps 43, so that the SMA actuator wire 42 does not slip out of the crimp 43 and so that the wire can be

powered/driven when required. If the SMA actuator wire 42 is coated with an electrically insulating layer 40, the insulation may hinder this requirement especially if it is relatively thick (e.g. of the order of 1 μ m or more) as the mechanical action of closing the jaws of the crimp 43 during manufacture is not sufficient to break down the electrically insulating layer 40 and make good contact with the SMA material beneath.

International Patent Publication No. WO2015/036761 describes how, in order to reduce this issue, the SMA actuator wires 42 may be coated with the electrically insulating layer along part of their length, but not at the crimps 43, as shown in Figure 2A. As can be seen, in this example the length 41 of the part of the SMA actuator wire 42 that is not coated with the electrically insulating layer 40 is greater than the length of contact between the SMA actuator wire 42 and the crimp 43, such that good contact is made within the crimp 43 while providing easy placement of the crimp 43.

Figures 2B and 2C are plan views of a strut element used to hold an SMA actuator wire in successive stages of a method of assembly. A fret 1 is a type of strut element. The fret 1 may be made of metal, for example phosphor bronze, steel or laminate containing conductive components. The fret 1 may be a flat or a formed strip. The fret 1 is shaped as follows. The fret 1 comprises a sacrificial strut body 8 having an elongate portion 8a and laterally protruding arms 8b at the extremes of the elongate portion 8a. The fret 1 further comprises crimp tabs 3 at the ends of the sacrificial strut body 8, i.e. at the ends of the arms 8b. The crimp tabs 3 may be formed into crimps as described below. Thus, the crimp tabs 3 are held apart by the sacrificial strut body 8.

The method comprises laying an SMA wire 2 onto the fret 1 in a predetermined position near the ends 3 of the fret 1 across the crimp tabs 3, as shown in Figure 2B. The SMA wire 2 may be made of any suitable SMA material, for example Nitinol or another Titanium-alloy SMA material. Next, the method comprises folding the crimp tabs 3 over the SMA wire 2 and pressing them to form crimps 4 that hold the SMA wire 2 therebetween, as shown in Fig. 2C. The folding and pressing may be performed by a crimp tool (not shown), or by using a punch

and anvil. The pressing is performed by the application of pressure and firmly traps the SMA wire 2 in the crimps 4.

Thus, generally speaking, an SMA actuator wire is provided in a crimp or crimp tab, which is folded and pressed to grip the SMA actuator wire. However, a crimp or crimp tab that is simply folded and pressed together to grip the SMA actuator wire does not form a good mechanical connection with the wire. This is because the wire is able to slip or move within the folded crimp and friction between the wire and the inner surfaces of the crimp are not sufficient to retain the wire in position. In order to improve the mechanical connection between the crimp and the SMA actuator wire, the crimp may be punched (e.g. using a punch and anvil) to form a dimple. This known technique for forming a good electrical and mechanical connection between a crimp and an SMA actuator wire is shown in Figure 3. Figure 3 shows a crimp 300 which is used to form a good mechanical and electrical connection between the crimp 300 and an SMA actuator wire 306. The crimp 300 comprises a first portion 302 and a second portion 304. As described above, the SMA actuator wire 306 is provided on the crimp 300, and the first portion 302 and second portion 304 are folded and pressed together, thereby holding the SMA actuator wire 306 in the crimp 300. The crimp 300 is then punched or stamped to form a dimple 308. The dimple 308 increases the friction between SMA actuator wire 306 and the first and second portions 302, 304 of the crimp 300, and thereby reduces the likelihood of, or degree of, the SMA actuator wire 306 slipping/moving within the crimp 300.

Many SMA-based actuators use the resistance of the SMA actuator wire(s) to determine where the moveable element (being moved by the SMA actuator wire(s)) is positioned relative to the static element, and the power which needs to be applied to the SMA actuator wire(s) to move the moveable element to a required target position. Drive signals for the SMA actuator wire(s) may be generated in a control circuit and supplied to the SMA actuator wires. Such a control circuit may receive an input signal representing a desired position for the moveable element and generates drive signals having powers selected to drive the moveable element to the desired position. The power of the drive signals may be either linear or varied using pulse width modulation. The drive signals may be generated using a resistance feedback control technique, in which case the control

circuit measures the resistance of the SMA actuator wire(s) and uses the measured resistance as a feedback signal to control the power of the drive signals. Such a resistance feedback control technique may be implemented as disclosed in any of WO2013/175197, WO2014/076463, WO2012/066285, WO2012/020212, WO2011/104518, WO2012/038703, WO2010/089529 or WO2010029316.

However, it has been found that when the crimp comprises a dimple 308, as per Figure 3, the resistance between the crimp 300 and the SMA actuator wire 306 as measured at a point along the wire is noisy and varies with time. The source of this noise may arise from the shape and nature of the crimp 300 itself. Generally speaking, when a material is folded it will always spring back slightly due to the elastic portion of the material deformation. For this reason, a flat crimp (i.e. a crimp that is simply formed by folding two flat portions/crimp tabs together) does not grip the wire it is crimping, as mentioned above. However, when a dimple 308 is formed in the crimp 300, spring back is prevented or significantly reduced because the crimp is distorted in the other direction (i.e. a direction opposite to the spring back direction). This causes the path of the SMA actuator wire 306 through the crimp 300 to not be straight (thereby increasing friction). The dimple 308 significantly reduces spring back in the region of the dimple because (i) the crimp material is caused to flow in a different direction removing the elastic strain that would otherwise open the crimp 300, and (ii) the path of the wire 306 lies at an angle to the direction the crimp 300 would open, thereby reducing the size of the gap caused by a spring back. However, as shown in Figure 3, spring back may still occur in the regions 316 of the crimp that are not next to the dimple 308. In these regions 316, the wire 306 is not securely gripped and so is able to move. As the wire 306 moves within the crimp 300, the contact resistance between the moving portion(s) of the wire 306 and the crimp 300 may change, thus causing the observed variation in resistance between the wire 306 and the crimp 300. Thus, it is desirable to limit the electrical connection to an area 312 around the dimple 308, and to have no electrical connection in other areas 310, 314 of the crimp 300.

The present techniques provide solutions to this problem and provide techniques for crimping a shape memory alloy (SMA) actuator wire to ensure that electrical connections between a crimp and SMA actuator wire are made in a

controlled manner. Embodiments of the present techniques provide crimps comprising a zone of electrical connection and at least one zone of electrical insulation where the SMA wire emerges from the crimp, and ensuring that electrical connections between the crimp and the SMA actuator wire are only made within the zone of electrical connection. Accordingly, even if the SMA actuator wire moves within the crimp, an electrical connection is only formed in a pre-determined zone, which reduces or removes any variation in resistance in the wire.

Embodiments of the present techniques provide an actuation mechanism which may comprise: a static component; a moveable component that is moveable relative to the static component; at least one shape memory alloy (SMA) actuator wire, each SMA actuator wire comprising a first portion coupled to the static component and a second portion coupled to the moveable component; at least one crimp connected to the static component and arranged to electrically and mechanically connect the first portion of one SMA actuator wire to the static component, the crimp comprising a zone of electrical connection and at least one zone of electrical insulation where the SMA wire emerges from the crimp; at least one crimp connected to the moveable component and arranged to electrically and mechanically connect the second portion of one SMA actuator wire to the moveable component, the crimp comprising a zone of electrical connection and at least one zone of electrical insulation where the SMA wire emerges from the crimp; and an electrical connection forming mechanism for forming an electrical connection between the SMA actuator wire and the crimps in the zone of electrical connection. In some cases, each crimp may comprise two zones of electrical insulation, one at each edge of the crimp where the SMA actuator wire emerges from the crimp.

Some example types of electrical connection forming mechanism are now described with reference to Figures 4A to 6.

Figures 4A and 4B show, respectively, a cross-sectional view of a first technique for forming a good electrical and mechanical connection between a crimp 400 and an SMA actuator wire 408, without the wire and with the wire in the crimp. Here, each SMA actuator wire 408 comprises an electrically insulating

coating 410 and an internal surface of each crimp 400 is conductive. Each crimp 400 comprises a zone of electrical connection 414 and zones of electrical insulation 412, 416 where the SMA actuator wire 408 (and coating 410) emerges from the crimp 400. The electrical connection forming mechanism comprises at least one feature 406 on each crimp 400 in the zone of electrical connection 414 to pierce the coating 410 and make electrical contact with the SMA actuator wire 408. No electrical connection is formed in the zones of electrical insulation 412, 416 because these regions comprise no features that pierce the insulating coating 410 around the SMA actuator wire 408. Advantageously, the at least one feature 406 may also hold the SMA actuator wire 408 in place/position within the crimp 400. The feature 406 may be any suitable feature for piercing the insulating coating 410 and forming an electrical connection with the SMA actuator wire 408.

Each crimp 400 may comprise a first portion 402 and a second portion 404 which are folded together, and the portion of the SMA actuator wire 408 within each crimp 400 is held between the first and second portions 402, 404, as shown in Figure 4B. The at least one feature 406 on each crimp 400 may be provided on the first portion 402 and/or the second portion 404 of the crimp 400. In embodiments, there may be one or more features 406 on one or both of the first and second portions 402, 404. The features 406 on the first and second portions 406 may be aligned (not shown), or may be spaced apart/separated (as shown in Figure 4B). Where there are multiple features 406, the features 406 may have the same form or be of the same type, or may be different or have a different form.

Figure 5 shows a cross-sectional view of a second technique for forming a good electrical and mechanical connection between a crimp 500 and an SMA actuator wire 508. Here, each SMA actuator wire 508 comprises an electrically insulating coating 510 along part of its length. An internal surface of each crimp 500 may be entirely conductive. Each crimp 500 comprises a zone of electrical connection 514 and zones of electrical insulation 512, 516 where the SMA actuator wire 508 (and coating 510) emerges from the crimp 500. A portion 506 of the SMA actuator wire 508 that is not coated with the electrically insulating coating 510 is provided in the zone of electrical connection in each crimp.

In this case, the electrical connection forming mechanism may comprise at least one feature (not shown) on each crimp 500 in the zone of electrical connection 514 to make contact with the portion 506 of the SMA actuator wire 508 that is not coated. In this way, only the uncoated portion 506 of the SMA actuator wire 508 in the zone of electrical connection 514 comes into contact with the at least one feature. The at least one feature that makes contact with the SMA actuator wire 508 is electrically conductive. The at least one feature on each crimp 500 may be provided on the first portion 502 and/or the second portion 504 of the crimp 500.

Alternatively, the electrical connection forming mechanism may comprise a dimple (not shown in Figure 5) in the crimp 500 in the zone of electrical connection 514. The dimple may be formed by punching or stamping the crimp 500 in the zone of electrical connection 514. This may solve the problem of variable resistance observed in crimps that take the form shown in Figure 3, as only the portion 506 of the SMA actuator wire 508 that is uncoated is able to form an electrical connection with the crimp 500. Thus, even if the SMA actuator wire 508 moves in the gaps regions away from the dimple, the SMA actuator wire 508 in these regions is coated with an insulative coating, and the movement therefore does not affect the resistance of the wire.

To achieve partial coating, the electrically insulating layer 510 may be provided along part of the length of the SMA actuator wire 508 during manufacture by selective coating (for example using a mask prior to coating), or by coating the entire length of the SMA actuator wire 508 and subsequently selectively removing part of the electrically insulating layer 510. In the latter case, removal of the electrically insulating layer 510 may be by mechanical abrasion, or other chemical or physical means, such as focussed laser- or plasma-ablation. Hence an electrically insulating coating may be selectively provided along part of the length to form the electrically insulating layer 510 at the zone of electrical insulation 512, 516. Alternatively, or in addition, electrical insulating layer 510 may be selectively provided at the zone of the electrical insulation 512, 516 by means of an electrical insulating tape, an electrical insulating sheath, an electrical insulating paint or an electrical insulating gel.

Figure 6 shows a plan view of a third technique for forming a good electrical and mechanical connection between a crimp 600 and an SMA actuator wire (not shown). Here, an internal surface of each crimp 600 is conductive and the SMA actuator wire is not coated with an insulating coating. Each crimp 600 comprises a zone of electrical connection 604 and zones of electrical insulation 602, 606 where the SMA actuator wire (and coating) emerges from the crimp 600. In this embodiment, the electrical connection forming mechanism comprises an electrically insulating layer on the internal surface of each crimp 600 in the at least one zone of electrical insulation 602, 606. An SMA actuator wire (uncoated) may be provided in the crimp such that it lies substantially parallel to line A, and the crimp 600 may be folded along line A and pressed to grip the wire within the crimp. Thus, the SMA actuator wire contacts the conductive inner surface of the crimp 600 only in the zone of electrical connection 604. In the zones of electrical insulation 602, 606, no electrical connection is formed between the wire and the crimp.

The electrically insulating layer may be formed by patterning the internal surface of each crimp 600 in the zones of electrical insulation 602, 606. The insulating layer is provided on the first and second portion of each crimp 600. The insulating layer may be formed by patterning using any one or more of the following techniques: wet etching, dry etching, electro plating, sputtering, photolithography and mechanical etching. It will be understood that this is a non-exhaustive list. Hence the electrically insulating layer may be selectively provided on the internal surface of each crimp 600 in the at least one zone of electrical insulation 602, 606. Alternatively, or in addition, electrical insulating layer may be selectively provided at the zone of the electrical insulation 602, 606 by means of an electrical insulating tape, an electrical insulating sheath, an electrical insulating paint or an electrical insulating gel.

The electrical connection forming mechanism may be, or may further comprise a liquid disposed within each crimp, wherein the liquid transforms into a solid within each crimp. The liquid may be electrically non-conductive (insulative) and may be disposed only in the at least one zone of electrical insulation of each crimp. Alternatively, the liquid may be electrically conductive and may be disposed in the zone(s) of electrical connection of each crimp. Further

alternatively, the electrical forming mechanism may be or may comprise disposing a non-conductive liquid in the at least one zone of electrical insulation in each crimp, and disposing an electrically conductive liquid in the zone of electrical connection in each crimp, wherein each liquid transforms into a solid within each crimp. The liquid may be an adhesive. The liquid may be transformed into a solid by using any one of the following techniques: an additive, drying, evaporation, pressure, heating, curing, light curing, moisture curing, chemical curing, and heat curing.

As described above, the problem of varying resistance arises when the mechanical connection between a crimp and an SMA actuator wire is improved by providing a dimple in the crimp. Another solution to this problem may be to replace the dimple with an alternative mechanism for improving the mechanical connection between crimp and wire. For example, each crimp may comprise a patterned inner surface for gripping an SMA actuator wire when the crimp is closed, where the pattern increases the friction between crimp and wire relative to a featureless or substantially flat folded crimp. The pattern may be, for example, a pattern of raised bumps, dots, or ridges. The pattern may be provided across the whole of the inner surface of the crimp or at least a portion of the inner surface of the crimp. The pattern may be provided on the first portion and/or the second portion of the crimp.

Thus, embodiments of the present techniques provide an actuation mechanism comprising: a static component; a moveable component that is moveable relative to the static component; at least one shape memory alloy (SMA) actuator wire, each SMA actuator wire comprising a first portion coupled to the static component and a second portion coupled to the moveable component; at least one crimp connected to the static component and arranged to electrically and mechanically connect the first portion of one SMA actuator wire to the static component, the crimp comprising a patterned inner surface for gripping the SMA actuator wire; and at least one crimp connected to the moveable component and arranged to electrically and mechanically connect the second portion of one SMA actuator wire to the moveable component, the crimp comprising a patterned inner surface for gripping the SMA actuator wire.

It will be understood that the techniques for limiting the electrical connection to the zone of electrical connection described with reference to Figures 4A to 6, and the technique for improving the mechanical connection between the wire and crimp described above, may be combined. Thus, embodiments of the present techniques provide an actuation mechanism comprising: a static component; a moveable component that is moveable relative to the static component; at least one shape memory alloy (SMA) actuator wire, each SMA actuator wire comprising a first portion coupled to the static component and a second portion coupled to the moveable component; at least one crimp connected to the static component and arranged to electrically and mechanically connect the first portion of one SMA actuator wire to the static component, the crimp comprising a zone of electrical connection, at least one zone of electrical insulation where the SMA wire emerges from the crimp, and a patterned inner surface for gripping the SMA actuator wire; at least one crimp connected to the moveable component and arranged to electrically and mechanically connect the second portion of one SMA actuator wire to the moveable component, the crimp comprising a zone of electrical connection, at least one zone of electrical insulation where the SMA wire emerges from the crimp, and a patterned inner surface for gripping the SMA actuator wire; and any of the electrical connection forming mechanisms described herein for forming an electrical connection between the SMA actuator wire and the crimps in the zone of electrical connection.

Those skilled in the art will appreciate that while the foregoing has described what is considered to be the best mode and where appropriate other modes of performing present techniques, the present techniques should not be limited to the specific configurations and methods disclosed in this description of the preferred embodiment. Those skilled in the art will recognise that present techniques have a broad range of applications, and that the embodiments may take a wide range of modifications without departing from any inventive concept as defined in the appended claims.

CLAIMS

1. An actuation mechanism comprising:
 - a static component;
 - 5 a moveable component that is moveable relative to the static component;
 - at least one shape memory alloy (SMA) actuator wire, each SMA actuator wire comprising a first portion coupled to the static component and a second portion coupled to the moveable component;
 - at least one crimp connected to the static component and arranged to
 - 10 electrically and mechanically connect the first portion of one SMA actuator wire to the static component, the crimp comprising a zone of electrical connection and at least one zone of electrical insulation where the SMA wire emerges from the crimp;
 - at least one crimp connected to the moveable component and arranged to electrically and mechanically connect the second portion of one SMA actuator wire
 - 15 to the moveable component, the crimp comprising a zone of electrical connection and at least one zone of electrical insulation where the SMA wire emerges from the crimp; and
 - an electrical connection forming mechanism for forming an electrical connection between the SMA actuator wire and the crimps in the zone of electrical
 - 20 connection;
 - wherein an electrically insulating layer is selectively provided in each zone of electrical insulation.
2. The actuation mechanism as claimed in claim 1 wherein each crimp
- 25 comprises two zones of electrical insulation, one at each edge of the crimp where the SMA actuator wire emerges from the respective edge of the crimp.
3. The actuation mechanism as claimed in claim 1 or 2 wherein each crimp comprises a first portion and a second portion which are folded together, and the
- 30 portion of the SMA actuator wire is held between the first and second portions.
4. The actuation mechanism as claimed in claim 1, 2 or 3 wherein each SMA actuator wire comprises an electrically insulating coating selectively provided along part of its length to form said electrically insulating layer, and wherein a

portion of the SMA actuator wire that is not coated with the electrically insulating coating is provided in the zone of electrical connection in each crimp.

5. The actuation mechanism as claimed in claim 4 wherein the electrical connection forming mechanism comprises at least one feature on each crimp in the zone of electrical connection configured to contact with the portion of the SMA actuator wire that is not coated.

6. The actuation mechanism as claimed in claim 5, when dependent on claim 3, wherein the at least one feature on each crimp is on the first portion and/or the second portion of the crimp.

7. The actuation mechanism as claimed in claim 4 wherein the electrical connection forming mechanism comprises a dimple in the crimp in the zone of electrical connection.

8. The actuation mechanism as claimed in claim 7 wherein the dimple is formed by punching the crimp in the zone of electrical connection.

9. The actuation mechanism as claimed in claim 1, 2 or 3 wherein an internal surface of each crimp is conductive and the electrically insulating layer is selectively provided on the internal surface of each crimp in the at least one zone of electrical insulation.

10. The actuation mechanism as claimed in claim 9 wherein the electrically insulating layer is formed by patterning the internal surface of each crimp in the at least one zone of electrical insulation.

11. The actuation mechanism as claimed in 9 or 10, when dependent on claim 3, wherein the electrically insulating layer is provided on the first and second portion of each crimp.

12. The actuation mechanism as claimed in claim 10 or 11 wherein the insulating layer is formed by patterning using any one or more of: wet etching, dry etching, electro plating, sputtering, photolithography and mechanical etching.

13. The actuation mechanism as claimed in any preceding claim wherein the electrical connection forming mechanism comprises a liquid disposed within each crimp, wherein the liquid transforms into a solid within each crimp.

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14. The actuation mechanism as claimed in claim 13 wherein the liquid is non-conductive and is disposed in the at least one zone of electrical insulation of each crimp.

10 15. The actuation mechanism as claimed in claim 13 wherein the liquid is electrically conductive and is disposed in the zone of electrical connection of each crimp.

15 16. The actuation mechanism as claimed in claim 13 wherein the electrical forming mechanism comprises disposing a non-conductive liquid in the at least one zone of electrical insulation in each crimp, and disposing an electrically conductive liquid in the zone of electrical connection in each crimp, wherein each liquid transforms into a solid within each crimp.

20 17. The actuation mechanism as claimed in any one of claims 13 to 16 wherein the liquid is an adhesive.

25 18. The actuation mechanism as claimed in any one of claims 13 to 17 wherein the liquid is transformed into a solid by using any one of: an additive, drying, evaporation, pressure, heating, curing, light curing, moisture curing, chemical curing, and heat curing.

30 19. A crimp for forming an electrical and mechanical connection with a shape memory alloy (SMA) actuator wire, the crimp comprising a zone of electrical connection and at least one zone of electrical insulation where the SMA wire emerges from the crimp, wherein an electrically insulating layer is selectively provided in each zone of electrical insulation.

35 20. A strut element comprising:
a sacrificial strut body; and

at least two crimps, held apart by the sacrificial strut body, for holding at least one shape memory alloy (SMA) actuator wire by being folded and pressed over the at least one SMA actuator wire, each crimp comprising a zone of electrical connection and at least one zone of electrical insulation where the SMA wire emerges from the crimp, wherein an electrically insulating layer is selectively provided in each zone of electrical insulation;

wherein the sacrificial strut body is removable from the crimps.

21. A method of forming the actuation mechanism as claimed in any one of claims 1 to 18, the method comprising:

selectively providing the electrically insulating layer in each zone of electrical insulation; and then

forming the electrical connections between the SMA actuator wire and the crimps in the zone of electrical connection.

22. The method of claim 21, wherein said selectively providing comprises: selectively coating the crimp in each zone of electrical insulation.

23. The method of claim 21 or 22, wherein selectively providing the electrically insulating layer in each zone of electrical insulation comprises:

selectively coating the SMA actuator wire in locations that, when the wire is connected to each crimp, correspond to the zones of electrical insulation.

24. The method of any one of claims 21 to 23, when dependent on any one of claims 13 to 18, comprising:

disposing a non-conductive liquid in the at least one zone of electrical insulation in each crimp;

disposing an electrically conductive liquid in the zone of electrical connection in each crimp; and

transforming each liquid into a solid within each crimp.

25. The method of claim 24, wherein said transforming comprises using any one of: an additive, drying, evaporation, pressure, heating, curing, light curing, moisture curing, chemical curing, and heat curing.

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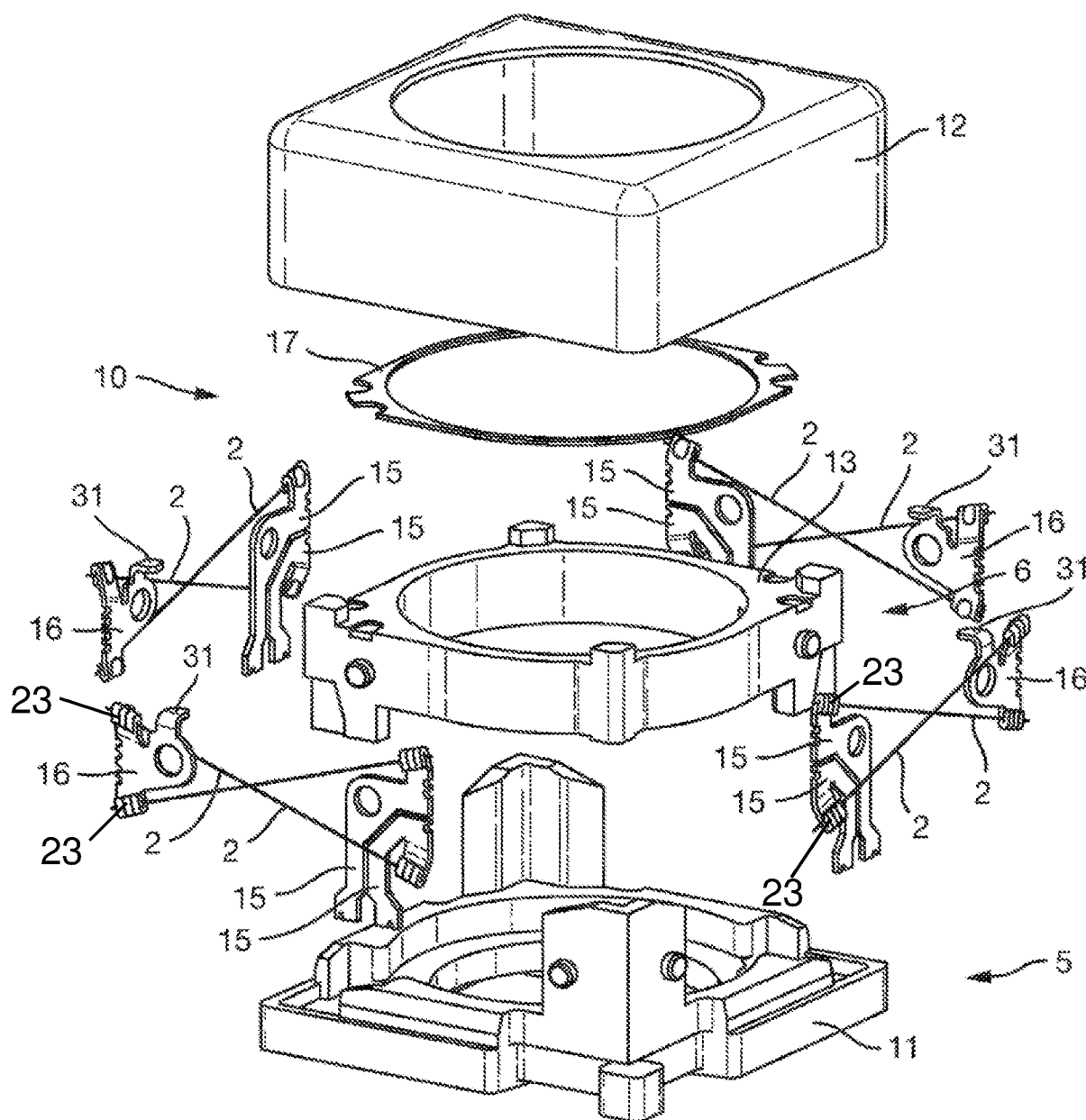
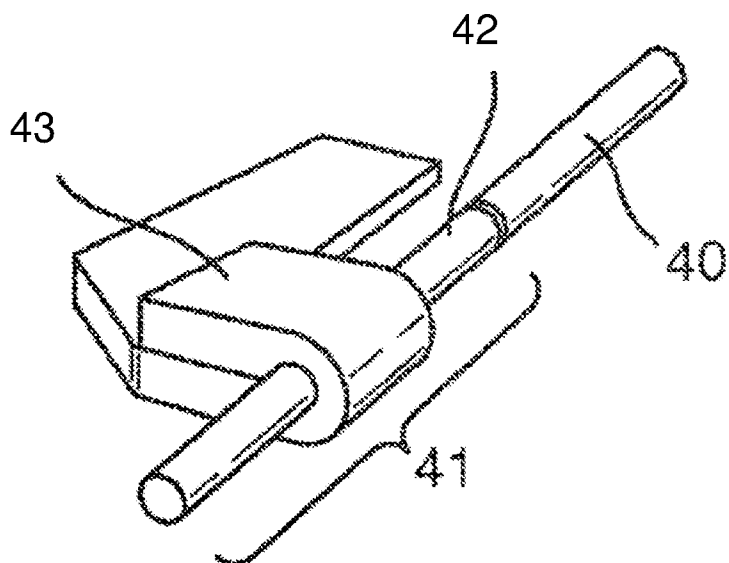


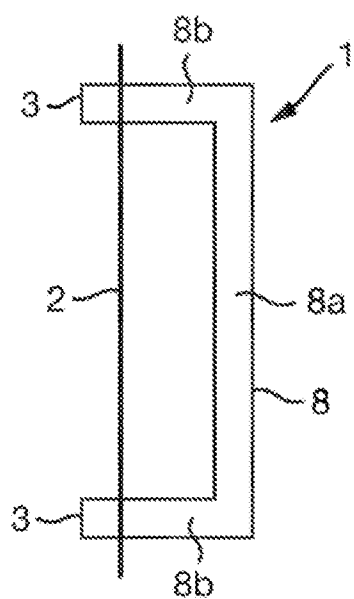
FIGURE 1

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(A)



(B)



(C)

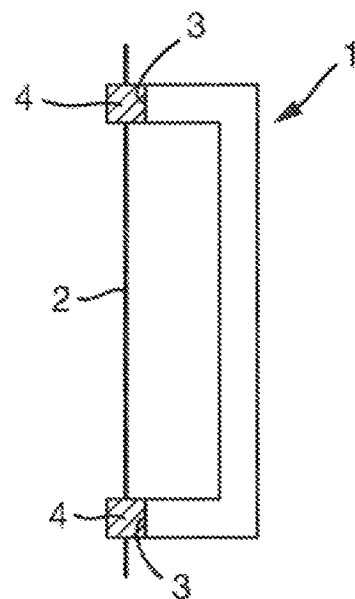


FIGURE 2

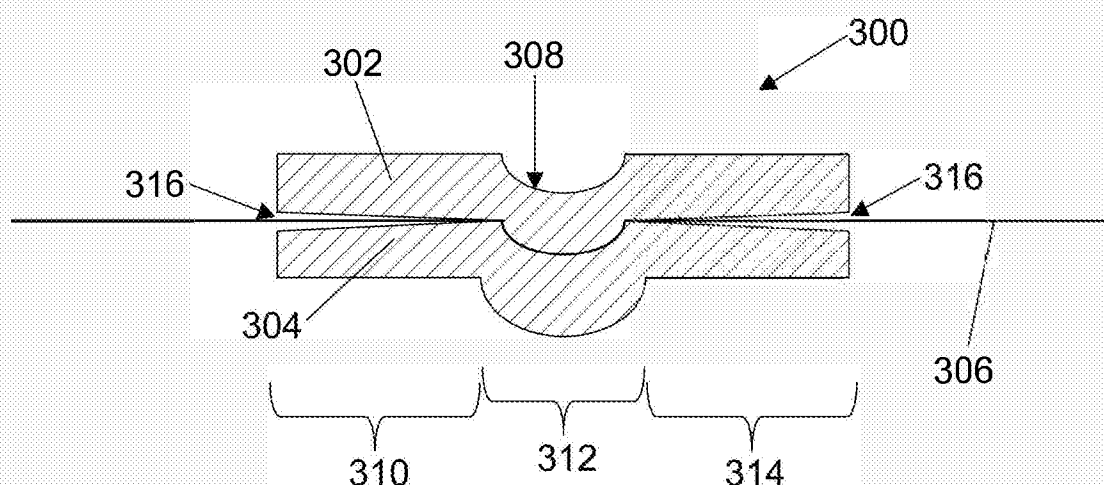


FIGURE 3

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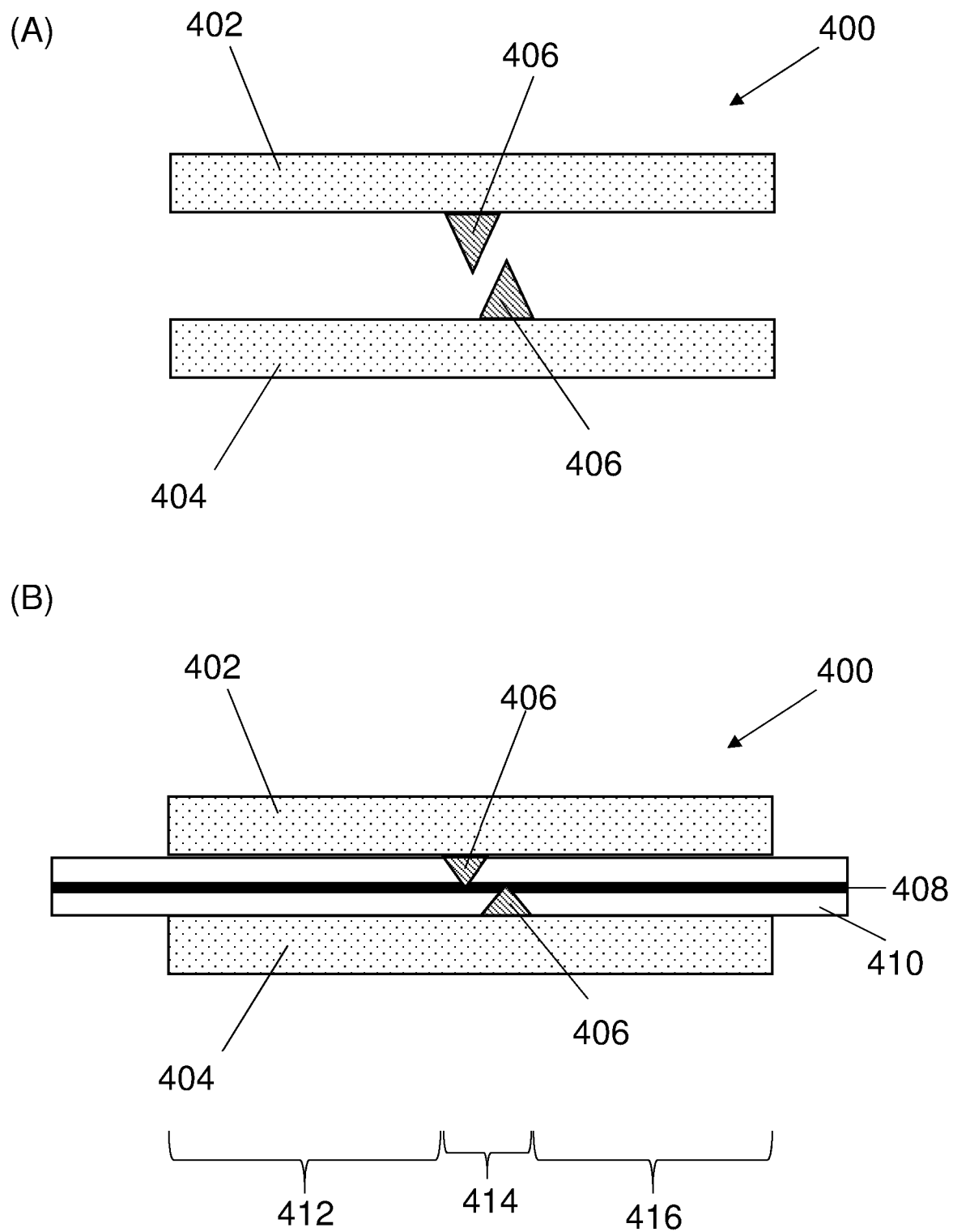


FIGURE 4

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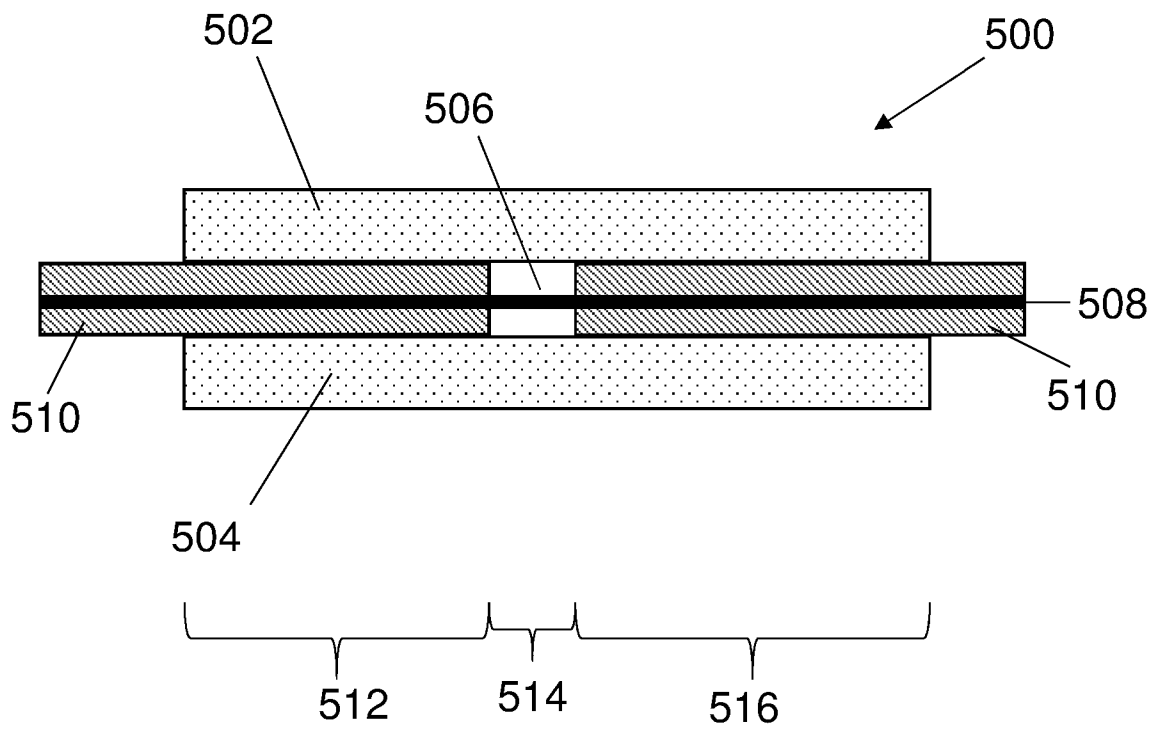


FIGURE 5

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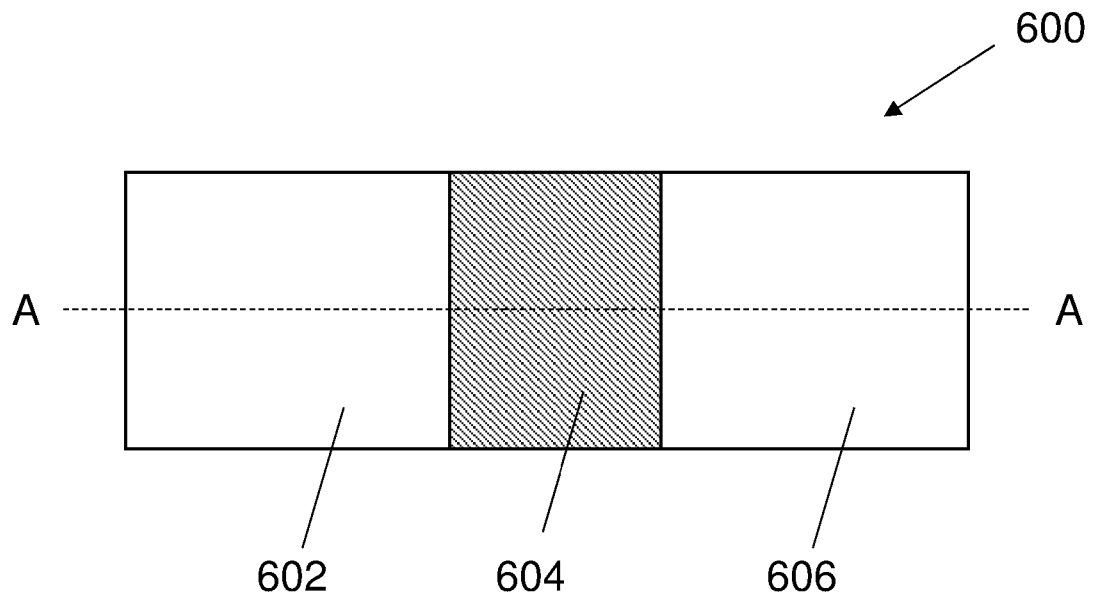


FIGURE 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2019/052305

A. CLASSIFICATION OF SUBJECT MATTER
INV. 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)
F03G H01R

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/227088 A1 (BROWN ANDREW BENJAMIN DAVID [GB] ET AL) 4 August 2016 (2016-08-04)	1-8, 19-21
A	paragraphs [0024] - [0045]; figures 2-5	9-18, 22-25
A	----- WO 2008/129291 A2 (1 LTD [GB]; TOPLISS RICHARD [GB]; HOOLEY ANTHONY [GB]) 30 October 2008 (2008-10-30) page 30, line 22 - page 31, line 22; figures 1, 13-15	1-25
A	----- US 3 897 992 A (WEIDLER CHARLES HARRY) 5 August 1975 (1975-08-05) column 2, line 54 - column 4, line 15; figures 1-8	1-25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

28 October 2019

Date of mailing of the international search report

06/11/2019

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Authorized officer

Jurado Orenes, A

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2019/052305

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