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(54) Title: A METHOD AND ARRANGEMENT FOR REDUCING THERMAL EFFECTS IN COMPACT ADJUSTABLE OPTICAL LENSES

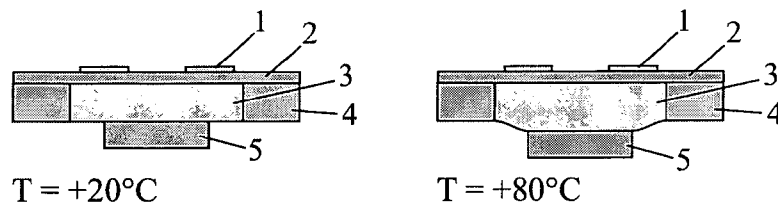


Fig. 3

(57) Abstract: The present invention provides thermal compensation for a lens assembly comprising a polymer lens body. Polymers do have different thermal expansion coefficients which makes it necessary to compensate for thermal expansions to keep optical characteristics of such lenses within specifications when used under different environmental conditions. Also, it is necessary to provide thermal compensation during manufacturing of such lenses due to high temperatures during manufacturing steps.

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A method and arrangement for reducing thermal effects in compact adjustable optical lenses.

The present invention is related to a method and arrangement for reducing thermal effects in compact adjustable optical lenses, and especially to a method and arrangement for reducing thermal effects in an optical lens comprising a deformable lens body made out of soft polymer, and wherein control signals actuate actuators deforming the lens body, thereby enabling adjustments of focal length, providing zooming etc. of an optical lens assembly.

There are many issues to be solved which are associated with adjustable optical elements, wherein a soft polymer is deformed by an actuator layer structure that is located adjacent to a surface of the soft polymer constituting the lens body. Polymers in general have the disadvantage of having a large thermal expansion coefficient, compared to inorganic materials such as metals, oxides and ceramics. Especially hybrid materials, built up of materials with large differences in thermal expansion, such as glass, silicon and polymer, will have problems both during operation and during manufacturing due to the large differences in thermal expansion. The present invention is related to both active and passive methods and arrangements of thermal compensation for adjustable lenses, prisms and other optical elements, comprising both soft polymers and stiffer materials such as glass, ceramics and metals, etc. so that the adjustable lens both can be manufactured and mounted using wide temperature ranges. For example, according to an example of embodiment of the present invention, manufacturing can be done at temperatures as high as 300°C and the lens may be operated at temperatures ranging from -25 to 80°C, or wider.

There is an increasing demand for low cost, high volume miniature lenses in an ever increasing number of applications. The popular use of cameras in mobile phones provides a market for millions of lenses. In order to exploit the increasing resolution of miniature cameras, there is an increasing need for adjustable lenses. Adjustable lenses can provide advanced functionalities, such as auto focus or zoom, in micro cameras. A demanding challenge for lenses in general and adjustable lenses in particular, is the demand for high volume manufacturing processes, such as semiconductor wafer processes. This invention relates to solutions for problems that will arise during operation and manufacturing of adjustable lenses or prisms, wherein a soft polymer constitutes the main part of the lens body. Adjustable optical elements with a

deformable soft polymer are described for example in for NO20064271, DE3644225A and NO20070797.

The adjustable lens illustrated in Fig 1 comprises five elements; an actuator (for
5 example a piezo ring) 1, mounted on a thin flexible membrane (typically glass) 2, in
contact with a soft polymer 3, and preferably a stiffer substrate on the other side 5. The
actuator deforms the thin flexible membrane, creating a lens shape. The deformable
polymer is attached to the membrane, and the whole glass-polymer-glass structure
functions as an adjustable lens. The adjustable lens design illustrated in Fig 1 has the
10 advantage of being producible using wafer processes, enabling high volume
manufacturing at low unit costs. The presence of a continuous membrane made of glass
or other relatively stiff, but flexible, materials in combination with a continuous or
semi-continuous rigid support material 4 enables relatively easy handling in wafer scale
processing, in addition to providing a support structure enabling assembly in a camera
15 system, for example. Other adjustable optical elements may be produced employing
basically the same principles, with modifications in for example the actuator geometry
and the flexible membrane thickness. An example of an adjustable prism is described in
patent application NO20070797.

20 Soft polymers used in the prior art techniques could have a coefficient of thermal
expansion of $>500\text{ppm/K}$. The large difference compared to typical values for example
glass or silicon ($2\text{-}10\text{ppm/K}$) and even stiff polymer materials (typically $50\text{-}200$
 ppm/K), will cause problems in a hybrid construction containing a mixture of such
materials, both during manufacturing and mounting and during continuous operation.
25 Typical operation temperatures for a mobile camera will be -25 to 55 degrees Celsius,
while manufacturing temperatures could go as high as 260 degrees Celsius for brief
periods of time.

It is possible to measure or simulate the effect of temperature increases for a lens
30 assembly as depicted in figure 1. Increasing the temperature will cause a bulging of the
thin glass membrane that could be several times larger than the bulging that arises from
applying a voltage to the actuator. An exaggerated schematic illustration is given in Fig
2. The adjustable lenses and prisms disclosed in prior art would then have a very narrow
operating temperature range, which will make the practical use of the components very
35 limited.

In the adjustable lens design illustrated in Fig 1, a polymer is enclosed in a cavity. Alternative designs suggest only partially filled cavity (seen on the right hand side of Fig 1, where 6 is an air filled void, which is also stated as reducing the effects of thermal expansion (PCT/NO2007/000332 and 000333). However, both simulated and experimentally verified results indicate that a partially filling of polymer in an enclosed cavity will not be sufficient compensation means for thermal effects. An example of simulated resulting compensating effect is shown schematically in Fig 2.

As illustrated in figure 2, and which also is evident for a person skilled in the art, the proposed prior art solution for compensating thermal expansion will not be sufficient as long as the lens material is a solid polymer. If the lens design comprises a liquid filled lens, as described for example in patents JP2002239769, JP2001257932, and JP2000081503, providing relief channels and space for expanding liquid would be sufficient. For solid polymers used as lens body, which are of course used for their advantageous properties, especially with regards to manufacturing and durability, stability etc., where one or more surfaces are physically attached to surrounding surfaces (for example the glass surfaces in the above described adjustable lenses), having a confined open space for the polymer to expand into will not be sufficient.

It is therefore an aspect of the present invention to provide both passive and active methods and arrangements for compensating or minimizing the effect of thermal expansion for adjustable optical elements which are made up of a combination of materials with large differences in thermal expansion.

It is another aspect of the present invention to provide solutions for making adjustable lenses, prisms and other optical elements that can be produced using high volume manufacturing processes, in wafer scale processes, integratable with fixed lenses and image sensors in wafer scale assembly of a complete micro camera.

Another aspect of the present invention is to provide an adjustable lens or prism component that withstands the highly desirable lead free soldering reflow processes, which takes place at temperatures higher than 250°C. Having a micro camera that can withstand this standard process for mounting electronic components onto chip boards, is essential for the implementation of high volume/low cost manufacturing of especially consumer electronics, such as mobile cameras etc.

Figure 1 illustrates examples of prior art adjustable lenses comprising lens bodies made out of polymer.

Figure 2 illustrates the effect of thermal expansion in a prior art lens assembly.

5

Figure 3 illustrates an example of embodiment of the present invention.

Figure 4a illustrates another example of embodiment of the present invention.

10 Figure 4b illustrates another example of embodiment of the present invention.

Figure 5 illustrates another example of embodiment of the present invention.

In an example of embodiment of the present invention a section of the bottom glass
15 element 5 is cut free from the supporting structures, as illustrated in Fig 3. The polymer
in this case fills the majority of the cavity created by the thin glass membrane and the
rigid walls. The bottom element 5 may be glass, or any material that is optically
transparent and stiffer than the soft polymer 3. Other materials that could be used are for
example moulded plastics and relatively stiff elastomers.

20

In an other example of embodiment of the present invention, illustrated in Fig 4a, the
polymer does not fill the whole cavity, but is provided in the optical light path of the
lens or prism.

25 Another variation of this embodiment is to include an element with optical power as the
bottom glass element, as illustrated in fig. 4.b This is particularly advantageous when
the adjustable lens is part of an optical objective, with one or more fixed lenses, as the
bottom optical interface contributes to the total optical power of the objective, which
has the function of collecting all light in focus downwards to a surface of an image
30 sensor, for example.

According to another aspect of the present invention it is an advantage from a thermal
compensation point of view to have a concave or a convex surface on the bottom glass
element. Due to the thermal expansion, there will be a slight shift of the optical
35 interfaces in the direction of the optical axis. This shift might in special lens designs
cause unwanted effects, such as poor focus in the image plane or other aberration errors.
A concave or convex shape - depending on the design of the whole camera objective -

of the bottom glass of the thermally compensated adjustable lens will in some cases reduce such unwanted effects.

In all the above presented embodiments, it might be advantageous to provide a small voltage to the piezo actuator as a function of temperature. This could be necessary for certain designs in order to achieve an even better compensation for thermal expansion. An example of lens profiles with (8) and without (7) such correction voltage is shown in Fig 5.

In order to manufacture the thermally compensated adjustable lenses in high volumes, it is evident to carry out processing on wafers, preferably using standard semi-conductor processing equipment.

All the above mentioned embodiments will also solve the problems related to thermal expansion for other adjustable optical elements than lenses, most notably adjustable prisms, but also for other adjustable optical elements in which an actuator structure (for example a piezo actuator mounted onto a glass membrane) is attached to both a soft polymer and supporting structures for handling during manufacturing and mounting in a imaging system (camera), where large differences in thermal expansion will cause unwanted effects. Examples of such adjustable optical elements could be filters and gratings.

The embodiments above have been described intended to work with circularly shaped or similar lenses and prisms. The same principles for thermal compensation will work also with cylindrical lenses or other lens body geometries.

According to another aspect of the present invention, when the soft polymer is shaped with two parallel surfaces perpendicular to the optical axis, this will ensure that thermal expansion occurs parallel to the optical axis, which will not cause any distortion of the angle. In special instances, it may be desirable to have a non-parallel structure of the soft polymer, and thermal expansion will in these cases occur with a slight angular distortion from the optical axis, which can be compensated for by other optical means as known to a person skilled in the art.

C l a i m s :

1.

An optical lens assembly comprising a soft and deformable lens body (3) confined in a
5 cavity bounded by a first side comprising actuators (1) on a thin glass surface (2)
supported by sidewalls (4), c h a r a c t e r i z e d i n
t h a t a second surface constituting a bottom side of the cavity is arranged as an
attached transparent plate (5) onto the lens body such that there is an opening between
the side walls and the edges of the transparent plate.

10

2.

The optical lens assembly according to claim 1, c h a r a c t e r i z e d
i n t h a t t h e soft and deformable lens body (2) is arranged in an
optical light path of the optical lens assembly, the lens body (2) is located in the cavity
15 with an opening around the lens body (2) and the sidewalls (4).

3.

The optical lens assembly according to claim 1, c h a r a c t e r i z e d
i n t h a t t h e attached transparent plate (5) has optical power.

20

4.

The optical lens assembly according to claim 1, c h a r a c t e r i z e d
i n t h a t t h e attached transparent plate (5) has a surface intersecting
an optical axis in the optical lens assembly, wherein the surface has a convex shape.

25

5.

The optical lens assembly according to claim 1, c h a r a c t e r i z e d
i n t h a t t h e attached transparent plate (5) has a surface intersecting
an optical axis in the optical lens assembly, wherein the surface has a concave shape.

30

6.

The optical lens assembly according to claim 1, c h a r a c t e r i z e d
i n t h a t t h e deformable lens body (2) comprises two opposite located parallel
surfaces perpendicular to a same optical axis in the lens body (2).

35

7.

The optical lens assembly according to claim 1, characterized in that the deformable lens body (2) comprises at least two opposite located surfaces intersecting a same optical axis in the lens body (2) that are non-parallel.

8.

The optical lens assembly according to claim 1, characterized in that the actuators (1) is applied a bias voltage, wherein the bias voltage is proportional to temperature of the optical lens assembly.

9.

A method for reducing thermal effects in a compact adjustable optical lens assembly, wherein the optical lens assembly comprises a soft and deformable lens body (3) confined in a cavity bounded by a first side comprising actuators (1) on a thin glass surface (2) supported by sidewalls (4), characterized in that the method comprises:

arranging a bottom transparent plate (5) of the lens assembly in a movable relationship with the sidewalls (4).

10.

The method according to claim 9, characterized in that the movable relationship is provided for by having an opening between the edges of the transparent plate (5) and the sidewalls (4).

11.

The method according to claim 9, characterized in that the method further comprises:

measuring the temperature of the lens assembly and using this measurement to provide a proportional bias voltage as a function of the temperature, and applying this bias voltage on the actuators (1).

12.

The method according to claim 9, characterized in that the method further comprises:

providing optical power in the bottom transparent plate (5), wherein the optical power is designed according to total optical requirements of the lens assembly.

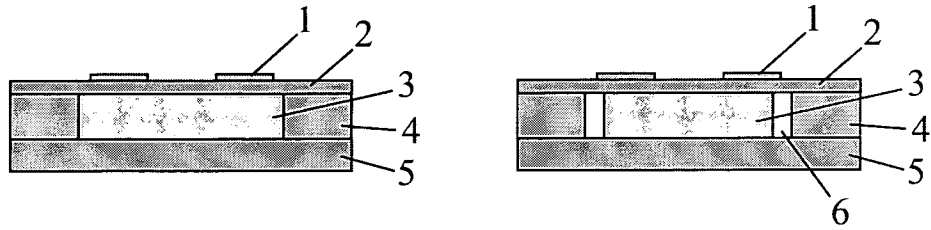


Fig. 1

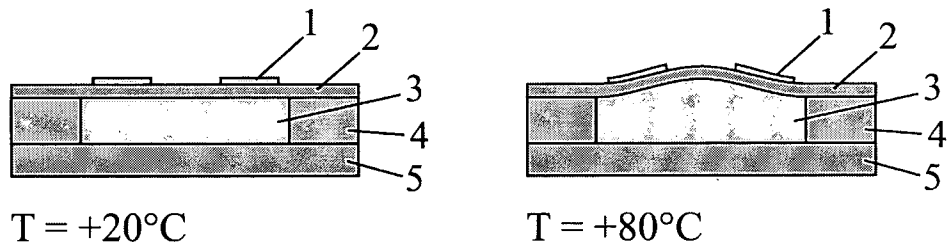


Fig. 2

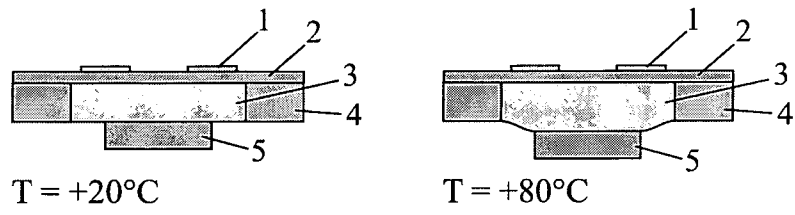


Fig. 3

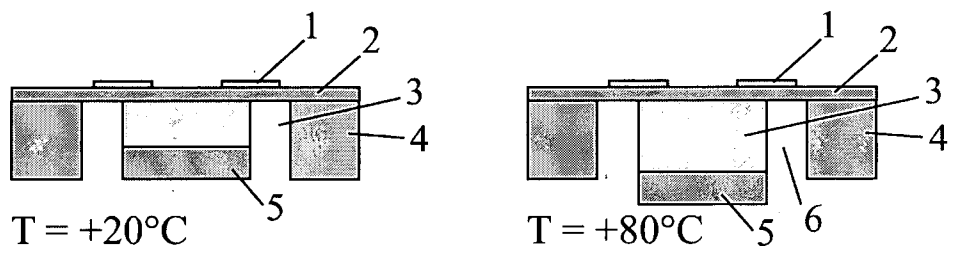


Fig. 4

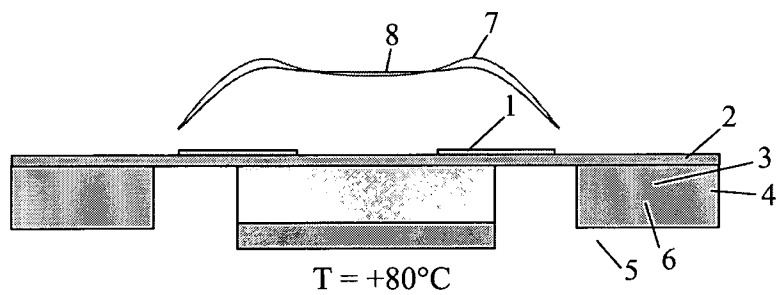


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO2009/000255

A. CLASSIFICATION OF SUBJECT MATTER		
IPC: see extra sheet 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)		
IPC: G02B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
SE,DK,FI,NO classes as above		
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EPO-INTERNAL, WPI DATA, PAJ		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6188526 B1 (T. SASAYA ET AL), 13 February 2001 (13.02.2001), column 5, line 30 - line 51, abstract, figures --	1-12
P,A	US 20080277480 A1 (S. THURIES ET AL), 13 November 2008 (13.11.2008), figure 3, paragraph (0010) --	1-12
A	GB 2163864 A (OLYMPUS OPTICAL CO LTD), 5 March 1986 (05.03.1986), abstract -- -----	1-12
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
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Date of the actual completion of the international search 16 November 2009		Date of mailing of the international search report 20-11-2009
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/NO2009/000255

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				JP	2000081503 A	21/03/2000

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