



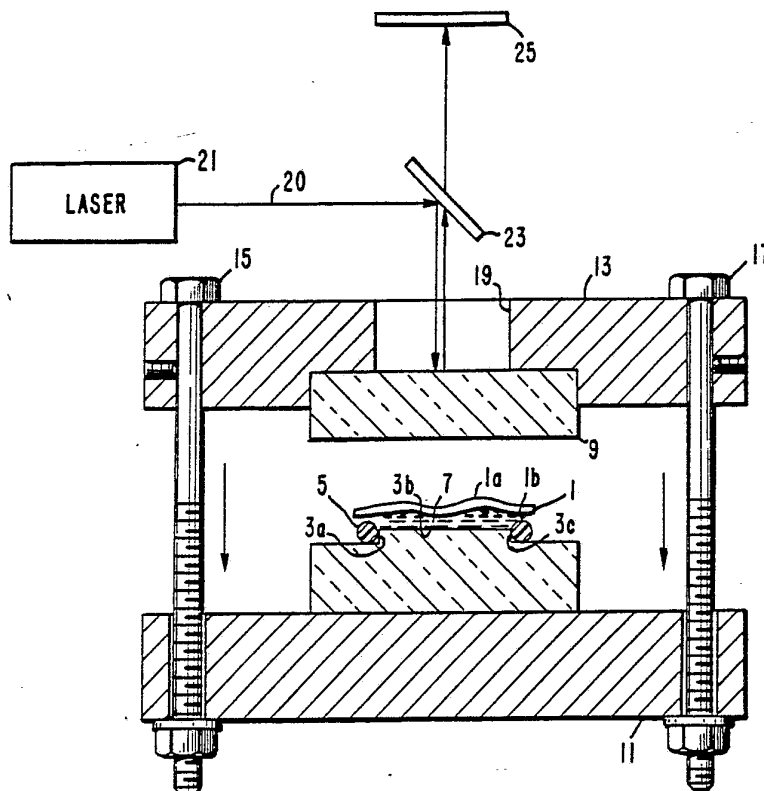
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification³ : H01L 31/02, 21/302; B21D 22/10 G01B 11/26</p>	A1	<p>(11) International Publication Number: WO 84/ 03176 (43) International Publication Date: 16 August 1984 (16.08.84)</p>
<p>(21) International Application Number: PCT/US83/01989 (22) International Filing Date: 16 December 1983 (16.12.83) (31) Priority Application Number: 464,442 (32) Priority Date: 7 February 1983 (07.02.83) (33) Priority Country: US (71) Applicant: HUGHES AIRCRAFT COMPANY [US/US]; P.O. Box 1042, El Segundo, CA 90245 (US). (72) Inventors: LITTLE, Michael, J. ; 5533 Sylvia Avenue, Tarzana, CA 91356 (US). BROWN, Roger, H. ; 1147 East Elmwood, Burbank, CA 91501 (US). EFRON, Uzi ; 2852 Sawtelle, #26, Los Angeles, CA (US). HOBBERG, Clarence, P. ; 1136 Monument Street, Pacific Palisades, CA 90272 (US).</p>		<p>(74) Agents: ROSENBERG, Gerald, B. et al.; Hughes Aircraft Company, P.O. Box 1042, Bldg. C2, M.S. A126, El Segundo, CA 90245 (US). (81) Designated States: AU, CH (European patent), DE (European patent), DK, FR (European patent), GB (European patent), JP, NO, SE (European patent). Published With international search report.</p>

(54) Title: SELF-COMPENSATING HYDROSTATIC FLATTENING OF SEMICONDUCTOR SUBSTRATES

(57) Abstract

A semiconductive substrate (1), such as a silicon wafer, is mounted on a baseplate (3), for inclusion in an optical device such as a liquid crystal light valve. An optical flat (9) presses the top surface of the silicon wafer toward the baseplate and against a ring seal (5) surrounding a fluid adhesive (7). The fluid adhesive hydrostatically distributes the force of compression to guarantee optical flatness and self-compensation for the amount fluid adhesive surrounded by the O-ring. The optical flatness of the semiconductor substrate is limited only by the flatness of the optical flat against which it is compressed. Parallel alignment of the optical flat (9), the substrate (1) and the baseplate (3) is achieved by reflecting a laser beam (20) through the semiconductive substrate and observing the interference fringes therein, while adjusting the relative alignment so as to maximize the distance between fringes.



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SELF-COMPENSATING HYDROSTATIC FLATTENING
OF SEMICONDUCTOR SUBSTRATES

1 BACKGROUND OF THE INVENTION

1 Semiconductor material such as silicon is used in
either wafer or chip form in several types of optical
devices. Some examples are the well-known infrared
5 detector focal plane array formed on a silicon chip and
another is a silicon liquid crystal light valve which
uses a silicon wafer, and is of the type described in
U. Efron et al, "A Silicon Photoconductor Based Liquid
Crystal Light Valve", Society for Information Display
10 Technical Digest, Vol. 12, 1981, page 142. The silicon
chip used in the infrared detector focal plane array
and the silicon wafer used in the liquid crystal light
valve must have a flat finish of optical quality. To
this end, particularly in the liquid crystal light
15 valve, the silicon may be polished using mechanical-
chemical techniques to achieve the optical quality
flatness.

 The substrate for the silicon based liquid crystal
light valve described in the above-referenced Efron
20 publication is a very thin silicon wafer, about 5 mils
thick and about 2 inches in diameter, that is chemically
and mechanically polished on both sides. Because the
wafer is very thin and therefore somewhat flexible and
because of the limitations of chemical-mechanical
25 polishing, such silicon wafers do not have the ideal
flatness preferred in liquid crystal light valves.



1 Specifically, peak-to-valley deviations from flatness
are typically on the order of 5 microns on each side.
Because the flatness deviations on one side are
independent of those on the other side of the wafer,
5 the thickness variations may be as much as 10 microns.

For ideal optical performance of a liquid crystal
light valve, the surface of the wafer should preferably
be flat to within 1 micron.

10

SUMMARY OF THE INVENTION

In the present invention, a silicon wafer or
silicon chip is flattened by compressing it between two
surfaces, one of which is optically flat and the other
of which the chip or wafer is to be fastened to. The
15 force of compression is hydrostatically distributed
through a fluid medium disposed between the wafer or
chip and the other surface. The fluid medium thereafter
solidifies as an adhesive between the chip or wafer and
the other surface to which it is to be mounted. The
20 hydrostatic distribution is achieved by sealing the
fluid adhesive between the wafer or substrate and the
mounting surface by means of a flexible O-ring which
expands to permit compensation for the amount of fluid
adhesive contained within the volume defined by the
25 O-ring, the optical flat surface and the wafer or chip.
Nearly perfect parallel alignment between the optical
flat surface and the wafer surface pressed against it
is achieved by a laser alignment technique in which a
laser beam is directed through an aperture in the
30 optical flat surface so that it is reflected from the
facing surface of the silicon wafer or chip and there-
after passes through a beam splitter onto an image
plane. The alignment between the optical flat and
the wafer surface is adjusted to maximize the spacing
35 between interference fringes observed in the image



1 plane. This adjustment causes them to come into nearly
perfect parallel alignment with one another. This,
therefore, forces the surface of the wafer or chip
facing the optically flat surface to deform to a
5 perfectly flat configuration, which is the desired
result. Thereafter, the adhesive hardens against the
opposite wafer surface and maintains the flat parallel
configuration permanently.

A silicon wafer is mounted on a bottom optical
10 flat using an adhesive in accordance with the present
invention as follows: first, a flexible O-ring is
placed on the bottom mounting surface. The space on the
optical flat surrounded by the O-ring is then filled
with a fluid adhesive. Thereafter, the wafer is placed
15 on the O-ring over the fluid adhesive. Finally, a the
optical flat surface is pressed directly onto the top
of the wafer so as to compress the O-ring and adhesive.

DESCRIPTION OF THE DRAWINGS

20 The invention is best understood by reference to
the accompanying drawings in which:

FIG. 1 is a simplified cross-sectional view
and partial diagram illustrating the basic method of
the present invention;

25 FIG. 2 is a plan view of the O-ring employed
in the method illustrated in FIG. 1;

FIG. 3 is a cross-sectional view corresponding
to view 3-3 of FIG. 2;

30 FIG. 4 is a plan view of an exemplary square
shaped flexible ring to be used in place of the O-ring
of FIG. 2 for a square shaped semiconductor substrate;

FIG. 5 is a cross-sectional view corresponding
to view 5-5 of FIG. 4; and

35 FIG. 6 is an exemplary plan view through the
image plane of FIG. 1 illustrating interference fringes
observed through the aperture of FIG. 1.



1 DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, a semiconductor substrate 1, which may be, for example, a silicon wafer or a silicon chip, is to be mounted to a base plate 3 in the course of fabricating an optical device, such as, for example, a silicon based liquid crystal light valve. The problem is that the substrate 1 is not perfectly flat and may have flatness deviations on the order of 5 microns on both its top surface 1a and its bottom surface 1b. The base plate 3 to which the substrate 1 is to be mounted includes a raised plateau 3a having a top surface 3b.

If only the top surface 1a of the wafer 1 is to be flattened, it is not necessary that the top surface 3b of the plateau 3a be optically flat. However, if the wafer 1 is to be used as a photo substrate in a photo-activated liquid crystal light valve, then the space between the wafer surface 1b and the plateau surface 3b should be minimized. In this particular instance, the plateau surface 3b preferably is of an optically flat quality, having flatness deviations therein on the order of only 1 micron or less.

A flexible O-ring 5 is stretched around the plateau 3a so that a perfect seal is achieved therebetween. The O-ring has a diameter which is somewhat greater than the height of the plateau 3b so that a fluid adhesive 7 poured on top of the plateau 3b is held thereover by the O-ring 5. It is after the O-ring has been stretched around the plateau 3b and the adhesive poured over the plateau that the substrate 1 is placed over the O-ring 5. A top optical flat 9 is then pressed down over the substrate 1. Pressing is achieved by means of a base plate 11 and a top plate 13 mounted together by means of two screws 15



1 and 17 and two other screws, not visible in the cross-
sectional view of FIG. 1, which are all tightened
together in unison to maintain a parallel alignment
between the baseplate 3 and top optical flat 9. The
5 hydrostatic pressure thus generated throughout the
fluid adhesive 7 forces virtually the entire surface
of the top wafer surface 1a to contact and press
uniformly against the bottom surface of the optical
flat 9.

10 Adjustment of the screws 15, 17 is made in
accordance with a laser alignment method made possible
by the presence of an aperture 19 in the top plate 13.
Specifically, a laser beam 20 from a laser 21 is
reflected by a beamsplitter 23 through the aperture 19
15 and through the top optical flat 9 (which is made of
high quality glass for this purpose) so that the beam
reflects from both the top surface 1a of the semicon-
ductor substrate 1 and from the bottom surface of the
optical flat 9. The reflected beams thereafter pass
20 through the beamsplitter 23 and form interference
fringes observed on an image plane 25. Misalignment
between the optically flat bottom surface of the
optical flat 9 and the top surface 1a of the wafer 1
is indicated by interference fringes of the type
25 illustrated in FIG. 6. The screws 15 and 17 are
adjusted while pressing the top optical flat 9 against
the substrate 1 so as to maximize the straightness of
the fringes of FIG. 6, which guarantees flatness of the
wafer surface 1a. In some cases, it may be desirable
30 to further adjust the screws 15 and 17 so as to maximize
the distance D between the dark interference fringes
illustrated in FIG. 6. This latter adjustment guarantees
parallel alignment between the bottom surface of the
optical flat 9 and the top wafer surface 1a to within

35



1 less than a wavelength of the laser 21. Observation of
the image plane 25 may be made by means of a screen, a
camera or a photodetection system.

5 As the screws 15, 17 are turned to tighten the
top optical flat 9 against the substrate 1, the force
of compression created thereby presses the substrate 1
closer to the top surface 3b of the baseplate 3 causing
the fluid adhesive 7 to spread itself so as to fill
10 all voids in the space defined by the O-ring 5, this
compression causing the O-ring 5 to expand radially
outward to accommodate the displacement of the
adhesive 7. The amount of fluid adhesive 7 present
15 in the space defined by the O-ring 5 is not critical
because the radial expansion of the O-ring 5 compensates
for any amount of adhesive 7 originally present in the
space defined by the O-ring 5. If the wafer 1 is to be
used as the photo-substrate of photo activated liquid
crystal light valve, it is desirable to minimize the
20 distance between the bottom wafer surface 1b and the
top mounting surface 3b. In this case, the O-ring
should be sufficiently flexible to permit optimum
displacement of the adhesive.

In the presently preferred embodiment of the
invention, the O-ring is made of a commercially
25 available substance, Viton, while the adhesive 7
is an epoxy known as Epon 828. The optical flat 9
comprises a well known high quality commercially
available glass known as B-K7.

30 FIG. 2 is a top plan view of the O-ring 5 and
FIG. 3 is a cross-sectional view of the preferred cross-
sectional configuration of the O-ring 5 corresponding
to view 3-3 of FIG. 2.

1 As previously mentioned, the method of this
invention is useful not only with a circular silicon
wafer but is also useful to flatten silicon chips, which
are generally of a square or rectangular configuration.
5 FIG. 4 illustrates the plane view of an O-ring 5 which
conforms to the shape of a square or a rectangular
silicon chip. The cross-sectional configuration of the
"square" O-ring of FIG. 4 may assume either the preferred
geometry illustrated in FIG. 3 or the alternative
10 geometry illustrated in FIG. 5 corresponding to view 5-5
of FIG. 4.

 In certain applications, the distance between
the bottom surface 1b of the substrate 1 and the top
surface 3b of the baseplate 3 may be critical. In
15 such a case, it is simply required to compress the
substrate 1 against the top surface 3b until this
critical distance is achieved, because the O-ring 5
will deform to compensate for any amount of compression.

 It is understood, of course, that once the
20 desired compression of the substrate 1 between the
optical flat 9 and the baseplate 3 has been achieved,
that the apparatus illustrated in FIG. 1 is left in
place until the adhesive 7 has completely solidified.
Thereafter, the screws 15 and 17 are backed off and
25 the baseplate 3 and substrate 1 are removed as a single
unit. After the method of this invention has been
performed as described above, the flatness of the top
surface 1a of the semiconductive substrate is limited
only by the flatness of the top optical flat 9, which
30 is a significant improvement over the flatness achieved
in prior art mechanical-chemical polishing techniques.



CLAIMSWhat is Claimed is:

- 1 1. A baseplate structure (1, 3, 7) characterized
by:
- a) a baseplate (3) having a top surface;
 - b) a layer of solidified fluid adhesive (7)
5 adjacent said baseplate top surface; and
 - c) a semiconductor member (1) having first
and second major surfaces (1a, 1b), said second major
surface being adjacent said solidified fluid adhesive
layer, said semiconductor member being held thereby in
10 a stressed condition such that said first major surface
is substantially optically flat.
- 1 2. The baseplate structure (1, 3, 7) of Claim 1
further characterized by a ring seal (5) interposed
between said baseplate (3) and said semiconductor member
(1) so as to encircle said solidified fluid adhesive
5 layer (7).
- 1 3. The baseplate structure (1, 3, 7) of Claim 1
or 2 further characterized in that said baseplate top
surface is substantially optically flat and parallel to
the first major surface of said semiconductor member (1).
- 1 4. The baseplate structure (1, 3, 7) of any of
the preceding claims fabricated in accordance with a
method characterized by:
- a) placing a flexible ring seal (5) on the
5 top surface of said baseplate (3);
 - b) placing a fluid adhesive (7) on the top
surface of said baseplate such that it is encircled by
said flexible ring seal;



c) placing said semiconductor member (1)
10 over said flexible ring seal; and

d) pressing an optically flat surface (9)
over said semiconductor member so as to compress and
displace both said flexible ring seal and said fluid
adhesive, the compression being maintained at least
15 until said fluid adhesive has solidified.

1 5. The method of Claim 4 further characterized
by the subsequent step of removing said flexible ring
seal.

1 6. The method of Claim 4 or 5 wherein said
optically flat surface (9) has an aperture (19)
therethrough and further characterized by the steps
of:

5 a) directing a laser beam (20) through said
aperture so that said beam reflects from the top and
bottom (1a, 1b) surfaces of said semiconductor member;

b) observing interference fringes from the
reflected beam at an image plane (25); and

10 c) adjusting the relative alignment between
said baseplate (3) and said optically flat surface (9)
so as to maximize first the straightness of the inter-
ference fringes and second the distance between said
interference fringes observed at said image plane (25).



Fig. 1.

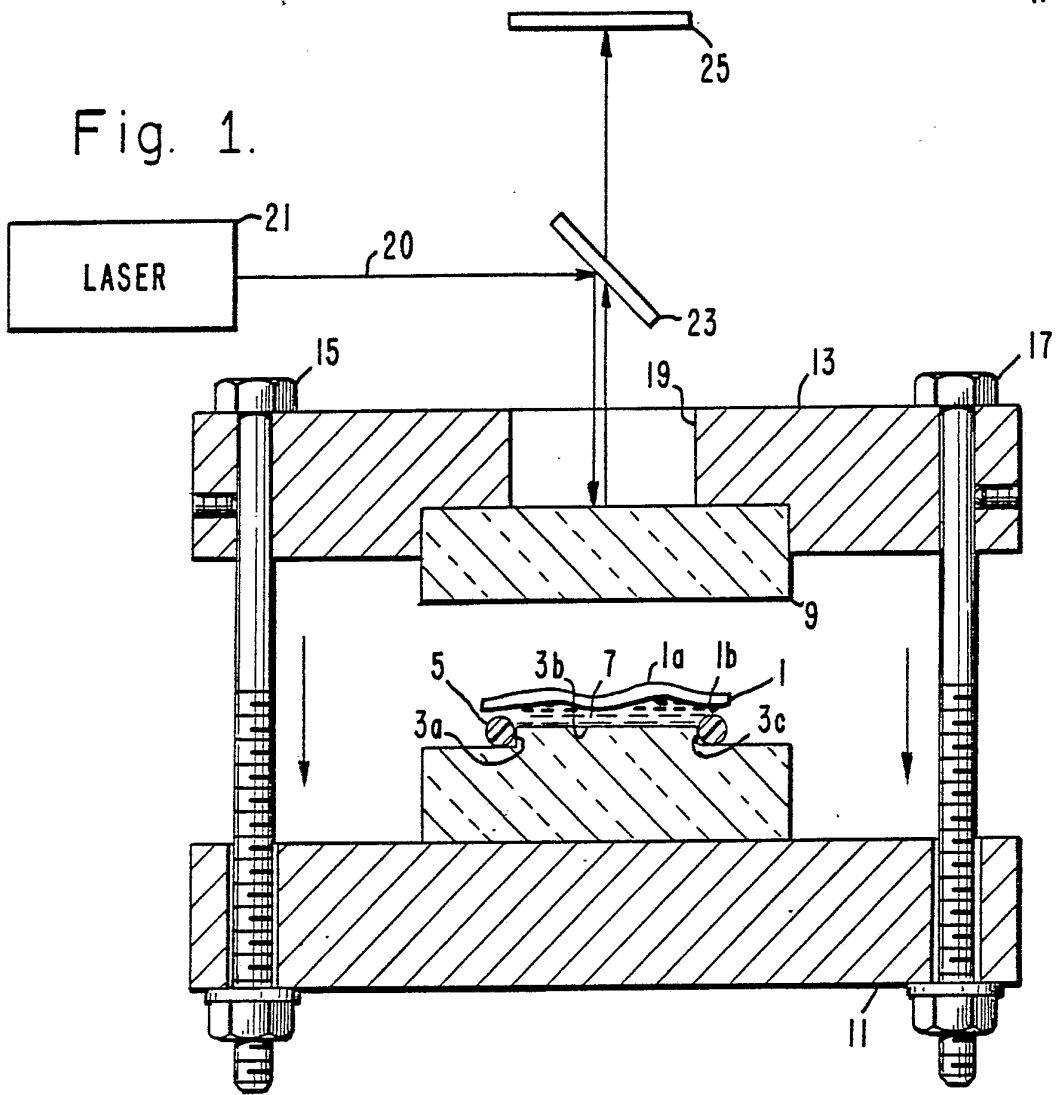


Fig. 2.

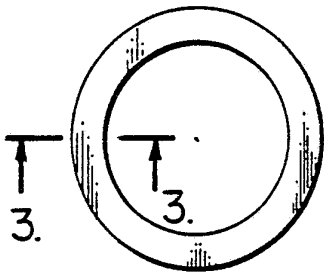


Fig. 4.

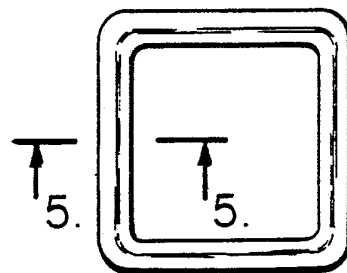


Fig. 3.

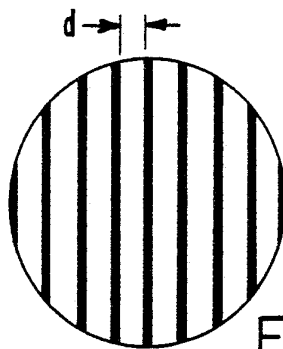


Fig. 6.

Fig. 5.



INTERNATIONAL SEARCH REPORT

International Application No PCT/US 83/01989

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC ³ : H 01 L 31/02; H 01 L 21/302; B 21 D 22/10; G 01 B 11/26		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁴		
Classification System	Classification Symbols	
IPC ³	H 01 L; B 21 B; G 01 B	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category *	Citation of Document, ¹⁵ with Indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
A	Patents Abstracts of Japan, vol. 5, no. 34, 4 March 1981 (Tokyo, JP) JP, A, 55- 159678 (TOKYO SHIBAURA DENKI K.K.) 11-12-1980 --	1,3
A	Patents Abstracts of Japan, vol. 5, no. 74, 16 May 1981 (Tokyo, JP) JP, A, 56- 21382 (TOKYO SHIBAURA DENKI K.K.) 27-02-1980 --	1,3
A	US, A, 3751956 (T. BLANCHI) 14 August 1973 see claims 1-5 --	1,2,5
A	US, A, 3914969 (B.A. BANKS) 28 October 1975 see claims 1-6 --	1,2,5
A	GB, A, 820027 (RADIATION LTD.) 16 September 1959 see figures --	1,2,5
A	US, A, 3681958 (A. RASMUSSEN) 8 August 1972 see claims 1-4 --	1,2,5
<p>* Special categories of cited documents: ¹⁵</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the International filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ³	Date of Mailing of this International Search Report ³	
16th April 1984	29 MAI 1984	
International Searching Authority ¹	Signature of Authorized Officer ²⁰	
EUROPEAN PATENT OFFICE	G.L.M. Krügerberg	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No ¹⁸
A	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 19, no. 9, February 1977 (New York, US) B.W. Styles: "Measuring the parallelism of planar items by interferometry", page 3565, see page 3565	6
	--	
A	MESURES, REGULATION, AUTOMATISME, vol. 46, no. 4, April 1981 (Paris, FR) "Mesure de parallélisme par interférométrie laser sur un objet opaque", pages 81,83,85, see the whole document	6

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/US 83/01989 (SA 6423)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 25/05/84

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 3751956	14/08/73	None	
US-A- 3914969	28/10/75	US-A- 3864797	11/02/75
GB-A- 820027		None	
US-A- 3681958	08/08/72	None	

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