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(54) **DUAL STAGE LITHOGRAPHIC APPARATUS AND DEVICE MANUFACTURING METHOD**

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G03B 27/52 (2006.01)
G03B 27/58 (2006.01)

(52) **U.S. Cl.** **355/53**; 355/30; 355/72

(58) **Field of Classification Search** 355/30, 355/52, 53, 55, 67, 72, 75; 356/399–401; 250/548
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,346,164 A 8/1982 Tabarelli et al.
4,465,368 A 8/1984 Matsuura et al.
4,480,910 A 11/1984 Takanashi et al.
5,121,256 A 6/1992 Corle et al.
5,243,195 A 9/1993 Nishi
5,610,683 A 3/1997 Takahashi et al.
5,650,840 A 7/1997 Taniguchi
5,715,039 A 2/1998 Fukuda et al.
5,825,043 A 10/1998 Suwa
5,969,441 A * 10/1999 Loopstra et al. 310/12.06
6,137,561 A 10/2000 Imai
6,262,796 B1 7/2001 Loopstra et al.
6,341,007 B1 1/2002 Nishi et al.
(Continued)

FOREIGN PATENT DOCUMENTS

DE 221 563 A1 9/1983
(Continued)

OTHER PUBLICATIONS

Preliminary Amendment filed on Jan. 8, 2008 in U.S. Appl. No. 11/785,716 of Ebihara.

(Continued)

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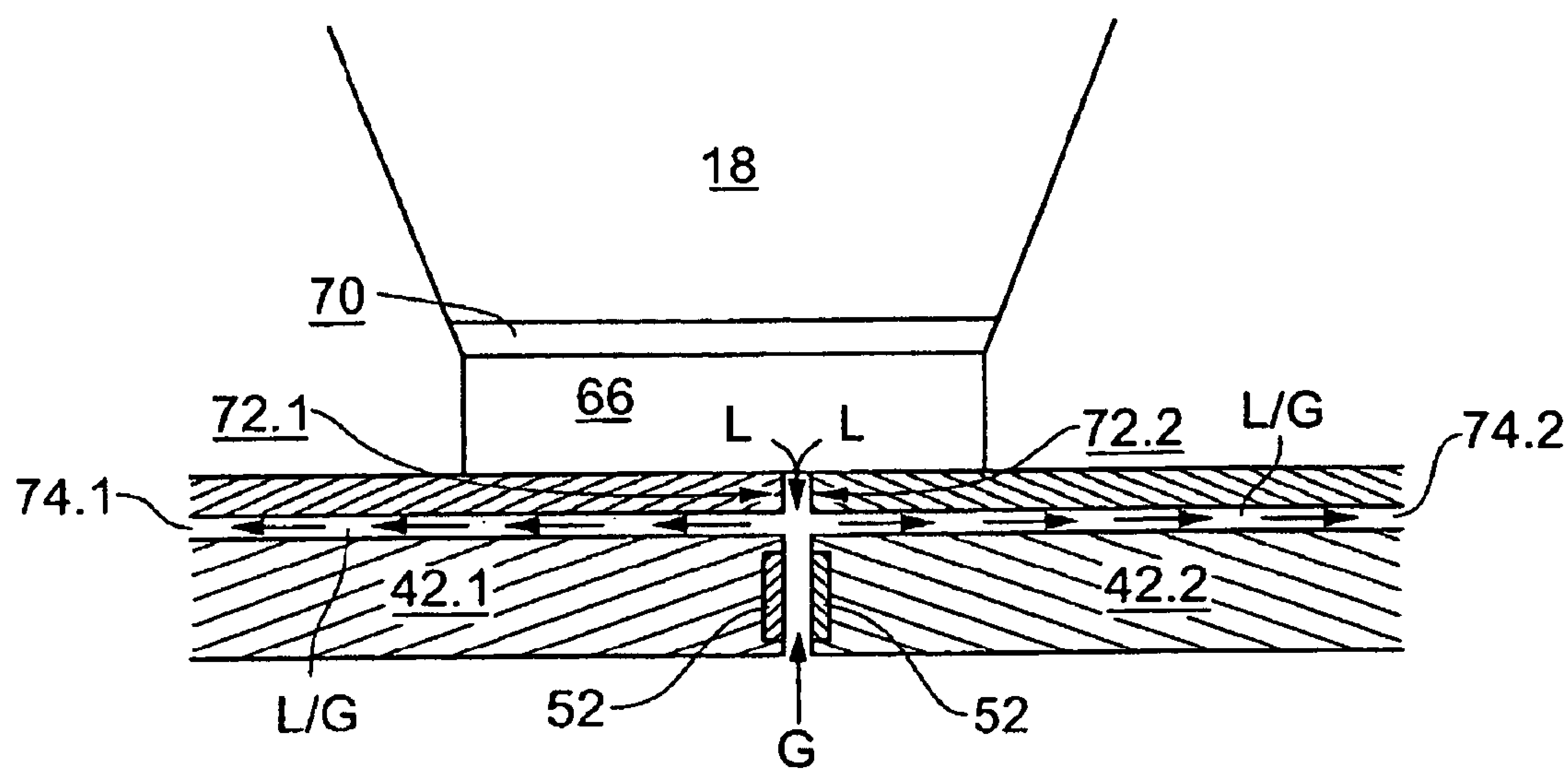
(57) **ABSTRACT**

The invention relates to a dual stage lithographic apparatus, wherein two substrate stages are constructed and arranged for mutual cooperation in order to perform a joint scan movement. The joint scan movement brings the lithographic apparatus from a first configuration, wherein immersion liquid is confined between a first substrate held by the first stage of the stages and a projection system of the apparatus, to a second configuration, wherein the immersion liquid is confined between a second substrate held by the second stage of the two stages and the projection system, such that during the joint scan movement the liquid is essentially confined within the space with respect to the projection system.

33 Claims, 9 Drawing Sheets



U.S. PATENT DOCUMENTS

6,400,441	B1	6/2002	Nishi et al.	
6,417,914	B1	7/2002	Li	
6,665,054	B2	12/2003	Inoue	
6,897,963	B1	5/2005	Taniguchi et al.	
7,075,616	B2	7/2006	Derksen et al.	
7,098,991	B2	8/2006	Nagasaka et al.	
7,119,876	B2	10/2006	Van Der Toorn et al.	
7,199,858	B2 *	4/2007	Lof et al.	355/30
7,349,069	B2	3/2008	Beems et al.	
7,388,649	B2 *	6/2008	Kobayashi et al.	355/53
7,405,811	B2	7/2008	Beems et al.	
7,456,929	B2	11/2008	Shibuta	
7,528,931	B2	5/2009	Modderman	
8,027,027	B2	9/2011	Ebihara	
2002/0041377	A1	4/2002	Hagiwara et al.	
2002/0061469	A1	5/2002	Tanaka	
2002/0163629	A1	11/2002	Switkes et al.	
2002/0196421	A1	12/2002	Tanaka et al.	
2003/0030916	A1	2/2003	Suenaga	
2003/0076482	A1	4/2003	Inoue	
2003/0117596	A1	6/2003	Nishi	
2003/0128350	A1	7/2003	Tanaka	
2003/0174408	A1	9/2003	Rostalski et al.	
2004/0000627	A1	1/2004	Schuster	
2004/0075895	A1	4/2004	Lin	
2004/0109237	A1	6/2004	Epple et al.	
2004/0114117	A1	6/2004	Bleeker	
2004/0118184	A1	6/2004	Violette	
2004/0119954	A1	6/2004	Kawashima et al.	
2004/0125351	A1	7/2004	Krautschik	
2004/0136494	A1	7/2004	Lof et al.	
2004/0160582	A1	8/2004	Lof et al.	
2004/0165159	A1	8/2004	Lof et al.	
2004/0169834	A1	9/2004	Richter et al.	
2004/0169924	A1	9/2004	Flagello et al.	
2004/0180294	A1	9/2004	Baba-Ali et al.	
2004/0180299	A1	9/2004	Rolland et al.	
2004/0207824	A1	10/2004	Lof et al.	
2004/0211920	A1	10/2004	Derkson et al.	
2004/0224265	A1	11/2004	Endo et al.	
2004/0224525	A1	11/2004	Endo et al.	
2004/0227923	A1	11/2004	Flagello et al.	
2004/0233405	A1	11/2004	Kato et al.	
2004/0253547	A1	12/2004	Endo et al.	
2004/0253548	A1	12/2004	Endo et al.	
2004/0257544	A1	12/2004	Vogel et al.	
2004/0259008	A1	12/2004	Endo et al.	
2004/0259040	A1	12/2004	Endo et al.	
2004/0263808	A1	12/2004	Sewell	
2004/0263809	A1	12/2004	Nakano	
2005/0002004	A1	1/2005	Kolesnychenko et al.	
2005/0007569	A1	1/2005	Streefkerk et al.	
2005/0007570	A1	1/2005	Streefkerk et al.	
2005/0018155	A1	1/2005	Cox et al.	
2005/0018156	A1	1/2005	Mulkens et al.	
2005/0024609	A1	2/2005	De Smit et al.	
2005/0030497	A1	2/2005	Nakamura	
2005/0030498	A1	2/2005	Mulkens	
2005/0030506	A1	2/2005	Schuster	
2005/0030511	A1	2/2005	Auer-Jongepier et al.	
2005/0036121	A1	2/2005	Hoogendam et al.	
2005/0036183	A1	2/2005	Yeo et al.	
2005/0036184	A1	2/2005	Yeo et al.	
2005/0036213	A1	2/2005	Mann et al.	
2005/0037269	A1	2/2005	Levinson	
2005/0041225	A1	2/2005	Sengers et al.	
2005/0042554	A1	2/2005	Dierichs et al.	
2005/0046813	A1	3/2005	Streefkerk et al.	
2005/0046934	A1	3/2005	Ho et al.	
2005/0048220	A1	3/2005	Mertens et al.	
2005/0048223	A1	3/2005	Pawloski et al.	
2005/0052632	A1	3/2005	Miyajima	
2005/0068639	A1	3/2005	Pierra et al.	
2005/0073670	A1	4/2005	Carroll	
2005/0074704	A1	4/2005	Endo et al.	
2005/0078286	A1	4/2005	Dierichs et al.	
2005/0078287	A1	4/2005	Sengers et al.	
2005/0084794	A1	4/2005	Meagley et al.	
2005/0088635	A1	4/2005	Hoogendam et al.	
2005/0094114	A1	5/2005	Streefkerk et al.	
2005/0094116	A1	5/2005	Flagello et al.	
2005/0094119	A1	5/2005	Loopstra et al.	
2005/0094125	A1	5/2005	Arai	
2005/0100745	A1	5/2005	Lin et al.	
2005/0106512	A1	5/2005	Endo et al.	
2005/0110973	A1	5/2005	Streefkerk et al.	
2005/0117135	A1	6/2005	Verhoeven et al.	
2005/0117224	A1	6/2005	Shafer et al.	
2005/0122497	A1	6/2005	Lyons et al.	
2005/0122505	A1	6/2005	Miyajima	
2005/0128445	A1	6/2005	Hoogendam et al.	
2005/0132914	A1	6/2005	Mulkens et al.	
2005/0134815	A1	6/2005	Van Santen et al.	
2005/0134817	A1	6/2005	Nakamura	
2005/0136361	A1	6/2005	Endo et al.	
2005/0141098	A1	6/2005	Schuster	
2005/0145265	A1	7/2005	Ravkin et al.	
2005/0145803	A1	7/2005	Hakey et al.	
2005/0146693	A1	7/2005	Ohsaki	
2005/0146694	A1	7/2005	Tokita	
2005/0146695	A1	7/2005	Kawakami	
2005/0147920	A1	7/2005	Lin et al.	
2005/0153424	A1	7/2005	Coon	
2005/0158673	A1	7/2005	Hakey et al.	
2005/0164502	A1	7/2005	Deng et al.	
2005/0174549	A1	8/2005	Duineveld et al.	
2005/0174550	A1	8/2005	Streefkerk et al.	
2005/0175776	A1	8/2005	Streefkerk et al.	
2005/0175940	A1	8/2005	Dierichs	
2005/0179877	A1	8/2005	Mulkens et al.	
2005/0185269	A1	8/2005	Epple et al.	
2005/0190435	A1	9/2005	Shafer et al.	
2005/0190455	A1	9/2005	Rostalski et al.	
2005/0205108	A1	9/2005	Chang et al.	
2005/0213061	A1	9/2005	Hakey et al.	
2005/0213072	A1	9/2005	Schenker et al.	
2005/0217135	A1	10/2005	O'Donnell et al.	
2005/0217137	A1	10/2005	Smith et al.	
2005/0217703	A1	10/2005	O'Donnell	
2005/0219481	A1	10/2005	Cox et al.	
2005/0219482	A1	10/2005	Baselmans et al.	
2005/0219488	A1	10/2005	Nei et al.	
2005/0219499	A1	10/2005	Zaal et al.	
2005/0225737	A1	10/2005	Weissenrieder et al.	
2005/0231694	A1 *	10/2005	Kolesnychenko et al.	355/53
2005/0233081	A1	10/2005	Tokita	
2005/0237501	A1	10/2005	Furukawa et al.	
2005/0237510	A1 *	10/2005	Shibazaki	355/72
2005/0243292	A1	11/2005	Baselmans	
2005/0245005	A1	11/2005	Benson	
2005/0253090	A1	11/2005	Gau et al.	
2005/0259232	A1	11/2005	Streefkerk et al.	
2005/0259233	A1	11/2005	Streefkerk et al.	
2005/0259234	A1	11/2005	Hirukawa et al.	
2005/0259236	A1	11/2005	Straaijer	
2005/0263068	A1	12/2005	Hoogendam et al.	
2005/0264778	A1	12/2005	Lof et al.	
2005/0270505	A1	12/2005	Smith	
2006/0061747	A1 *	3/2006	Ishii	355/53
2006/0082741	A1	4/2006	Van Der Toorn et al.	
2006/0103820	A1	5/2006	Donders et al.	
2006/0114445	A1	6/2006	Ebihara	
2006/0126037	A1	6/2006	Jansen et al.	
2006/0132733	A1	6/2006	Modderman	
2007/0127006	A1	6/2007	Shibazaki	
2007/0211234	A1	9/2007	Ebihara	
2007/0211235	A1	9/2007	Shibazaki	
2007/0247607	A1	10/2007	Shibazaki	
2008/0002163	A1	1/2008	Fujiwara et al.	
2008/0117393	A1	5/2008	Fujiwara et al.	
2009/0109413	A1	4/2009	Shibazaki et al.	
2010/0182584	A1	7/2010	Shibazaki	

FOREIGN PATENT DOCUMENTS

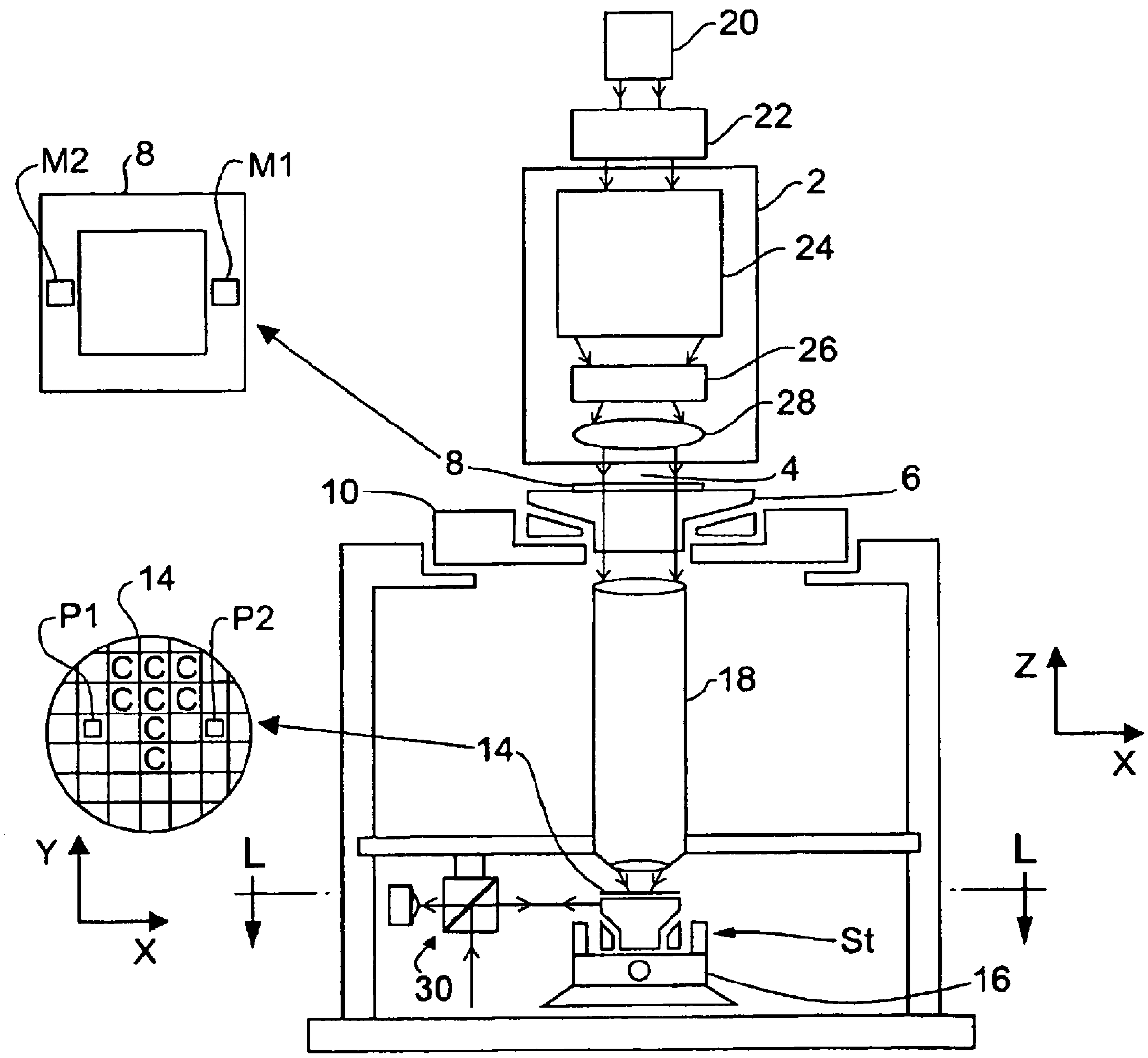
DE	224 448	A1	7/1985
EP	1 041 357	A1	10/2000
EP	1 220 037		7/2002

EP	1 306 592	A2	5/2003
EP	1 420 299	A2	5/2004
EP	1 486 827	A2	12/2004
EP	1 494 267	A1	1/2005
EP	1 486 827	A3	3/2005
EP	A 1 635 382	A1	3/2006
JP	A 57-117238		7/1982
JP	A 57-153433		9/1982
JP	A 58-202448		11/1983
JP	A 59-19912		2/1984
JP	A 62-65326		3/1987
JP	A 63-157419		6/1988
JP	A 4-065603		3/1992
JP	A 4-305915		10/1992
JP	A 4-305917		10/1992
JP	A 5-021314		1/1993
JP	A 5-062877		3/1993
JP	A 6-124873		5/1994
JP	A 7-176468		7/1995
JP	A 7-220990		8/1995
JP	A-7-335748		12/1995
JP	A 8-037149		2/1996
JP	A 8-316125		11/1996
JP	A 10-163099		6/1998
JP	A 10-214783		8/1998
JP	A 10-255319		9/1998
JP	A 10-303114		11/1998
JP	A 10-340846		12/1998
JP	A 11-016816		1/1999
JP	A 11-176727		7/1999
JP	A 2000-58436		2/2000
JP	A 2000-505958		5/2000
JP	A 2000-164504		6/2000
JP	A 2000-511704		9/2000
JP	A 2001-160530		6/2001
JP	A 2001-241439		9/2001
JP	A 2001-267239		9/2001
JP	A 2002-014005		1/2002
JP	A 2002-134390		5/2002
JP	A 2002-305140		10/2002
JP	A 2003-017404		1/2003
JP	A 2003-249443		9/2003
JP	A 2004-165666		6/2004
JP	A 2004-207696		7/2004
JP	A 2004-207711		7/2004
JP	A 2004-289128		10/2004
WO	WO 98/40791		9/1998
WO	WO 99/23692		5/1999
WO	WO 99/49504		9/1999
WO	WO 2002/091078	A1	11/2002
WO	WO 2003/077037	A1	9/2003
WO	WO 03/085708	A1	10/2003
WO	WO 2004/019128	A2	3/2004
WO	WO 2004/053953	A1	6/2004
WO	WO 2004/053955	A1	6/2004
WO	WO 2004/114380	A1	6/2004
WO	WO 2004/055803	A1	7/2004
WO	WO 2004/057589	A1	7/2004
WO	WO 2004/057590	A1	7/2004
WO	WO 2004/077154	A2	9/2004
WO	WO 2004/081666	A1	9/2004
WO	WO 2004/090577	A2	10/2004
WO	WO 2004/090633	A2	10/2004
WO	WO 2004/090634	A2	10/2004
WO	WO 2004/092830	A2	10/2004
WO	WO 2004/092833	A2	10/2004
WO	WO 2004/093130	A2	10/2004
WO	WO 2004/093159	A2	10/2004
WO	WO 2004/093160	A2	10/2004
WO	WO 2004/095135	A2	11/2004
WO	WO2004/105107	*	12/2004
WO	WO 2004/114380		12/2004
WO	WO 2005/001432	A2	1/2005
WO	WO 2005/001572	A2	1/2005
WO	WO 2005/003864	A2	1/2005
WO	WO 2005/006026	A2	1/2005
WO	WO 2005/008339	A2	1/2005
WO	WO 2005/010611	A2	2/2005
WO	WO 2005/013008	A2	2/2005
WO	WO 2005/015283	A1	2/2005
WO	WO 2005/017625	A2	2/2005
WO	WO 2005/019935	A2	3/2005
WO	WO 2005/022266	A2	3/2005
WO	WO 2005/024325	A2	3/2005
WO	WO 2005/024517	A2	3/2005
WO	WO 2005/034174	A2	4/2005
WO	WO 2005/048328	A1	5/2005
WO	WO 2005/050324	A2	6/2005
WO	WO 2005/054953	A2	6/2005
WO	WO 2005/054955	A2	6/2005
WO	WO 2005/059617	A2	6/2005
WO	WO 2005/059618	A2	6/2005
WO	WO 2005/059645	A2	6/2005
WO	WO 2005/059654	A1	6/2005
WO	WO 2005/062128	A2	7/2005
WO	WO 2005/062351	A1	7/2005
WO	WO 2005/064400	A2	7/2005
WO	WO 2005/064405	A2	7/2005
WO	WO 2005/069055	A2	7/2005
WO	WO 2005/069078	A1	7/2005
WO	WO 2005/069081	A2	7/2005
WO	WO 2005/071491	A2	8/2005
WO	WO 2005/074606	A2	8/2005
WO	WO 2005/076084	A1	8/2005
WO	WO 2005/081030	A1	9/2005
WO	WO 2005/081067	A1	9/2005
WO	WO 2005/098504	A1	10/2005
WO	WO 2005/098505	A1	10/2005
WO	WO 2005/098506	A1	10/2005
WO	WO 2005/106589	A1	11/2005
WO	WO 2005/111689	A2	11/2005
WO	WO 2005/111722	A2	11/2005
WO	WO 2005/119368	A2	12/2005
WO	WO 2005/119369	A1	12/2005

OTHER PUBLICATIONS

Preliminary Amendment filed on Jan. 8, 2008 in U.S. Appl. No. 11/812,919 of Shibazaki.
Information Disclosure Statement Letter filed on Jan. 9, 2008 in U.S. Appl. No. 12/007,348 of Fujiwara et al.
Lin, B.J., "Semiconductor Foundry, Lithography, and Partners", Proceedings of SPIE, vol. 4688, pp. 11-24, 2002.
Switkes, M., et al., "Resolution Enhancement of 157nm Lithography by Liquid Immersion", Proceedings of SPIE, vol. 4691, pp. 459-465, 2002.
Switkes, M., et al., "Resolution Enhancement of 157nm Lithography by Liquid Immersion", J. Microlith., Microfab., Microsyst., vol. 1, No. 3, pp. 225-228 (2002).
Owa, Soichi, et al., "Nikon F2 Exposure Tool", slides 1-25, 3rd 157nm Symposium, Sep. 4, 2002.
Owa, Soichi, et al., "Immersion Lithography; its Potential Performance and Issues", Proceedings of SPIE, vol. 5040, pp. 724-733, 2003.
Owa, Soichi, et al., "Potential Performance and Feasibility of Immersion Lithography", slides 1-33, NGL Workshop 2003, Jul. 2003.
Owa, Soichi, et al., "Update on 193nm Immersion Exposure Tool", slides 1-38, Immersion Workshop 2004, Jan. 27, 2004.
Owa, Soichi, et al., "Update on 193nm Immersion Exposure Tool", slides 1-51, Litho Forum, Jan. 28, 2004.
Chinese Office Action dated Aug. 31, 2011 in corresponding Chinese Patent Application No. 201110039515.9.
Office Action dated Sep. 9, 2009 in U.S. Appl. No. 11/812,919.
Office Action dated Apr. 23, 2010 in U.S. Appl. No. 11/812,919.
Office Action dated Mar. 1, 2011 in U.S. Appl. No. 11/812,919.
Office Action dated Sep. 1, 2011 in U.S. Appl. No. 11/812,919.
Office Action dated Dec. 3, 2008 in U.S. Appl. No. 11/785,716.
Office Action dated Nov. 10, 2011 in U.S. Appl. No. 12/007,348.
Office Action dated Apr. 14, 2011 in U.S. Appl. No. 12/007,348.
Office Action dated Aug. 20, 2010 in U.S. Appl. No. 12/007,348.
Office Action dated Nov. 18, 2009 in U.S. Appl. No. 12/007,348.
Office Action dated Jan. 6, 2009 in U.S. Appl. No. 12/007,348.

* cited by examiner



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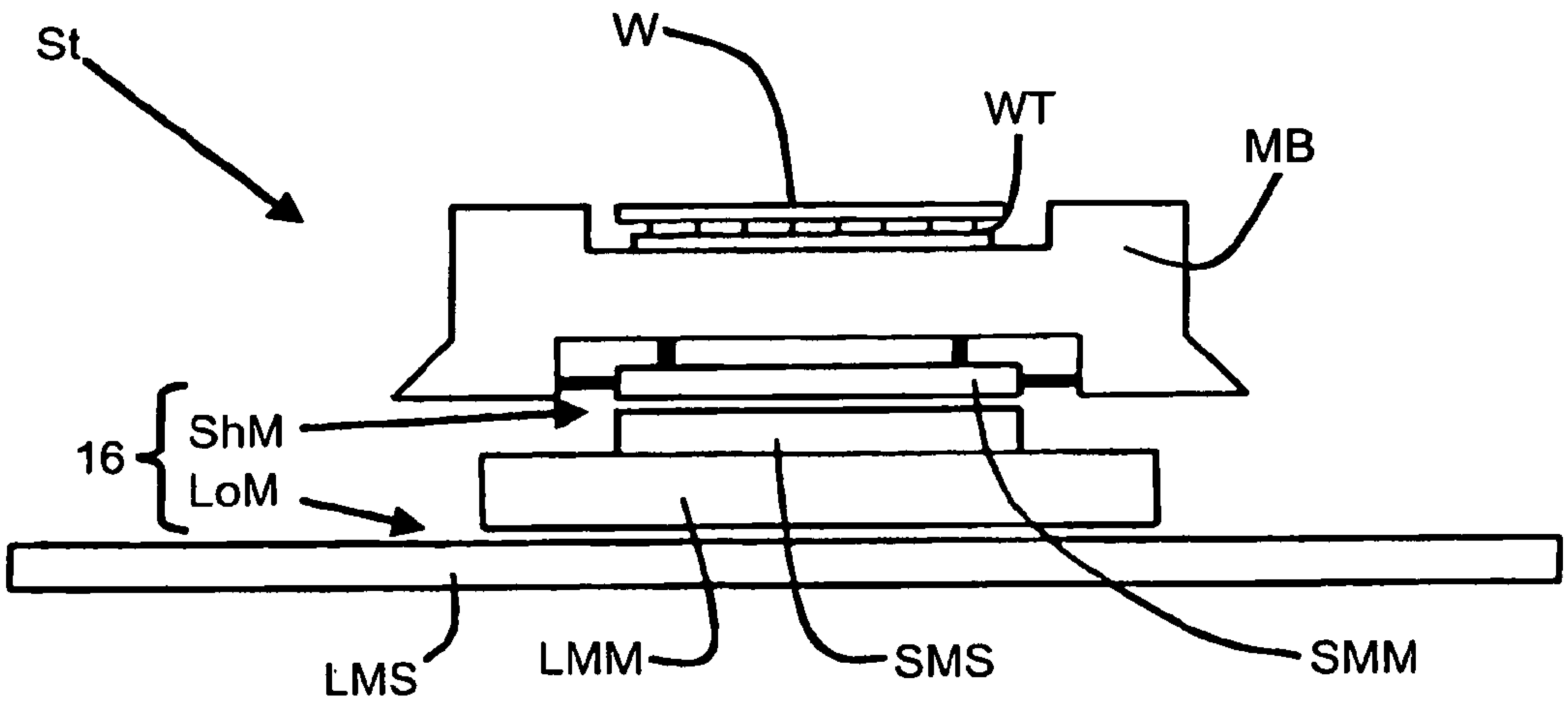

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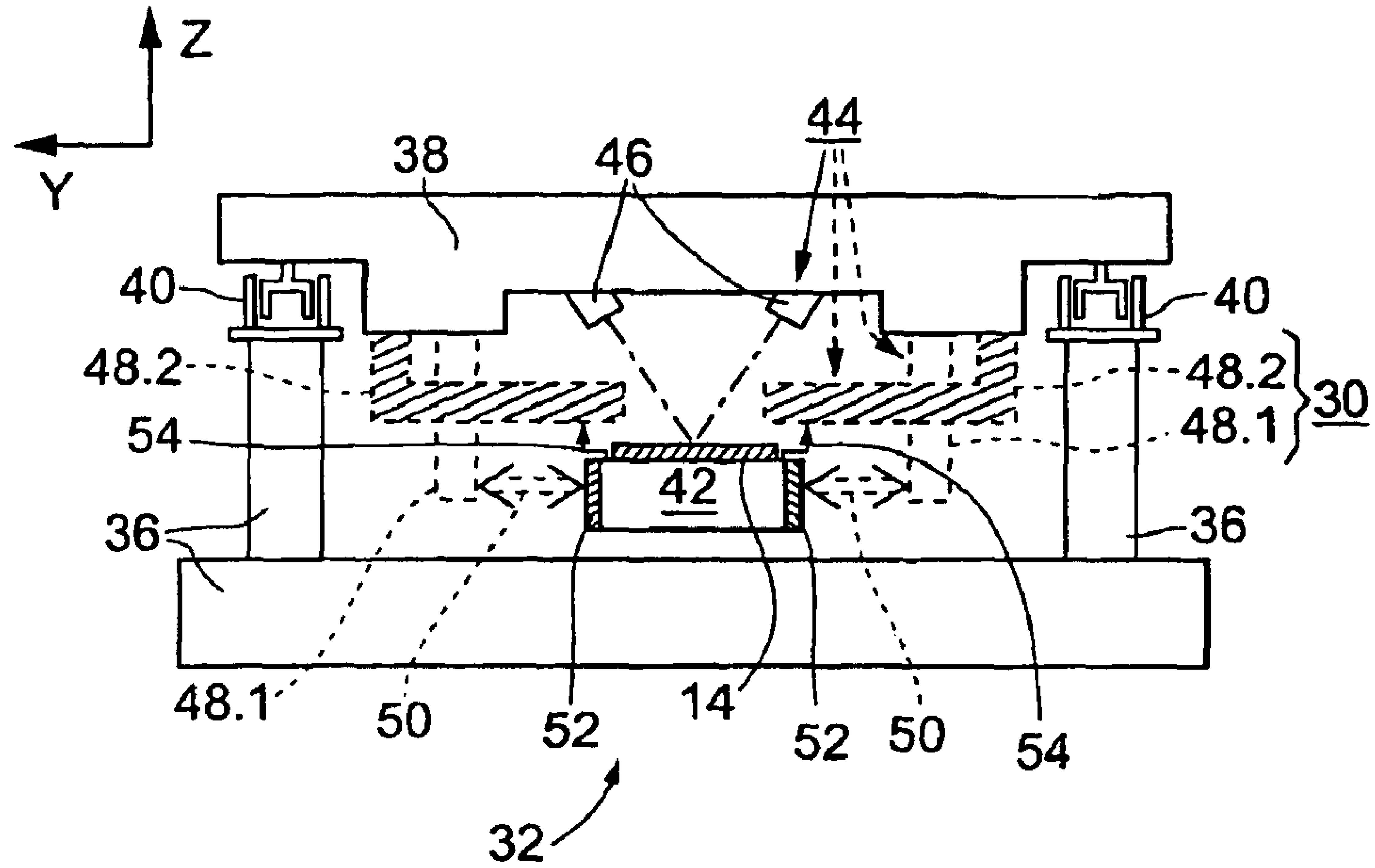
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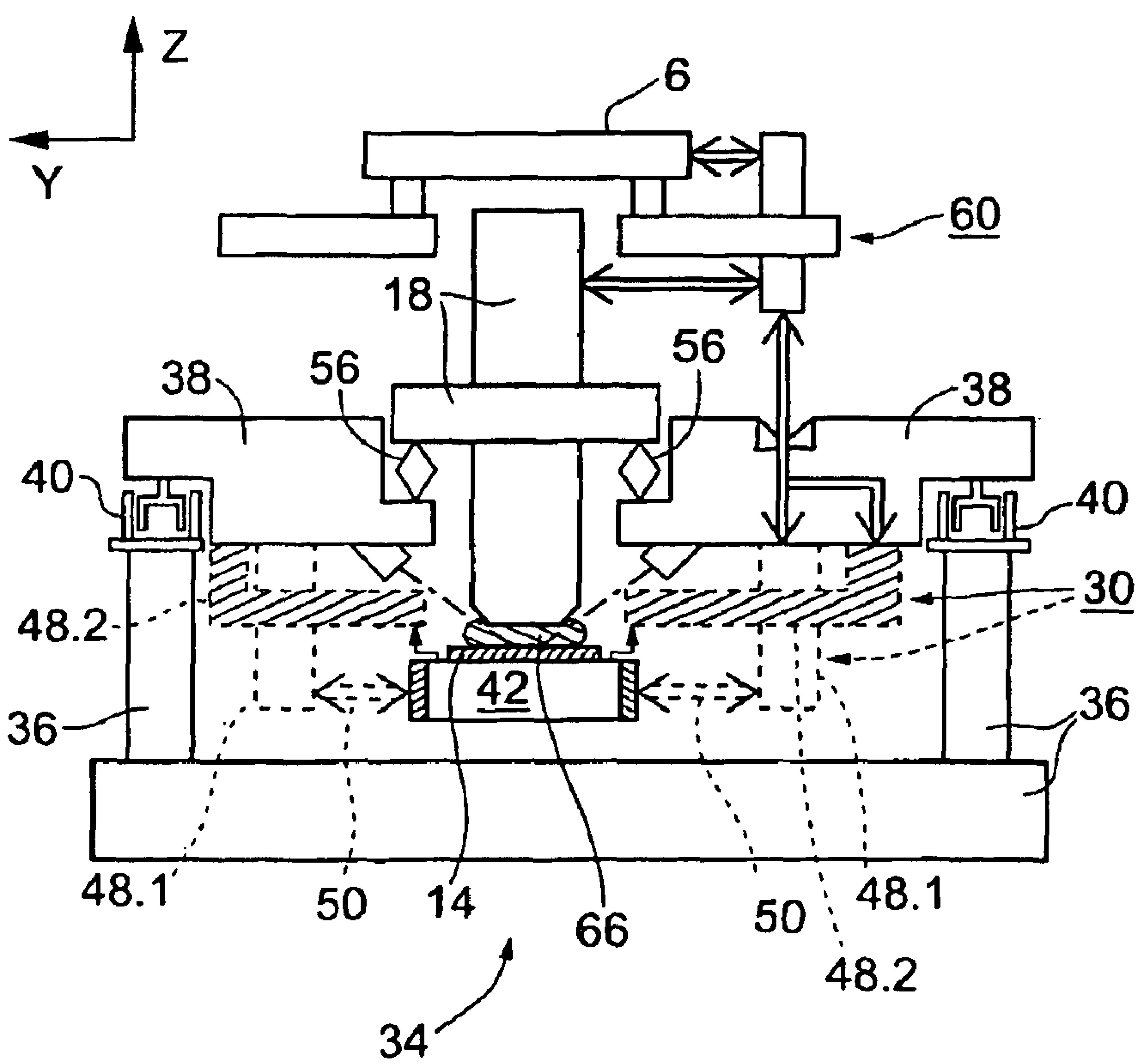
Fig. 2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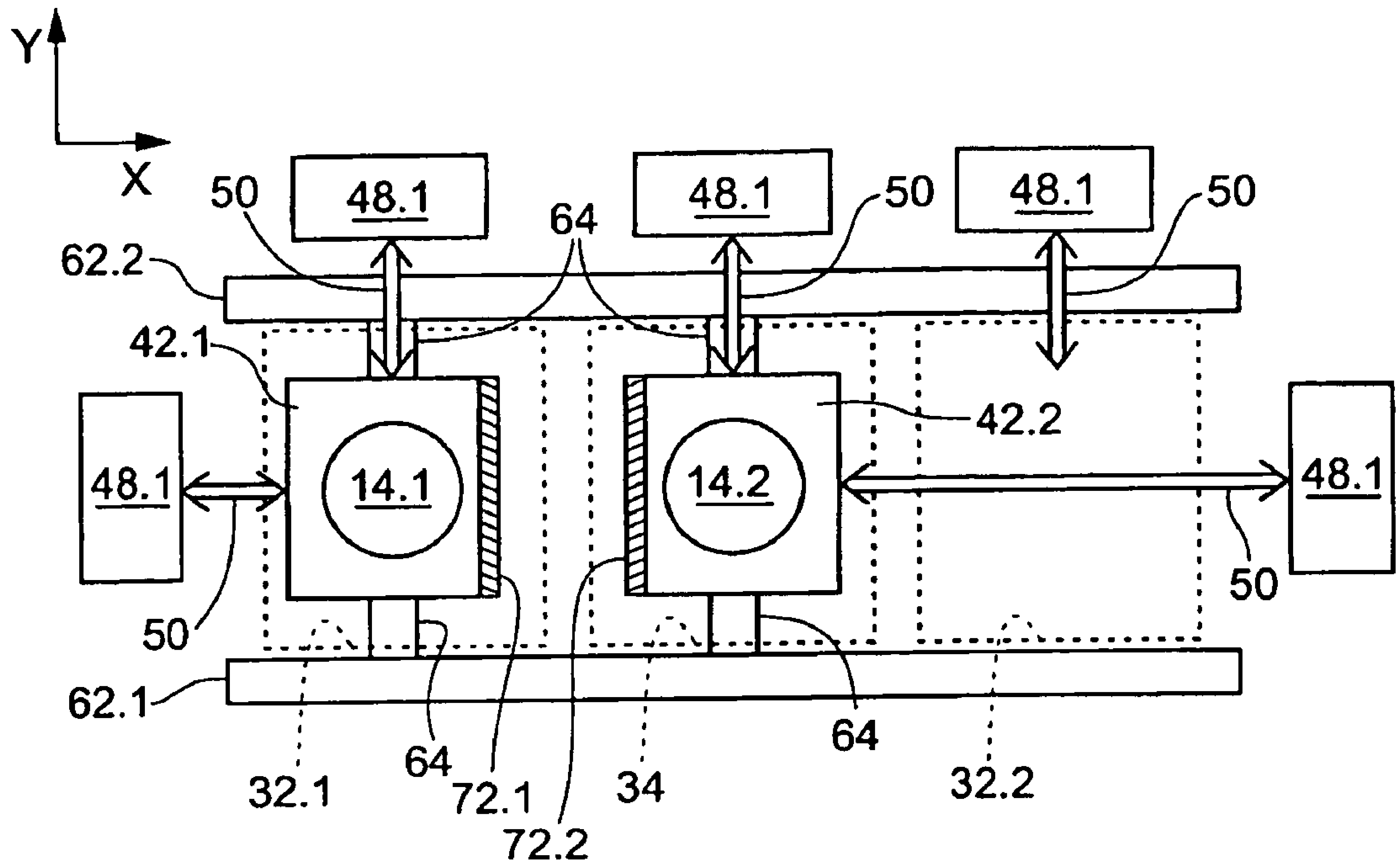

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Fig. 4

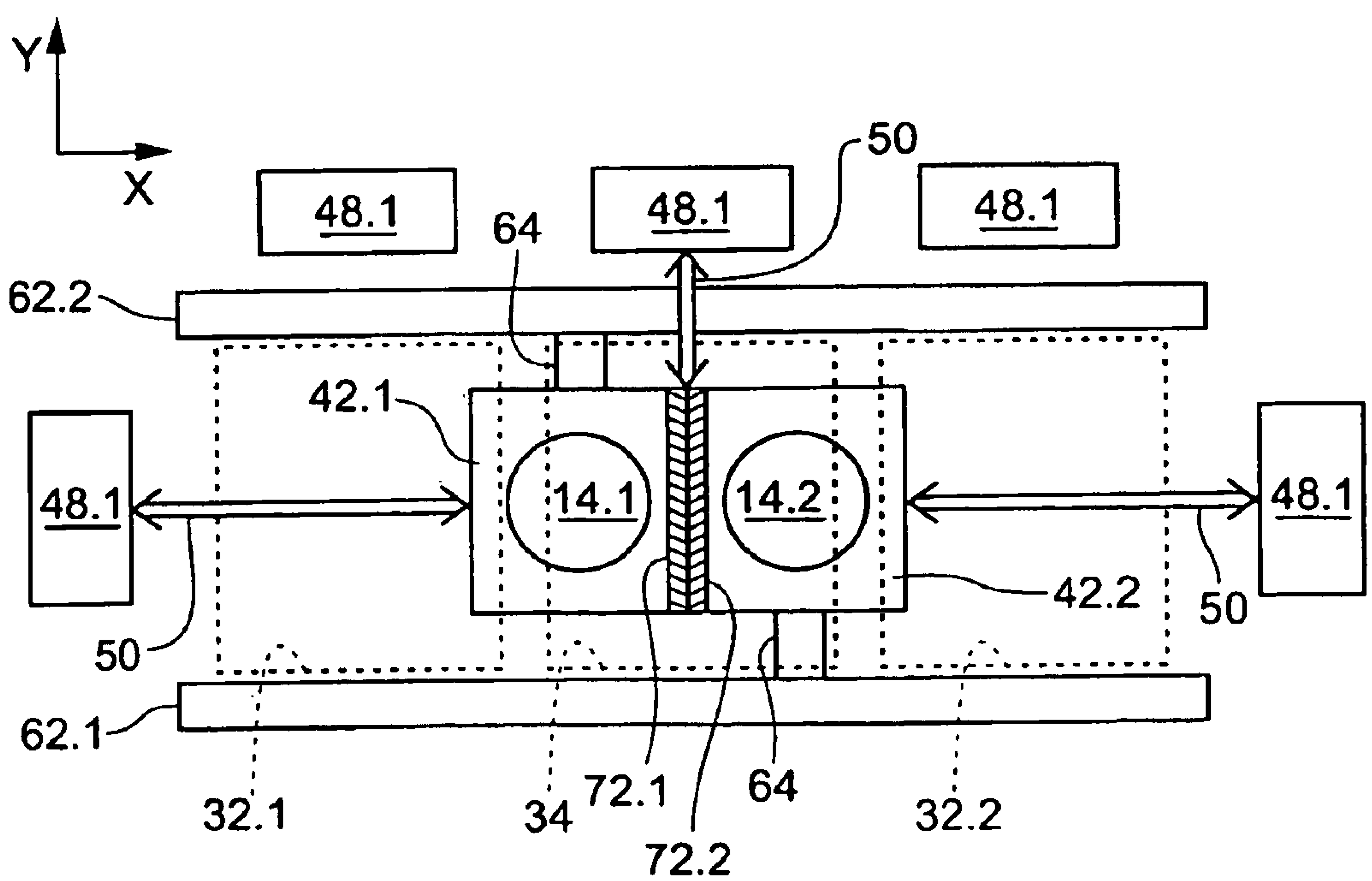

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Fig. 5

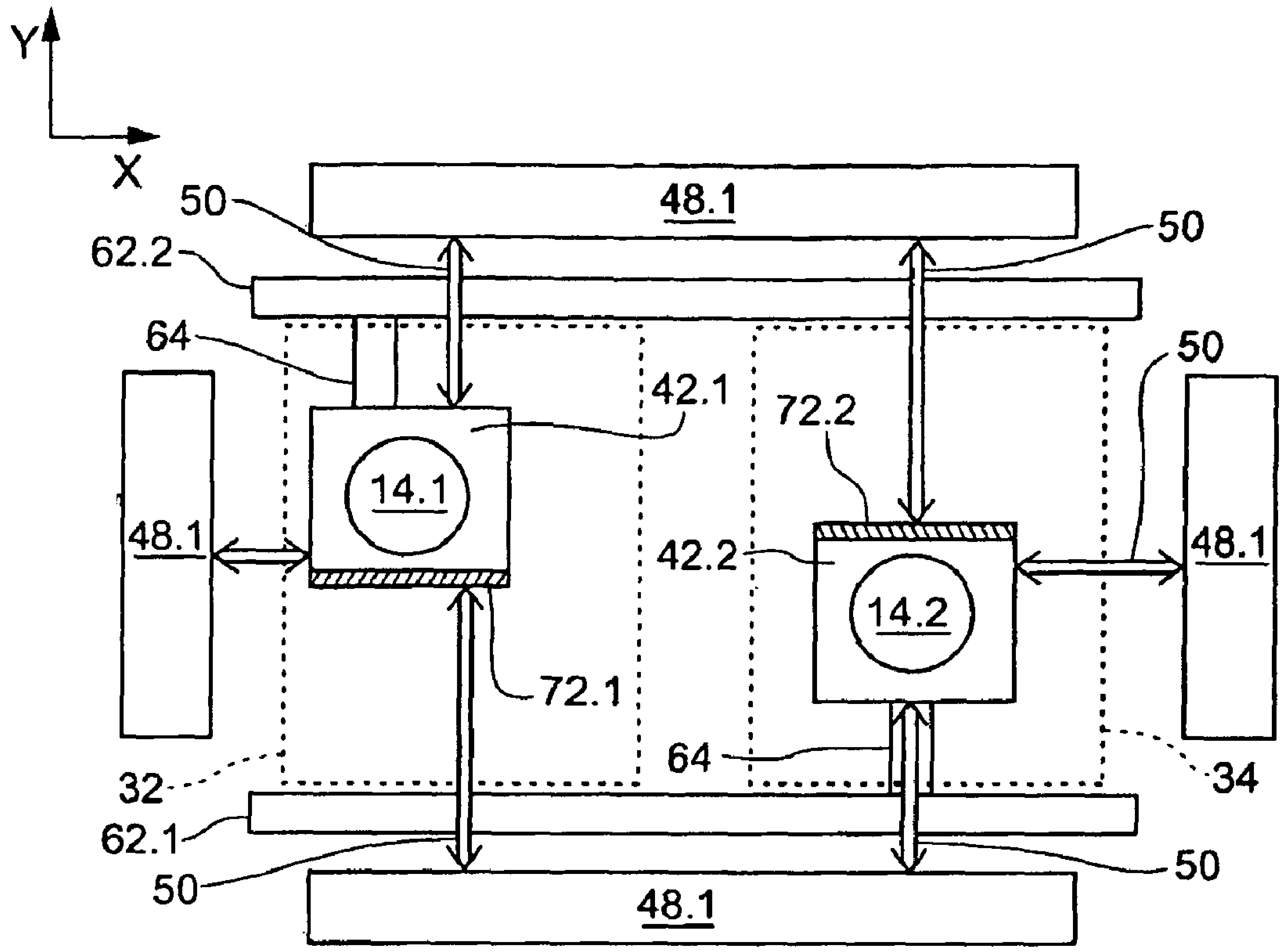
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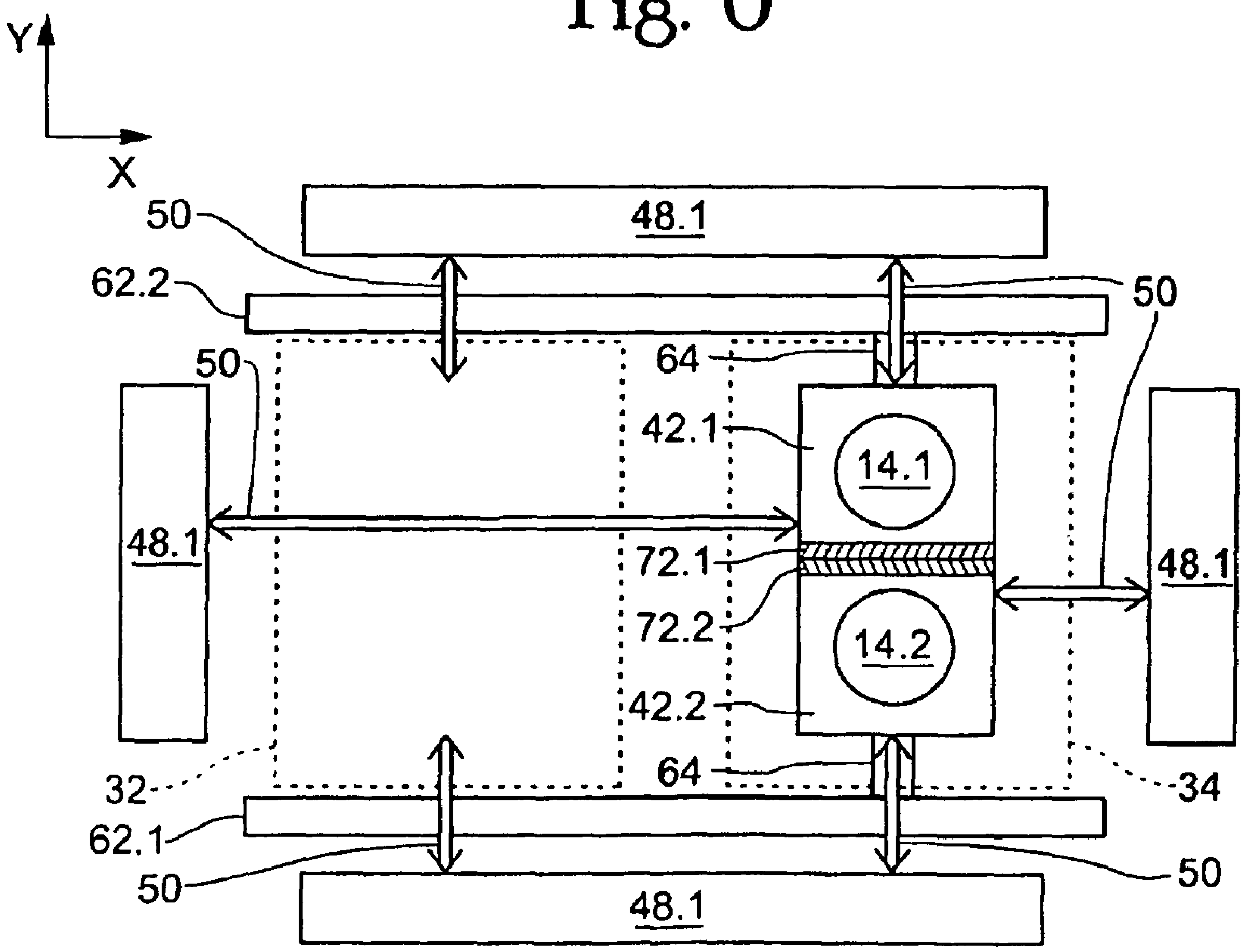
Fig. 6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48.1

Fig. 7

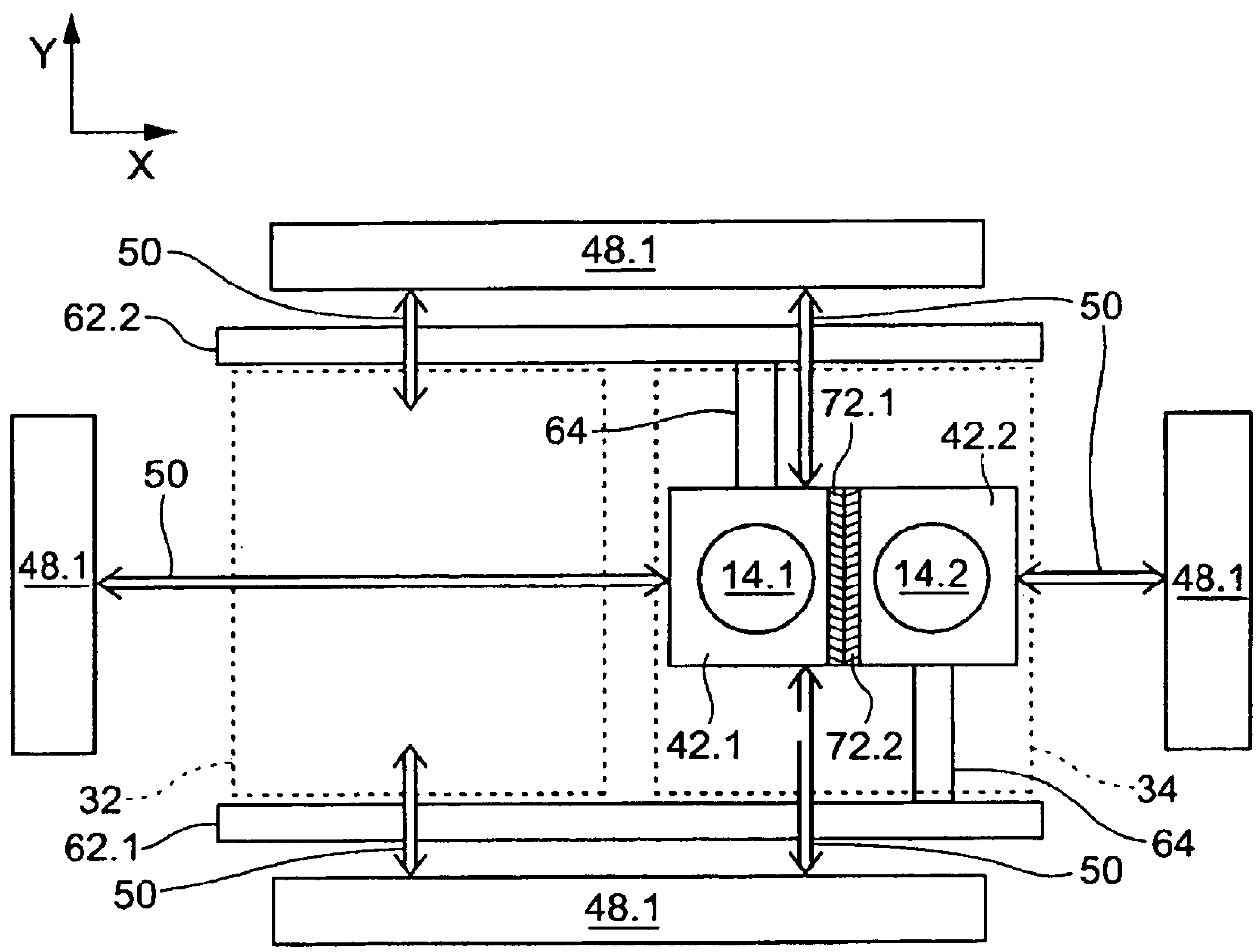
Y
X
48.1
50
62.2
50
64
72.1
42.2
50
48.1
14.1
14.2
48.1
42.1
72.2
32
34
62.1
64
50
50
48.1

Fig. 8

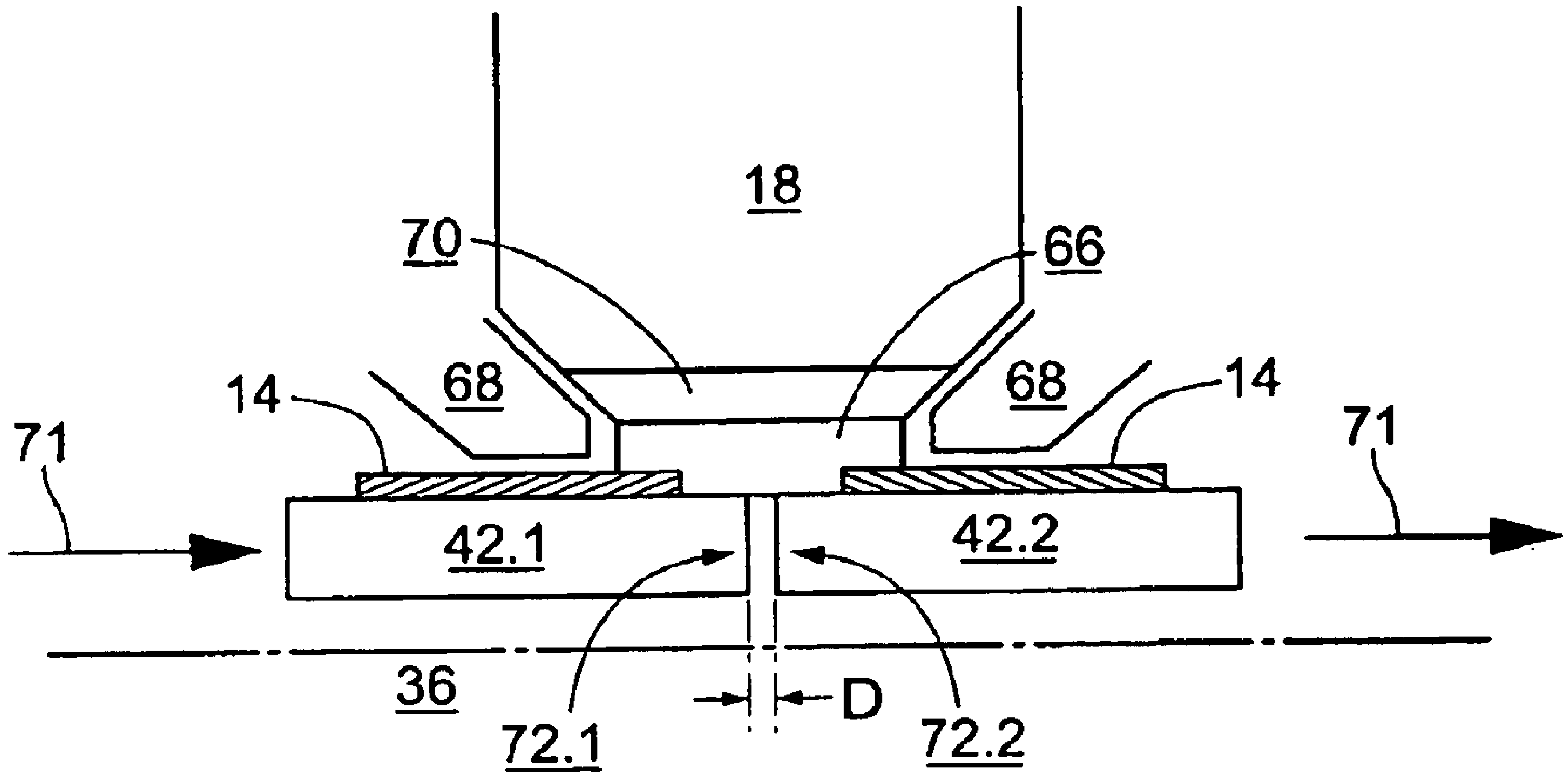
18
70
66
68
68
14
14
71
71
42.1
42.2
36
D
72.1
72.2

Fig. 9

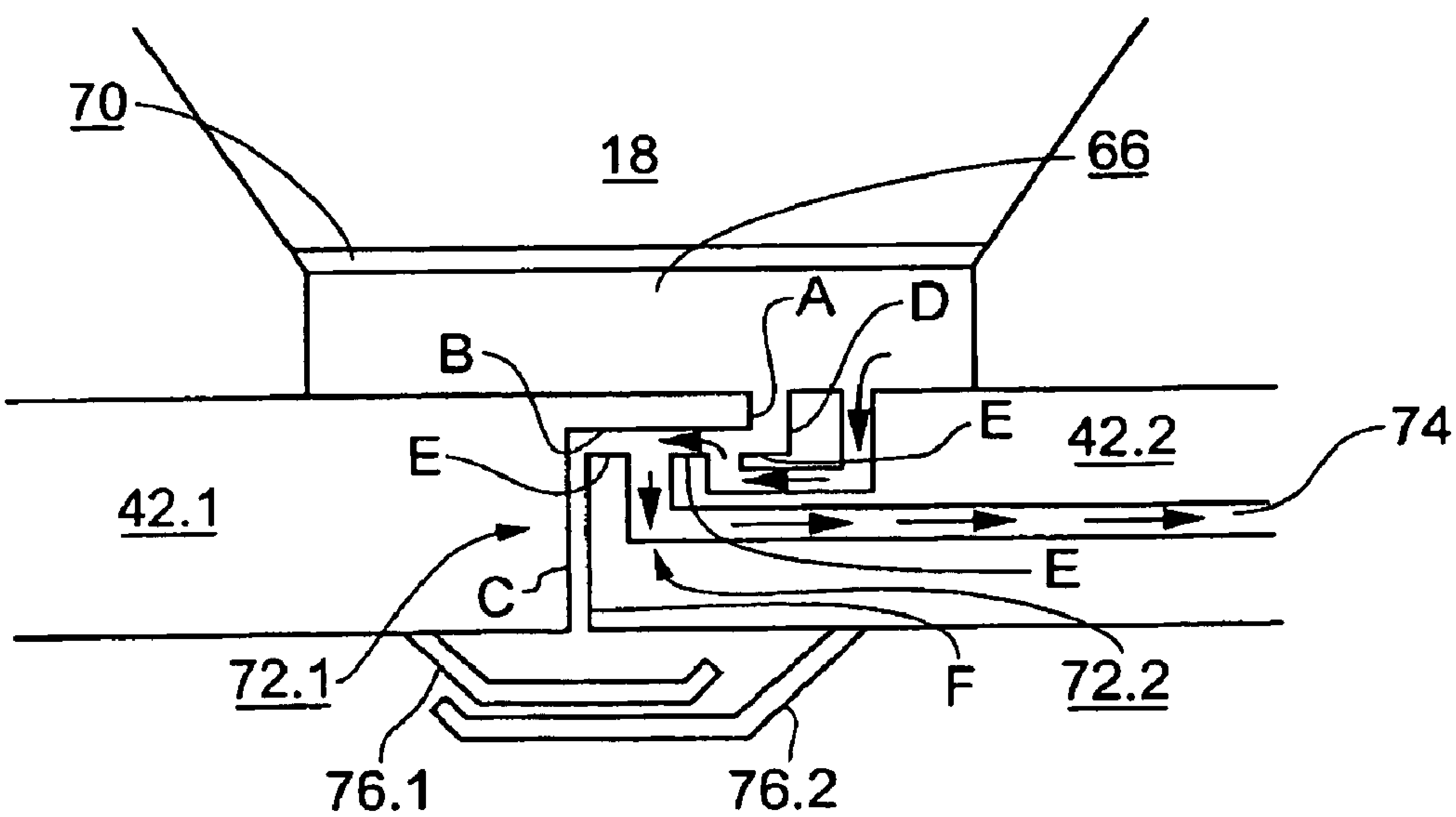
70
18
66
A
D
B
E
E
42.2
74
42.1
E
C
72.1
F
72.2
76.1
76.2

Fig. 10

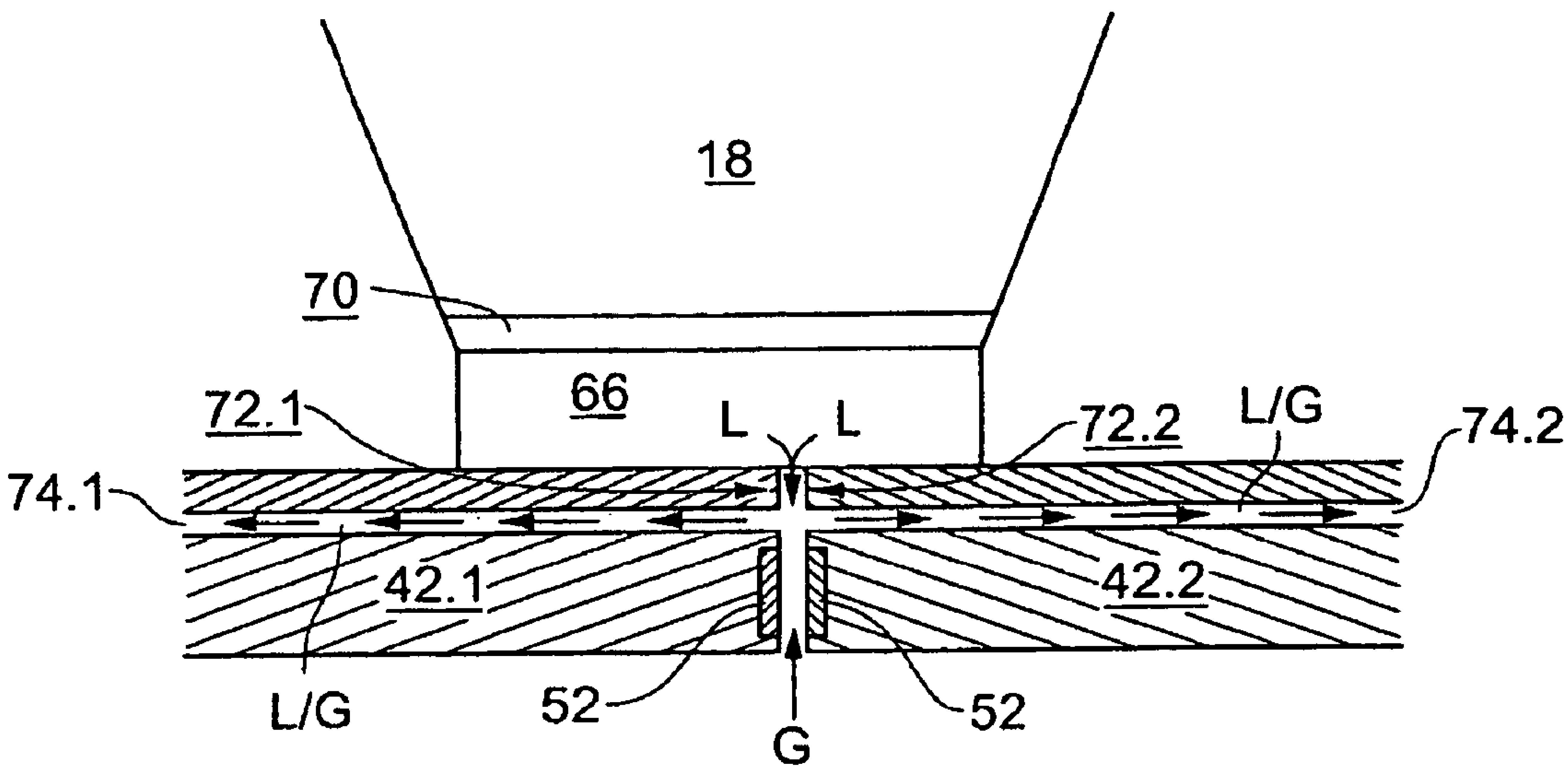
18
70
66
72.1
L
L
72.2
L/G
74.2
74.1
42.1
42.2
L/G
52
G
52

Fig. 11

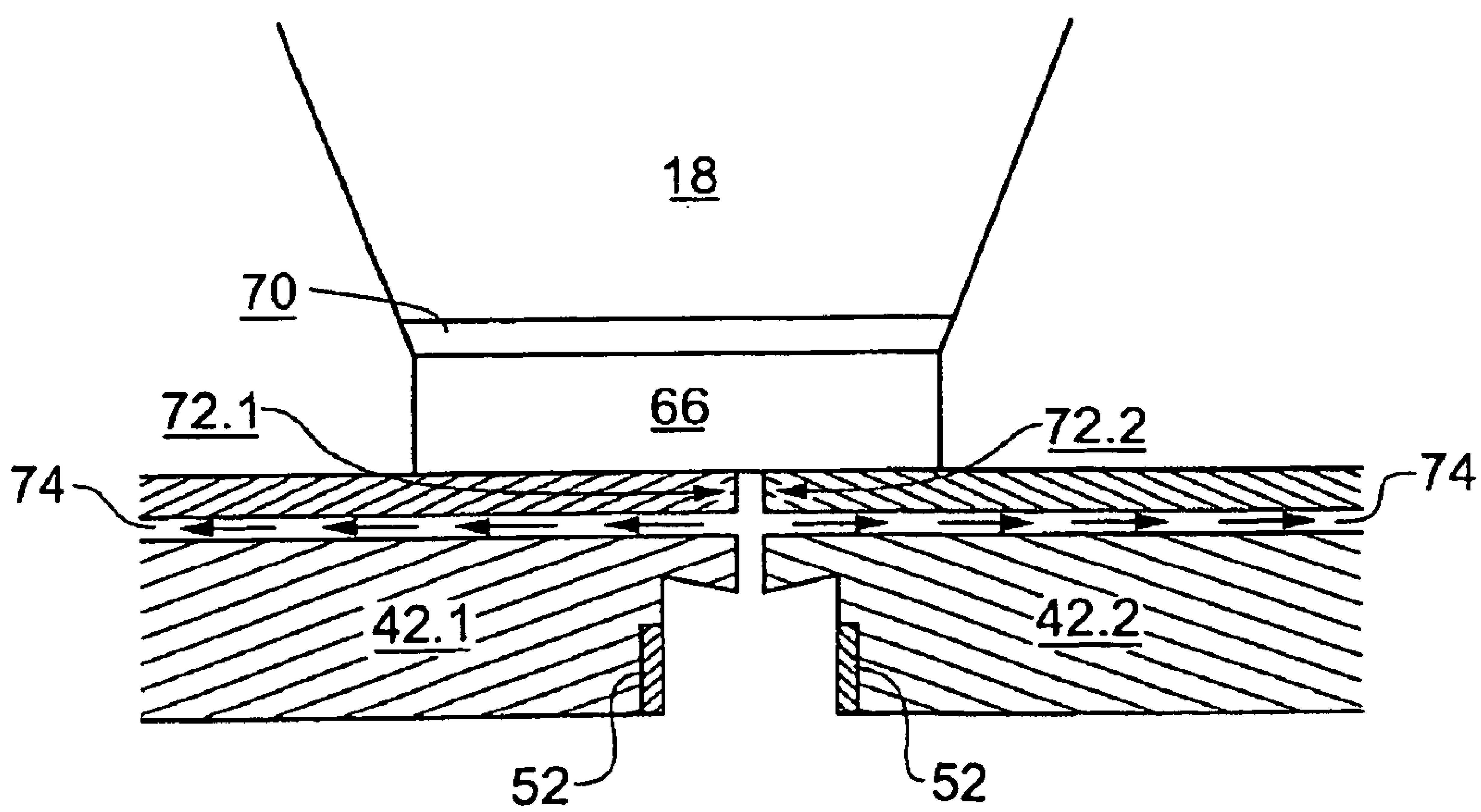
18
70
66
72.1
72.2
74
74
42.1
42.2
52
52

Fig. 12

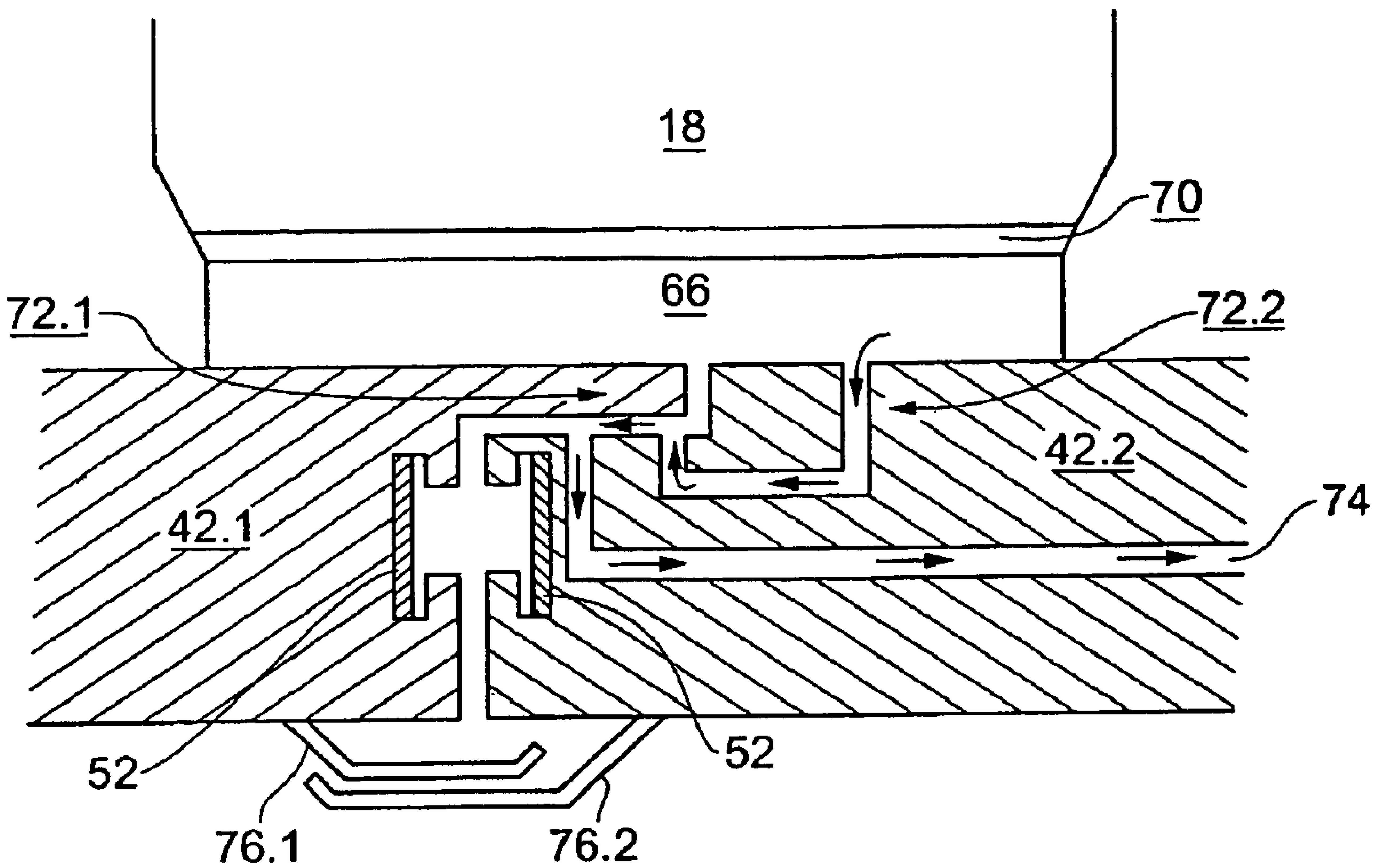
18
70
66
72.1
72.2
42.2
42.1
74
52
52
76.1
76.2

Fig. 13

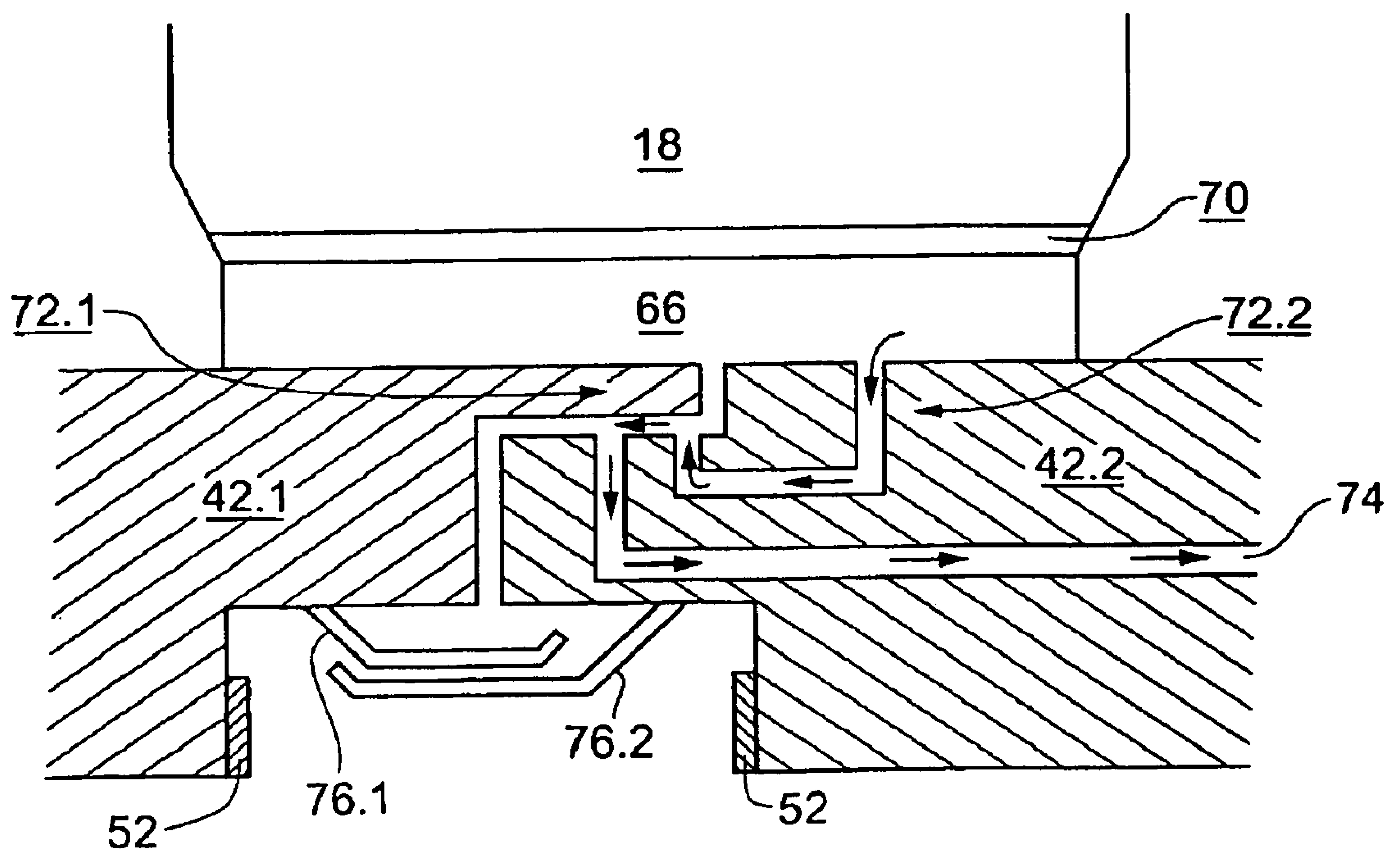
18
70
66
72.1
72.2
42.2
42.1
74
76.2
76.1
52
52

Fig. 14

DUAL STAGE LITHOGRAPHIC APPARATUS AND DEVICE MANUFACTURING METHOD

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

RELATED APPLICATION

The present application is a Continuation In Part Application of U.S. application Ser. No. 11/101,631, filed on Apr. 8, 2005 now abandoned.

FIELD

The present invention relates to a multi stage lithographic apparatus and a method for manufacturing a device with the multi stage lithographic apparatus.

BACKGROUND

A lithographic apparatus is a machine that applies a desired pattern onto a substrate, usually onto a target portion of the substrate. A lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In that instance, a patterning device, which is alternatively referred to as a mask or a reticle, may be used to generate a circuit pattern to be formed on an individual layer of the IC. This pattern can be transferred onto a target portion (e.g. comprising part of, one, or several dies) on a substrate (e.g. a silicon wafer). Transfer of the pattern is typically via imaging onto a layer of radiation-sensitive material (resist) provided on the substrate. In general, a single substrate will contain a network of adjacent target portions that are successively patterned. Known lithographic apparatus include so-called steppers, in which each target portion is irradiated by exposing an entire pattern onto the target portion at one time, and so-called scanners, in which each target portion is irradiated by scanning the pattern through a radiation beam in a given direction (the "scanning"-direction) while synchronously scanning the substrate parallel or anti-parallel to this direction. It is also possible to transfer the pattern from the patterning device to the substrate by imprinting the pattern onto the substrate.

There is an ongoing development in improving current lithographic apparatus. An aspect herewith is to increase the throughput (throughput is related to the number of substrates that can be processed in a certain time by a lithographic apparatus). For example, Dual Stage Lithographic apparatus generally have a larger throughput than Single stage apparatus since a substrate on a first substrate stage may be measured in a metrology station while another substrate on a second substrate stage is exposed in an exposure station on the basis of data measured previously in the metrology station. Another aspect is to improve the capability of lithographic apparatus to transfer patterns with smaller structures (but with a given quality) on substrates. For example, an Immersion lithographic apparatus is capable of transferring patterns with smaller structures in comparison with non-immersion lithographic apparatus (see for example EP 1486827, incorporated herein by reference).

In U.S. Pat. No. 5,969,441 (incorporated herein by reference) a Dual Stage lithographic apparatus is described that is provided with "H-drives" (see for example FIGS. **4**, **5**: respective X-actuators **105** and **107** connected to respective sets of opposite Y-actuators **109**, **111** and **113**, **115**) for its substrate

stages (substrate holders **11**, **13**). The described Dual Stage yields a relatively high throughput but a disadvantage is that the substrate stages need a "stage-swap" (according to the transition between FIG. **4** and FIG. **5** wherein substrate holder **11** is uncoupled from unit **25** and coupled to unit **27** and wherein substrate holder **13** is uncoupled from unit **27** and coupled to unit **25**) for passing each other while moving between the metrology station and the exposure station (column 16, lines 47–52). The apparatus has the disadvantage that the stage-swap takes time, thus yielding a decreased throughput.

In U.S. Pat. No. 6,341,007 (incorporated herein by reference) (see in particular FIGS. **2**, **3**, **4**) a Dual Stage lithographic apparatus is described that is provided with one exposure station situated between two metrology stations. The substrates in the batch are measured alternately in the metrology stations before exposure in the exposure station. The stages can not pass each other while moving between the metrology stations and the exposure station (see FIG. **3**). A disadvantage of this lithographic apparatus is that it requires two metrology stations. Therefore, there is a necessity of providing a double substrate conveying path. The extra metrology station and the extra conveying path yield an expensive lithographic apparatus. Furthermore, the system layout takes relatively much (floor)-space in the facrories (large footprint). A further disadvantage is that this concept yields problems of a logistics nature. Furthermore, the lithographic apparatus is not suitable for immersion lithographic applications such that it is not capable to project relatively small structures on the substrates.

SUMMARY

It is desirable to at least partially alleviate one of the mentioned disadvantages. In particular it is an aspect of the invention to provide a lithographic apparatus with a relatively high throughput and the capability of transferring patterns with relatively small structures on substrates.

In order to meet the desire the invention proposes a lithographic apparatus comprising:

a support constructed to support a patterning device, the patterning device being capable of imparting a radiation beam with a pattern in its cross-section to form a patterned radiation beam;

a measuring system for measuring characteristics of substrates in a metrology station of the apparatus;

a projection system configured to project the patterned radiation beam onto a substrate in an exposure station of the apparatus;

a liquid confinement system for confining liquid between a final element of the projection system and the substrate;

a positioning system and at least two substrate stages constructed to hold substrates, wherein the positioning system is constructed for moving the stages between the metrology station and the exposure station, and wherein the positioning system is constructed for positioning one of the stages holding a substrate during exposure in the exposure station on the basis of at least one measured characteristic of that substrate;

wherein the stages are constructed and arranged for mutual cooperation in order to perform a joint scan movement for bringing the lithographic apparatus from a first situation, wherein the said liquid is confined between a first substrate held by the first stage of the said stages and the final element, towards a second situation, wherein the said liquid is confined between a second substrate held by the second stage of the two stages and the final element, such that during the joint scan movement the liquid is essentially confined within said space with respect to the final element. The joint scan movement yields an increased throughput compared to conventional immersion lithographic apparatus wherein a separate closing disc is used for confining the liquid between the transfer from the said first situation and the said second situation.

In order to meet the desire the invention proposes a lithographic apparatus comprising:

a support constructed to support a patterning device, the patterning device being capable of imparting a radiation beam with a pattern in its cross-section to form a patterned radiation beam;

a measuring system for measuring characteristics of substrates in a metrology station of the apparatus;

a projection system configured to project the patterned radiation beam onto a substrate in an exposure station of the apparatus;

a positioning system for positioning at least two substrate stages of the lithographic apparatus, wherein the stages are constructed to hold substrates;

a machine frame which is provided with a first part of a planar motor for cooperating with respective second parts of the planar motor in the respective stages, wherein the positioning system is constructed and arranged to control the planar motor for moving the stages between the metrology station and the exposure station and for moving each of the said stages in the exposure station in six degrees of freedom on the basis of at least one measured characteristic of the substrate on the stage, wherein the machine frame is constructed and arranged to allow the stages to pass each other while moving between the metrology station and the exposure station. Since the stages can pass each other there is no need for a "stage-swap". In this way an apparatus is provided with a relatively high throughput while having only one metrology station and only one exposure station, and wherein the apparatus has a relatively small "footprint".

In order to meet the desire the invention proposes a lithographic apparatus comprising:

a support constructed to support a patterning device, the patterning device being capable of imparting a radiation beam with a pattern in its cross-section to form a patterned radiation beam;

a measuring system for measuring characteristics of substrates in a metrology station of the apparatus;

a projection system configured to project the patterned radiation beam onto a substrate in an exposure station of the apparatus;

a positioning system and at least two stages constructed to hold substrates, wherein the positioning system is constructed for moving the stages between the metrology station and the exposure station, and wherein the positioning system is constructed for positioning one of the stages holding a substrate during exposure in the exposure station on the basis of at least one measured characteristic of that substrate,

a machine frame having two essentially parallel guides extending in a first direction in a horizontal plane, wherein each guide is coupled to an element which can be moved along the guide by means of a motor, and wherein each element is coupled to a stage by means of a motor for moving the stage in a second direction directed in the horizontal plane and perpendicular to the first direction, wherein the positioning system is constructed and arranged for controlling the motors in order to move the stages in the plane, wherein the machine frame is constructed and arranged to allow the stages to pass each other while moving between the metrology station and the exposure station. Since the stages can pass each other there is no need for a "stage-swap". In this way an apparatus is provided with a relatively high throughput while having only one metrology station and only one exposure station, and wherein the apparatus has a relatively small "footprint".

In order to meet the desire the invention proposes a lithographic apparatus comprising:

a support constructed to support a patterning device, the patterning device being capable of imparting a radiation beam with a pattern in its cross-section to form a patterned radiation beam;

a measuring system for measuring characteristics of substrates in a metrology station of the apparatus;

a projection system configured to project the patterned radiation beam onto a substrate in an exposure station of the apparatus;

a positioning system and at least two stages constructed to hold substrates, wherein the positioning system is constructed for moving the stages between the metrology station and the exposure station, and wherein the positioning system is constructed for positioning one of the stages holding a substrate during exposure in the exposure station on the basis of at least one measured characteristic of that substrate;

a base frame carrying a metro frame which supports the measuring system and the projection system, wherein the metro frame is dynamically isolated from the base frame, and wherein the measuring system comprises an encoder system extending in both the metrology station and the exposure station for measuring the position of the stages. The said encoder system for example reduces the need of frequent TIS alignments (aligning masks/reticles on the one hand with substrates on the other hand via Transmission Image Sensors such as described in EP 1510870, incorporated herein by reference, see in particular FIGS. **8**A, **8**B). The reduction of the necessity of frequent TIS-alignments increases throughput of the lithographic apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

FIG. **1**A schematically depicts a lithographic apparatus according to an embodiment of the invention in a side-view;

FIG. **1**B shows a stage of the lithographic apparatus according to FIG. **1**A;

FIG. **2** is a schematic side-view of a metrology station of the lithographic apparatus according to the invention;

FIG. **3** is a schematic side-view of an exposure station of the lithographic apparatus according to the invention;

FIG. **4** is a schematic top-view of a first embodiment of the drive and stage configuration of the dual stage immersion lithography apparatus according to FIG. **1**A;

FIG. **5** is a schematic top-view of the apparatus of FIG. **4** showing a joint scan movement;

FIG. **6** is a schematic top-view of a second embodiment of the drive and stage configuration of the dual stage immersion lithography apparatus according to FIG. **1**A;

FIG. **7** is a schematic top-view of the apparatus of FIG. **6** showing a joint scan movement;

FIG. **8** is a schematic top-view of a third embodiment of the drive and stage configuration of the dual stage immersion lithography apparatus according to FIG. **1**A, wherein the lithographic apparatus performs a joint scan movement;

FIG. **9** is a schematic side-view showing two substrate stages in a vertical cross section, wherein the stages perform a joint scan movement;

FIG. **10** is a schematic vertical cross section of a first embodiment of the stages in FIG. **9**;

FIG. **11** is a schematic vertical cross section of a second embodiment of the stages in FIG. **9**;

FIG. **12** is a schematic vertical cross section of a third embodiment of the stages in FIG. **9**;

FIG. **13** is a schematic vertical cross section of a fourth embodiment of the stages in FIG. **9**;

FIG. **14** is a schematic vertical cross section of a fifth embodiment of the stages in FIG. **9**.

DETAILED DESCRIPTION

FIG. **1**A schematically depicts a lithographic apparatus according to one embodiment of the invention. The apparatus comprises:

an illumination system (illuminator) **2** configured to condition a radiation beam **4** (e.g. UV radiation).

a support structure (e.g. a mask table) **6** constructed to support a patterning device (e.g. a mask) **8** and coupled to a first positioner **10** configured to accurately position the patterning device in accordance with certain parameters;

a substrate table (e.g. a wafer table) WT constructed to hold a substrate (e.g. a resist-coated wafer) **14** and coupled (via a mirror block MB) to a second positioner **16** configured to accurately position the substrate in accordance with certain parameters; and

a projection system (e.g. a refractive projection lens system) **18** configured to project a pattern imparted to the radiation beam **4** by patterning device **8** onto a target portion C (e.g. comprising one or more dies) of the substrate **14**.

The illumination system may include various types of optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, for directing, shaping, or controlling radiation.

The support structure supports, i.e. bears the weight of, the patterning device. It holds the patterning device in a manner that depends on the orientation of the patterning device, the design of the lithographic apparatus, and other conditions, such as for example whether or not the patterning device is held in a vacuum environment. The support structure can use mechanical, vacuum, electrostatic or other clamping techniques to hold the patterning device. The support structure may be a frame or a table, for example, which may be fixed or movable as required. The support structure may ensure that the patterning device is at a desired position, for example with respect to the projection system. Any use of the terms "reticle" or "mask" herein may be considered synonymous with the more general term "patterning device."

The term "patterning device" used herein should be broadly interpreted as referring to any device that can be used to impart a radiation beam with a pattern in its cross-section such as to create a pattern in a target portion of the substrate. It should be noted that the pattern imparted to the radiation beam may not exactly correspond to the desired pattern in the target portion of the substrate, for example if the pattern includes phase-shifting features or so called assist features. Generally, the pattern imparted to the radiation beam will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit.

The patterning device may be transmissive or reflective. Examples of patterning devices include masks, programmable mirror arrays, and programmable LCD panels. Masks are well known in lithography, and include mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. An example of a programmable mirror array employs a matrix arrangement of small mirrors, each of which can be individually tilted so as to reflect an incoming radiation beam in different directions. The tilted mirrors impart a pattern in a radiation beam which is reflected by the mirror matrix.

The term "projection system" used herein should be broadly interpreted as encompassing any type of projection system, including refractive, reflective, catadioptric, magnetic, electromagnetic and electrostatic optical systems, or any combination thereof, as appropriate for the exposure radiation being used, or for other factors such as the use of an immersion liquid or the use of a vacuum. Any use of the term "projection lens" herein may be considered as synonymous with the more general term "projection system".

As here depicted, the apparatus is of a transmissive type (e.g. employing a transmissive mask). Alternatively, the apparatus may be of a reflective type (e.g. employing a programmable mirror array of a type as referred to above, or employing a reflective mask).

The lithographic apparatus may be of a type having two (dual stage) or more substrate tables (and/or two or more mask tables). In such machines the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposure.

The lithographic apparatus may also be of a type wherein at least a portion of the substrate may be covered by a liquid having a relatively high refractive index, e.g. water, so as to fill a space between the projection system and the substrate. An immersion liquid may also be applied to other spaces in the lithographic apparatus, for example, between the mask and the projection system. Immersion techniques are well known in the art for increasing the numerical aperture of projection systems. The term "immersion" as used herein does not mean that a structure, such as a substrate, must be submerged in liquid, but rather only means that liquid is located between the projection system and the substrate during exposure.

Referring to FIG. **1**A, the illuminator **2** receives a radiation beam from a radiation source **20**. The source and the lithographic apparatus may be separate entities, for example when the source is an excimer laser. In such cases, the source is not considered to form part of the lithographic apparatus and the radiation beam is passed from the source **20** to the illuminator **2** with the aid of a beam delivery system **22** comprising, for example, suitable directing mirrors and/or a beam expander. In other cases the source may be an integral part of the lithographic apparatus, for example when the source is a mercury lamp. The source **20** and the illuminator **2**, together with the beam delivery system **22** if required, may be referred to as a radiation system.

The illuminator **2** may comprise an adjuster **24** for adjusting the angular intensity distribution of the radiation beam. Generally, at least the outer and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in a pupil plane of the illuminator can be adjusted. In addition, the illuminator **2** may comprise various other components, such as an integrator **26** and a condenser **28**. The illuminator may be used to condition the radiation beam, to have a desired uniformity and intensity distribution in its cross-section.

The radiation beam **4** is incident on the patterning device (e.g., mask **8**), which is held on the support structure (e.g., mask table **6**), and is patterned by the patterning device. Having traversed the mask **8**, the radiation beam **4** passes through the projection system **18**, which focuses the beam onto a target portion C of the substrate **14**. With the aid of the second positioner **16** and position sensor **30** (e.g. an interferometric device, linear encoder or capacitive sensor), the substrate table WT of a wafer stage St can be moved accurately, e.g. so as to position different target portions C in the path of the radiation beam **4**. For this, known measure & Control algorithms with feedback and/or feedforward loops may be used. Similarly, the first positioner **10** and another position sensor (which is not explicitly depicted in FIG. **1**A) can be used to accurately position the mask **8** with respect to the path of the radiation beam **4**, e.g. after mechanical retrieval from a mask library, or during a scan. In general, movement of the mask table **6** may be realized with the aid of a long-stroke module (coarse positioning) and a short-stroke module (fine positioning), which form part of the first positioner **10**. Similarly, movement of the substrate table WT may be realized using a long-stroke module and a short-stroke module, which form part of the second positioner **16**. In the case of a stepper (as opposed to a scanner) the mask table **6** may be connected to a short-stroke actuator only, or may be fixed. Mask **8** and substrate **14** may be aligned using mask alignment marks M**1**, M**2** and substrate alignment marks P**1**, P**2**. Although the substrate alignment marks as illustrated occupy dedicated target portions, they may be located in spaces between target portions (these are known as scribe-lane alignment marks). Similarly, in situations in which more than one die is provided on the mask **8**, the mask alignment marks may be located between the dies.

FIG. **1**B shows a substrate stage St (also called substrate chuck) for the lithographic apparatus according to FIG. **1**A. The stage St comprises the non-stationary parts of the second positioner **16**, a mirror block MB, and the substrate table WT mounted to the mirror block MB. In this example the mirror block MB is provided with interferometer-mirrors which are arranged for cooperation with interferometers for measuring the position of the mirror block MB.

The second positioner **16** is arranged for positioning the mirror block MB and the substrate table WT. The second positioner **16** comprises the short stroke module (which is provided with a short stroke motor ShM) and the long stroke module (which is provided with a long stroke motor LoM).

The long stroke motor LoM comprises a stationary part LMS that can be mounted to a stationary frame or a balance mass (not shown) and a non-stationary part LMM that is displaceable relative to the stationary part. The short stroke motor ShM comprises a first non-stationary part SMS (that may be mounted to the non-stationary part LMM of the long stroke motor) and a second non-stationary part SMM (that may be mounted to the mirror block MB).

It should be noted that the mask table **6** and the first positioner **10** (see FIG. **1**A) may have a similar structure as depicted in FIG. **1**B.

A so-called dual stage (multi stage) machine may be equipped with two (or more) stages as described. Each stage can be provided with an object table (such as the substrate table WT). In such an arrangement, a preparatory step such as the measurement of a height map of the substrate disposed on one of the object tables can be performed in parallel with the exposure of the substrate disposed on another object table. In order to expose a substrate that previously has been measured, the stages may change position from the measurement location to the exposure location (and vice versa). As an alternative, the object tables can be moved from one stage to an other.

The apparatus depicted in FIG. **1**A could be used in at least one of the following modes:

1. In step mode, the mask table **6** and the substrate table WT are kept essentially stationary, while an entire pattern imparted to the radiation beam is projected onto a target portion C at one time (i.e. a single static exposure). The substrate table WT is then shifted in the X and/or Y direction so that a different target portion C can be exposed. In step mode, the maximum size of the exposure field limits the size of the target portion C imaged in a single static exposure.
2. In scan mode, the mask table **6** and the substrate table WT are scanned synchronously while a pattern imparted to the radiation beam is projected onto a target portion C (i.e. a single dynamic exposure). The velocity and direction of the substrate table WT relative to the mask table **6** may be determined by the (de-)magnification and image reversal characteristics of the projection system **18**. In scan mode, the maximum size of the exposure field limits the width (in the non-scanning direction) of the target portion in a single dynamic exposure, whereas the length of the scanning motion determines the height (in the scanning direction) of the target portion.
3. In another mode, the mask table **6** is kept essentially stationary holding a programmable patterning device, and the substrate table WT is moved or scanned while a pattern imparted to the radiation beam is projected onto a target portion C. In this mode, generally a pulsed radiation source is employed and the programmable patterning device is updated as required after each movement of the substrate table WT or in between successive radiation pulses during a scan. This mode of operation can be readily applied to maskless lithography that utilizes programmable patterning device, such as a programmable mirror array of a type as referred to above.

Combinations and/or variations on the above described modes of use or entirely different modes of use may also be employed.

FIG. **4** is a schematic top-view of an embodiment of a drive and stage configuration of the lithographic apparatus schematically shown in FIG. **1**A. The part is defined by a plane indicated in FIG. **1**A by the line LL. The lithographic apparatus comprises a first metrology station **32**.**1**, a second metrology section **32**.**2** and an exposure station **34** which is situated between the metrology stations **32**.**1**, **32**.**2**.

In FIG. **2** a schematic side view of a metrology station **32** is provided. The metrology station is supported by a base frame **36** which carries a metro frame **38**. The base frame **36** may be placed directly on the floor in a factory. The base frame **36** and the metro frame **38** are dynamically isolated by isolation means **40** (the isolation means **40** may be passive isolation means such as airmounts, active isolation means such a pneumatic pistons or combinations thereof). Due to the dynamical isolation, it is prevented that vibrations or other disturbance movements in the base frame transfer into the metro frame (the disturbances will at least be reduced to a relatively large amount). The metro frame and elements which are connected to it are sometimes called the "silent world".

FIG. **2** also shows a (substrate) stage **42** holding a substrate **14** and a measuring system **44** comprising a height measurement sensor **46** and a position sensor **30**. In this example, the position sensor **30** is capable of measuring the position of the stage **42** in six degrees of freedom. The measuring system **44** is carried by the metro frame and is therefore part of the silent world. The sensors **46**, **30** may be used for measuring a characteristic (height map) of the substrate **14** held by the stage **42**. The height map is used later during exposure in the exposure station **34**.

The position sensor **30** for measuring the position of the stage **42** may be an interferometer sensor **48**.**1** which is capable of directing interferometer measurement beams **50** towards interferometer mirrors **52** attached to the stage **42**. As an alternative, the position sensor may be an encoder system **48**.2 for measuring the position of the stage **42**. However, it is noted here that combinations of interferometers and encoders, whereby the interferometer system measures different parameters than the encoder are also possible.

In the presented example of FIG. **2** the encoder system **48.2** is an encoder plate which is attached to the metro frame **38**. The stage **42** is provided with encoder heads **54** which are capable of cooperating with the encoder plate **48**.2 for measuring the position of the stage **42**. Note that the encoder plate is provided with a cut-away to let the height measurement sensor **46** directing a light measurement beam through the cut-away on the surface of the substrate **8** for measuring the height of the surface of the substrate. Preferably, each corner (at or near each corner) of the upper surface of the stage **42** is provided with an encoder head **54**. The position of the stage can be measured at any location under the cut-away with the encoder system **48.2**.

FIG. **3** is a schematic side view of an exposure station **34**. The exposure station **34** is supported by the base frame **36**. The base frame carries the metro frame **38**, the metro frame **38** is dynamically isolated from the base frame **36** by the isolation means **40**. The projection system **18** is supported by the metro frame **38** via supporting members **56** (the supporting members **56** may also be dynamical isolation means). In this example the metro frame **38** carries the position sensor **30** (an interferometer **48.1** and/or an encoder system **48.2**, whereby it is noted that the encoder system **48**.2 is provided with a cut away for the projection system **18**). However, it is noted that the position sensor **30** may also be carried by the projection system **18** (or, equivalently, by a frame attached to the projection system **18**).

If the position sensor **30** is an encoder plate **48.2**, then this encoder plate may extend both in the exposure station **34** and the metrology station **32**. In an advanced embodiment there is only one encoder plate which extends completely from the metrology station **32** to the exposure station **34**.

A reticle stage or mask stage **6** is located above the projection system **18**. The position of the reticle stage and the position of the mask/reticle are measured by a measuring system **60**. The measuring system **60** cooperates with the position sensor **30** in order to align the mask/reticle with the substrate **14** under the projection system **18**. Aligning the mask/reticle to the substrate is usually performed according to zero point sensors and TIS-alignment techniques (see for a description EP 1510870). For applying the TIS-alignment it is required that the position of the substrate with respect to the base frame **36** is known within a certain accuracy (rough indication as starting point for the fine TIS measurements) such that the substrate is in the capture range of the TIS sensor.

Generally, interferometer sensors measure relative positions (by counting fringes). In order to obtain absolute position measurements via the interferometer sensor the interferometer sensors can be "zerod" by means of a so-called zeroing-operation, which means that a reference point is defined in order to obtain absolute position measurements. Defining such a reference point is of special interest in a multi-stage apparatus, since in such an apparatus it frequently occurs that one stage eclipses another stage yielding a loss of an already defined reference point. If this happens it may be necessary to define a new reference point (according to a new zeroing operation) has to be defined which costs time and reduces throughput. However, the application of the encoder plate may yield an absolute measurement system which reduces or even eliminates the necessary zeroing operations which is beneficial for throughput. Furthermore, if the encoder plate has a high accuracy, the frequency of TIS-alignments itself may also be reduced or even eliminated (at least partly replaced by the encoder measurements), such that the throughput of the corresponding apparatus is further increased.

As shown in FIG. **4**, the stages holding substrates can be exchanged between, on the one hand, the metrology stations **32**.1, **32**.2 and, on the other hand, the exposure station **34**. This will be described in more detail hereinafter. FIG. **4** schematically depicts two guides **62.1**, **62.2** which extend in a first direction (the X-direction) in a horizontal plane. The guides **62** may be attached to the base frame **36**, but it is preferred to attach the guides **62** to a machine frame which is completely separated (thus no dynamical coupling) from the said base frame **36**, the metro frame **38** and the projection lens **18**.

Each guide **62** is coupled to elements **64** which can be moved along the guide **62** in the first direction (X-direction) by means of a motor of the positioning system. In the configuration of FIG. **4** each stage **42.1**, **42.2** is coupled to two elements **64**. Each stage can be moved in the horizontal plane in the Y-direction (which is essentially perpendicular to the first direction) by motors in the elements **64**. In a preferred embodiment the motors in the guides **62** and/or in the elements **64** cooperate with balance masses in order to reduce effects of reaction forces. The stages **42.1**, **42.2** may be supported by the base frame **36** via an air bearing which yields a dynamical isolation of the base frame **26** and the stages **42.1**, **42.2**. It is noted that as an alternative of the described drive configuration a planar motor configuration may be applied.

In the configuration of FIG. **4** the stages can not pass each other. Therefore, the working sequence of the lithographic apparatus which belongs to this configuration is as follows. A substrate **14.1** is provided on the first stage **42.1** via a first substrate convey path to the first metrology station **32.1**. Then this substrate is measured (see FIG. **2**, measurement system **44**, generation of a height map) in the metrology station **32.1** while being scanned in the horizontal plane (the stage **42.1** is moved in the horizontal plane for this). The position of the stages **42.1**, **42.2** is, in the example of FIG. **4**, measured by an interferometer system **48.1**. Next the stage is transferred to the exposure station **34** in order to expose the substrate **14.1** held by the stage **42.1**. The exposure is based on the measured height map of the substrate **14.1**, wherein the stage **42.1** holding the substrate is positioned by the positioning system. (It is noted that the said motors are capable of positioning the stage in six degrees of freedom, however within a limited range, under the projection system **18**). At the same time, the other stage **42.2** is in the second metrology station **32.2** and holds a substrate **14.2** which is measured. The substrate **14.2** has been supplied via a second substrate convey path. After the exposure of substrate **14.1** has been performed the stage **42.1** with the exposed substrate moves to the first metrology station **32.1**, the exposed substrate **14.1** is conveyed via the first substrate convey path, and a new substrate to be measured is loaded on the stage **42.1** via the first substrate convey path. At the same time the substrate **14.2** held by the stage **42.2** is exposed. The sequence continues in this way. It is clear that the configuration requires a double substrate convey path.

It is noted that the beams of the interferometers sometimes have to bridge relatively great distances between the interferometer system and the interferometer-mirror attached to the stage (see FIG. **4**, interferometer beams in the X-direction). This decreases the accuracy of the measurement in this direction, since pressure variations in the air disturb the interferometer measurement beam (this effect increases with an increased distance). Application of the discussed encoder system **48.2** alleviates this disadvantage and may yield higher measurement accuracies.

FIG. **6** schematically depicts another dual stage concept in a top-view defined by the line LL in FIG. **1**. In this concept stages with substrates **42.1**, **42.2** can be exchanged between the metrology station **32** and the exposure station **34**. The concept is provided with two guides **62.1**, **62.2** which extend in a first direction (the X-direction) in a horizontal plane. The guides **62** may be attached to the base frame **36**, but it is preferred to attach the guides **62** to a machine frame which is completely separated (thus no dynamical coupling) from the said base frame **36**, the metro frame **38** and the projection lens **18**. Each guide **62** carries an element **64** which can be moved along the guide **62** in the first direction (X-direction) by means of a motor (part of and) controlled by the positioning system. In this example the elements **64** are T-elements which are part of a so-called "T-drive". Each stage **42.1**, **42.2** is coupled to one T-element **64**, wherein the T-element **64** can move the stage to which it is coupled in the Y-direction by a motor which may be present in the element **64**. The motor is (preferably part of and) controlled by the positioning system. In a preferred embodiment the motors in the guides **62** and/or in the elements **64** cooperate with balance masses in order to reduce effects of reaction forces. It is noted that the stages **42.1**, **42.2** may be supported by the base frame **36** via a dynamically isolating air bearing.

The dual stage concept according to FIG. **6** allows the stages **42.1** and **42.2** to pass each other while being moved between the metrology station **32** and the exposure station **34**. This concept based on the T-drives does not require a stage swap (in contrast to the H-drive concept described in U.S. Pat. No. 5,969,441). Therefore a relatively high throughput can be achieved since a continuous transfer movement of the stages is possible without a stop for a swap.

As an alternative of the depicted "T-drive system" (guides **62.1**, **62.2** and T-elements **64** in FIG. **6**) a planar motor configuration can be used. According to the planar motor configuration the lithographic apparatus is provided with a machine frame with coils and/or magnets (the first part of the planar motor) for cooperating with magnets and/or coils in the said stages **42.1**, **42.2** (the respective second parts of the planar motor) such that the positioning system can move each of the said stages **42.1**, **42.2** between the metrology station **32** and the exposure station **34**. Such a planar motor can also be used to position the stages in the exposure station **34** in six degrees of freedom. The machine frame may be part of the base frame **36** (then the coils and/or magnets) are integrated in the base frame **36**, or the machine frame is separated (dynamically isolated) from the base frame **36**. The planar motor is under control of the positioning system.

According to an embodiment of the lithographic apparatus according to the invention there is provided an immersion liquid **66** between a final optical (lens) element of the projection system **18** and a target portion of the substrate **14** (FIG. **3**). The application of immersion fluid yields the advantage that during exposure smaller structures of patterns can be transferred from the reticle or mask to substrates **14** than in a comparable system without immersion fluid. The lithographic apparatus has a liquid confinement system for confining liquid between a final element of the projection system and the substrate. The liquid confinement system comprises a so-called immersion hood **68** (see FIG. **9**). The immersion fluid may be kept in place during illumination by the immersion hood **68**. The immersion hood **68** may comprise a mechanical contact-seal and/or may also comprise a contactless seal which operation is based on guiding a pressure-gas-flow towards the fluid to be confined (combinations are possible).

After exposure of a substrate the stage holding it has to move away, for example towards a metrology station. Since it is desired that the immersion fluid **66** is kept in its space under the final element of the projection system **18**, special measures have to be taken before the stage can be moved away from its position under the space of the immersion liquid **66**. A possibility is to use a separate closing disc or a separate small closing stage (unable to hold a substrate) which closes the space at the bottom, until a stage holding a substrate to be exposed takes the place of the closing disc/closing stage.

However, the said closing disc/closing stage yields extra take-over operations which cost valuable time and which appear to decrease the throughput of the lithographic apparatus significantly.

Therefore, it is an aspect of the invention to prevent the necessity of a closing disc (or closing stage) and to provide a lithographic apparatus wherein the stages are constructed and arranged for mutual cooperation in order to perform a joint scan movement for bringing the lithographic apparatus from a first situation, wherein the said liquid is confined between a first substrate held by the first stage of the said stages and the final element, towards a second situation, wherein the said liquid is confined between a second substrate held by the second stage of the two stages and the final element, such that during the joint scan movement the liquid is essentially confined within said space with respect to the final element.

The said joint scan movement of the stages **42.1** and **42.2** is illustrated schematically in FIG. **9** (the arrows **71** indicate the direction of movement of the stages with respect to the projection system **18**). The joint scan movement is performed such that the liquid **66** stays confined in its space under the final lens element **70**. At the bottom of the space the stages **42.1**, **42.2** confine the liquid **66**. At the sides it is the immersion hood (which preferably stays in an essentially fixed position with respect to the projection system **18**) which confines the liquid **66**.

In an advanced embodiment the respective first stage **42.1** and second stage **42.2** have respective immersion cross edges **72.1**, **72.2** (situated at or near a side of the relevant stage, see FIG. **9**), wherein the immersion cross edges are constructed and arranged to cooperate with each other during the joint scan movement. Preferably each immersion cross edge **72** comprises one or more essentially plane and smooth surface(s). Thus, it is possible to perform the said joint scan movement in such a way that a well-defined space is obtained between plane surfaces of different immersion cross edges (for example a space defined by parallel surfaces). In FIG. **9** an example is provided wherein the cooperating immersion cross edges of the stages define a space with a mutual distance D during the joint scan movement.

A different shape of the immersion cross edges **72.1**, **72.2** is shown in FIG. **10**. In FIG. **10** the stage **42.1** shows an immersion cross edge with respectively a vertical plane A, a horizontal plane B and a vertical plane C. These planes are constructed to cooperate with respective planes D, E, F of the immersion cross edge **72.2**.

The lithographic apparatus according to the invention may comprise a control system (using a feedback and/or a feedforward loop) that may be fed with position measurements (actually the term position measurement may include position, velocity, acceleration and/or jerk measurements) of the stages (the measurements may be performed by the measurement system **44**) for calculating setpoint-signals for the relevant motors. The motors are controlled during the joint scan movement of the stages by the positioning system according to the setpoint-signals such that the mutual constant distance D between the planes of the respective immersion cross edges corresponds to a pre-determined function. The pre-determined function may be chosen such that the space between the immersion cross edges functions a liquid channel character (see below for further description).

According to an embodiment of the lithographic apparatus, the positioning system is constructed and arranged to control the motors for moving the stages such that stage **42.1** pushes the stage **42.2** gently during the joint scan movement. Herewith, a control system (using a feedback and/or a feedforward loop) of the positioning system is fed with position measurements (actually the term position measurement may include position, velocity, acceleration and/or jerk measurements) of the stages (performed by the measurement system **44**) and calculates setpoint-signals for the relevant motors. Next, motors are controlled by the positioning system according to the setpoint-signals such that the mutual constant distance D between the planes of the respective immersion cross edges is essentially zero.

According to a preferred embodiment of the lithographic apparatus, the positioning system is constructed and arranged to control the motors for moving the stages such that during the joint scan movement the said mutual distance D is larger than zero but smaller that 1 millimeter. A favorable mutual distance D appears to be between 0.05 and 0.2 millimeter. A distance D in this distance-range is especially favorable if one of the stages is provided with a channel system **74** leading to and from an opening the immersion cross edge, wherein the channel system **74** is constructed and arranged for generating a flow of gas and/or liquid along the immersion cross edge during the joint scan movement. The generation of this flow is of importance to reduce the chance that bubbles (bubbles deteriorate the projection of patterns on the substrate) are generated in the immersion liquid **66**. A stable and well controlled distance D results in a stable and well favorable flow thereby avoiding the generation of bubbles in the immersion liquid during the joint scan movement.

The application of a channel system **74** may yield (during the joint scan movement) a gas flow from under the stages **42** (see for example FIG. **11** with indication G) and a liquid flow from above the stages (see for example FIG. **11** with indication L). Then a mixture of gas and liquid will be drained away via the channel system **74** (see indication L/G). Flexible tubes may be connected to the (channel system **74** of the) stage for further transport of the mixture L/G.

In the example of FIG. **11** each stage (**42.1** respectively **42.2**) has a channel system (**74.1** respectively **74.2**), wherein each channel system leads to an opening in a plane surface of the immersion cross edge (**72.1** respectively **72.2**). In the example of FIG. **10** only the stage **42.2** is provided with a channel system **74**, wherein the channel system **74** has three openings in the surface E of the immersion cross edge **72.2**. Little arrows in the channel system **74** show the direction of the flow during the joint scan movement.

FIG. **10**, **13**, **14** show a configuration wherein the stages **42.1**, **42.2** are provided with a water gutter **76.1**, **76.2** under the immersion cross edges **72.1**, **72.2**. The water gutter is capable of catching liquid possible dripped along the immersion cross edge before, during and after the joint scan movement. Application of only one water gutter attached to only one of the stages is in principle sufficient for only catching liquid during the joint scan movement.

The said interferometer system **48.1** uses interferometer-mirrors attached to the stages for position measuring. In the example of FIG. **4** it does not make sense for the interferometer system **48.1** to have interferometer mirrors **52** on the stages at the sides of the immersion cross edges. However, for the drive and stage configuration in FIG. **6**, it may be advantageous to have an interferometer-mirrors **52** at the stages at the sides of the immersion cross edges (for example to have relative short distances of the interferometer beam, which generally yields relative high measurement accuracies). This also holds for the configuration of FIG. **8**, for example in the situation whereby the stage **42.1** visits the exposure station **34** (the immersion cross edge is at the side of the positive X-direction, and in the left X-direction is a relatively long interferometer beam path). In these case it is preferred that the stages are provided with an interferometer-mirror **52** at the immersion cross edge. It is noted that the chance on contamination (liquid flow) and or damage arising during the joint scan movement is greater than for the other interferometer-mirrors. Therefore it is advantageous to stagger the interferometer-mirror with respect to the immersion cross edge as indicated in FIG. **12**. As an alternative the interferometer-mirrors **52** are placed it in a protective niche of the stage, as indicated in FIG. **13**. Another alternative is to place the interferometer-mirror **52** below the said water gutter **76** which catches liquid (and possible contamination). FIG. **14** shows an example of a combination of the mentioned measures whereby the interferometer-mirrors are both staggered with respect to the immersion cross edge **72** and placed at a level under the water gutter **76**. In this way the interferometers stay clean and undamaged which yield a reliable performance of the measurement system.

Although specific reference may be made in this text to the use of lithographic apparatus in the manufacture of ICs, it should be understood that the lithographic apparatus described herein may have other applications, such as the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, flat-panel displays, liquid-crystal displays (LCDs), thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms “wafer” or “die” herein may be considered as synonymous with the more general terms “substrate” or “target portion”, respectively. The substrate referred to herein may be processed, before or after exposure, in for example a track (a tool that typically applies a layer of resist to a substrate and develops the exposed resist), a metrology tool and/or an inspection tool. Where applicable, the disclosure herein may be applied to such and other substrate processing tools. Further, the substrate may be processed more than once, for example in order to create a multi-layer IC, so that the term substrate used herein may also refer to a substrate that already contains multiple processed layers.

Although specific reference may have been made above to the use of embodiments of the invention in the context of optical lithography, it will be appreciated that the invention may be used in other applications, for example imprint lithography, and where the context allows, is not limited to optical lithography. In imprint lithography a topography in a patterning device defines the pattern created on a substrate. The topography of the patterning device may be pressed into a layer of resist supplied to the substrate whereupon the resist is cured by applying electromagnetic radiation, heat, pressure or a combination thereof. The patterning device is moved out of the resist leaving a pattern in it after the resist is cured.

The terms “radiation” and “beam” used herein encompass all types of electromagnetic radiation, including ultraviolet (UV) radiation (e.g. having a wavelength of or about 365, 355, 248, 193, 157 or 126 nm) and extreme ultra-violet

(EUV) radiation (e.g. having a wavelength in the range of 5-14 20 nm), as well as particle beams, such as ion beams or electron beams.

The term "lens", where the context allows, may refer to any one or combination of various types of optical components, including refractive, reflective, magnetic, electromagnetic and electrostatic optical components.

While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. For example, the invention may take the form of a computer program containing one or more sequences of machine-readable instructions describing a method as disclosed above, or a data storage medium (e.g. semiconductor memory, magnetic or optical disk) having such a computer program stored therein.

The descriptions above are intended to be illustrative, not limiting. Thus, it will be apparent to one skilled in the art that modifications may be made to the invention as described without departing from the scope of the claims set out below.

The invention claimed is:

1. A lithographic apparatus comprising:

a support constructed to support a patterning device, the patterning device being capable of imparting a radiation beam with a pattern in its cross-section to form a patterned radiation beam;

a measuring system configured to measure characteristics of substrates in a metrology station of the apparatus;

a projection system configured to project the patterned radiation beam onto a substrate in an exposure station of the apparatus;

a liquid confinement system configured to at least partly confine liquid in a space between the projection system and the substrate;

a positioning system and at least two substrate stages, each stage constructed to hold a **[**substrates**]** *substrate*, wherein the positioning system is constructed to move the stages between the metrology station and the exposure station, and wherein the positioning system is constructed to position one of the stages holding a substrate during exposure in the exposure station on the basis of at least one measured characteristic of that substrate;

wherein the stages are constructed and arranged for mutual cooperation in order to perform a joint scan movement to bring the lithographic apparatus from a first situation, wherein the liquid is confined between a first substrate held by a first stage of the two stages and the projection system, towards a second situation, wherein the liquid is confined between a second substrate held by a second stage of the two stages and the projection system, such that during the joint scan movement the liquid is essentially confined within the space with respect to the projection system.

2. The lithographic apparatus according to claim **1**, wherein each of the first stage and second stage has an immersion cross edge at or near a side of the stage which is constructed and arranged to cooperate with an immersion cross edge of another stage during the joint scan movement.

3. The lithographic apparatus according to claim **2**, wherein each immersion cross edge comprises an essentially plane surface.

4. The lithographic apparatus according to claim **2**, wherein the positioning system is constructed and arranged to position the respective stages during their joint scan movement such that surfaces of their respective immersion cross edges remain at an essentially mutual constant distance, wherein the distance is in the range of zero to about 1 millimeter**[**, wherein a preferred distance is about 0.1 millimeter**]**.

5. The lithographic apparatus according to claim **2**, wherein at least one of the respective stages is provided with a channel system having an opening in a surface of the immersion cross edge of the stage, wherein the channel system is constructed and arranged to generate a flow of gas and/or liquid along the immersion cross edge during the joint scan movement.

6. The lithographic apparatus according to claim **2**, wherein at least one of the respective stages is provided with a liquid gutter under its immersion cross edge, wherein the liquid gutter is capable of catching liquid possibly dripped along the immersion cross edge.

7. The lithographic apparatus according to claim **2**, wherein at least one of the respective stages is provided with an interferometer-mirror near the immersion cross edge, wherein the interferometer-mirror is staggered with respect to the immersion cross edge **[**and preferably placed in a niche of the stage in order to protect the interferometer-mirror**]**.

8. The lithographic apparatus according to claim **6**, wherein at least one of the respective stages is provided with an interferometer-mirror near the immersion cross edge, wherein the interferometer-mirror is placed at a level below that of the liquid gutter in order to protect the interferometer-mirror.

9. The lithographic apparatus according to claim **1**, further comprising an exposure station situated between a first metrology station and a second metrology station such that alternately substrates measured by the first metrology station and substrates measured by the second metrology station may be fed towards the exposure station.

10. The lithographic apparatus according to claim **1**, further comprising a base frame configured to carry a metro frame which supports the measuring system and the projection system, wherein the metro frame is dynamically isolated from the base frame, and wherein the measuring system comprises at least one encoder plate configured to cooperate with an encoder head placed at one of the stages to measure the position of that stage.

11. The lithographic apparatus according to claim **10**, wherein the at least one encoder plate extends in the exposure station and the metrology station.

12. The lithographic apparatus according to claim **10**, further comprising a machine frame **[**which is preferably separated from the base frame, wherein the machine frame is provided with**]** *having* a first part of a planar motor to cooperate with respective second parts of the planar motor in the respective stages, wherein the positioning system is constructed and arranged to control the planar motor in order to position the respective stages between the metrology station and the exposure station.

13. The lithographic apparatus according to claim **10**, further comprising a machine frame **[**which is preferably separated from the base frame, wherein the machine frame has**]** *having* two essentially parallel guides extending in a first direction in a horizontal plane, wherein each guide is coupled to an element which can be moved along the guide by means of a motor, and wherein each element is coupled to a stage of the respective stages by means of a motor to move that stage in a second direction directed in the horizontal plane and perpendicular to the first direction, wherein the positioning system is constructed and arranged to control the motors in order to move the stage in the plane.

14. A lithographic product with a lithographic apparatus according to claim **1**.

15. A lithographic apparatus comprising:

a substrate stage configured to support a substrate and a second stage;

a liquid confinement system configured to at least partly confine liquid in a space between a projection system and the substrate stage, a substrate supported by the substrate stage, or both;

the substrate stage and the second stage constructed and arranged for mutual cooperation to perform a joint *movement wherein the liquid in the liquid confinement structure is transferred from being confined by the substrate or the substrate stage or both to being confined by the second stage, the liquid crossing an edge of the substrate stage and an opposing edge of the second stage,*

wherein the substrate stage, the second stage, or both, comprises a channel system in fluid communication with an opening defined by the edge of the stage, the channel system constructed and arranged to generate a fluid flow along the edge during the joint movement, the fluid flow including liquid from the liquid confinement structure.

16. A lithographic apparatus comprising:

a substrate stage configured to support a substrate and a second stage;

a liquid confinement system configured to at least partly confine liquid in a space between a projection system and the substrate stage, a substrate supported by the substrate stage, or both;

the substrate stage and the second stage constructed and arranged for mutual cooperation to perform a joint movement wherein the liquid in the liquid confinement structure is transferred from being confined by the substrate or the substrate stage or both to being confined by the second stage, the liquid crossing an edge of the substrate stage and an opposing edge of the second stage,

wherein the substrate stage, the second stage, or both, comprises a gutter located under the edge of the respective stage, the gutter constructed and arranged to collect liquid from the liquid confinement structure flowing down one or both edges during the joint movement.

17. A lithographic apparatus comprising:

a substrate stage configured to support a substrate and a second stage;

a liquid confinement system configured to at least partly confine liquid in a space between a projection system and the substrate stage, a substrate supported by the substrate stage, or both;

the substrate stage and the second stage constructed and arranged for mutual cooperation to perform a joint movement wherein the liquid in the liquid confinement structure is transferred from being confined by the substrate or the substrate stage or both to being confined by the second stage, the liquid crossing an edge of the substrate stage and an opposing edge of the second stage,

wherein the substrate stage, the second stage, or both, comprises a fluid extraction system constructed and arranged to collect liquid flowing between the edges during the joint movement.

18. A lithographic apparatus comprising:

a substrate stage configured to support a substrate, the substrate stage having an edge;

a further stage having a corresponding edge, the corresponding edge constructed and arranged to mutually co-operate with the edge when the substrate stage and the further stage are arranged adjacently to define a gap; and

a liquid confinement structure configured to at least partly confine immersion liquid in a space between a projection system and a substrate, the substrate stage, or both,

wherein, during a joint movement of the substrate stage and the further stage, confinement of liquid in the space by the substrate stage, the substrate or both is replaced by the further stage, and the substrate stage, the further stage, or both, comprises a fluid extraction system constructed and arranged to collect immersion liquid in the gap during the joint movement.

19. The lithographic apparatus of claim 18, wherein the fluid extraction system comprises a gutter constructed and arranged to collect immersion liquid under the substrate stage, the further stage or both flowing from the gap before, during and/or after joint movement.

20. The lithographic apparatus of claim 19, wherein the gutter is attached to the substrate stage and/or the further stage.

21. The lithographic apparatus of claim 20, wherein the gutter is located under the edge of the stage to which it is attached.

22. The lithographic apparatus of claim 18, wherein the fluid extraction system comprises a channel system comprised in the substrate stage, the further stage or both and which is in fluid communication with an opening defined in the edge, the corresponding edge or both, the channel system constructed and arranged to generate a fluid flow along the gap during the joint movement.

23. The lithographic apparatus of claim 22, wherein the fluid flow comprises liquid and gas away from the gap.

24. The lithographic apparatus of claim 18, further comprising a positioning system comprising a motor to move the substrate stage and/or the further stage and constructed and arranged to control the motor during the joint movement so that the distance between the edge and the corresponding edge is controlled.

25. The lithographic apparatus of claim 24, wherein the distance between the edge and the corresponding edge is controlled to be in the range of 0 to 1 mm.

26. The lithographic apparatus of claim 24, wherein the positioning system comprises an interferometer system comprising a mirror located on the edge or the corresponding edge.

27. The lithographic apparatus of claim 26, wherein the mirror is on a surface staggered away from the edge or the corresponding edge.

28. The lithographic apparatus of claim 26, wherein the mirror is located in a protective niche defined in the edge or the corresponding edge.

29. The lithographic apparatus of claim 26, wherein the mirror is located underneath the fluid extraction system.

30. The lithographic apparatus of claim 18, wherein the further stage is a substrate stage configured to support a further substrate.

31. The lithographic apparatus of claim 18, wherein the further stage is an actuated closing stage.

32. A device manufacturing method, comprising:

supporting a substrate on a substrate table, wherein the substrate table is laterally movable with respect to an adjacent table;

at least partly confining immersion liquid in a space between a projection system and the substrate table, the substrate or both;

jointly moving the substrate table with the adjacent table, the adjoining edges of the substrate table and the adjacent table mutually cooperating to define a gap, so that the liquid in the space is contained by the adjacent table instead of the substrate table; and

collecting immersion liquid in the gap during joint movement using a fluid extraction system.

33. The lithographic apparatus according to claim 7, wherein the interferometer-mirror is in a niche of the stage in order to protect the interferometer-mirror.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO.	: RE43,576 E
APPLICATION NO.	: 12/318821
DATED	: August 14, 2012
INVENTOR(S)	: Van Den Brink et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the specification,

Column 1, line 12 please insert the following text:

-- Notice: More than one reissue application has been filed for the reissue of Patent No. 7,161,659. The reissue applications are application numbers 12/318,821 (the present application), filed on January 8, 2009, 13/584,522 (now RE44,446), filed on August 13, 2012, which is a continuation reissue patent application of application no. 12/318,821, and 13/970,429, filed on August 19, 2013, which is a continuation reissue patent application of application no. 13/584,522. --

Signed and Sealed this
Twenty-eighth Day of April, 2015

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office