Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2414741 C 2009/10/20

(11)(21) **2 414 741**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(86) **Date de dépôt PCT/PCT Filing Date:** 2000/05/24
(87) **Date publication PCT/PCT Publication Date:** 2001/01/11
(45) **Date de délivrance/Issue Date:** 2009/10/20
(85) **Entrée phase nationale/National Entry:** 2002/12/30
(86) **N° demande PCT/PCT Application No.:** AU 2000/000582
(87) **N° publication PCT/PCT Publication No.:** 2001/002289
(30) **Priorité/Priority:** 1999/06/30 (AU PQ 1309)

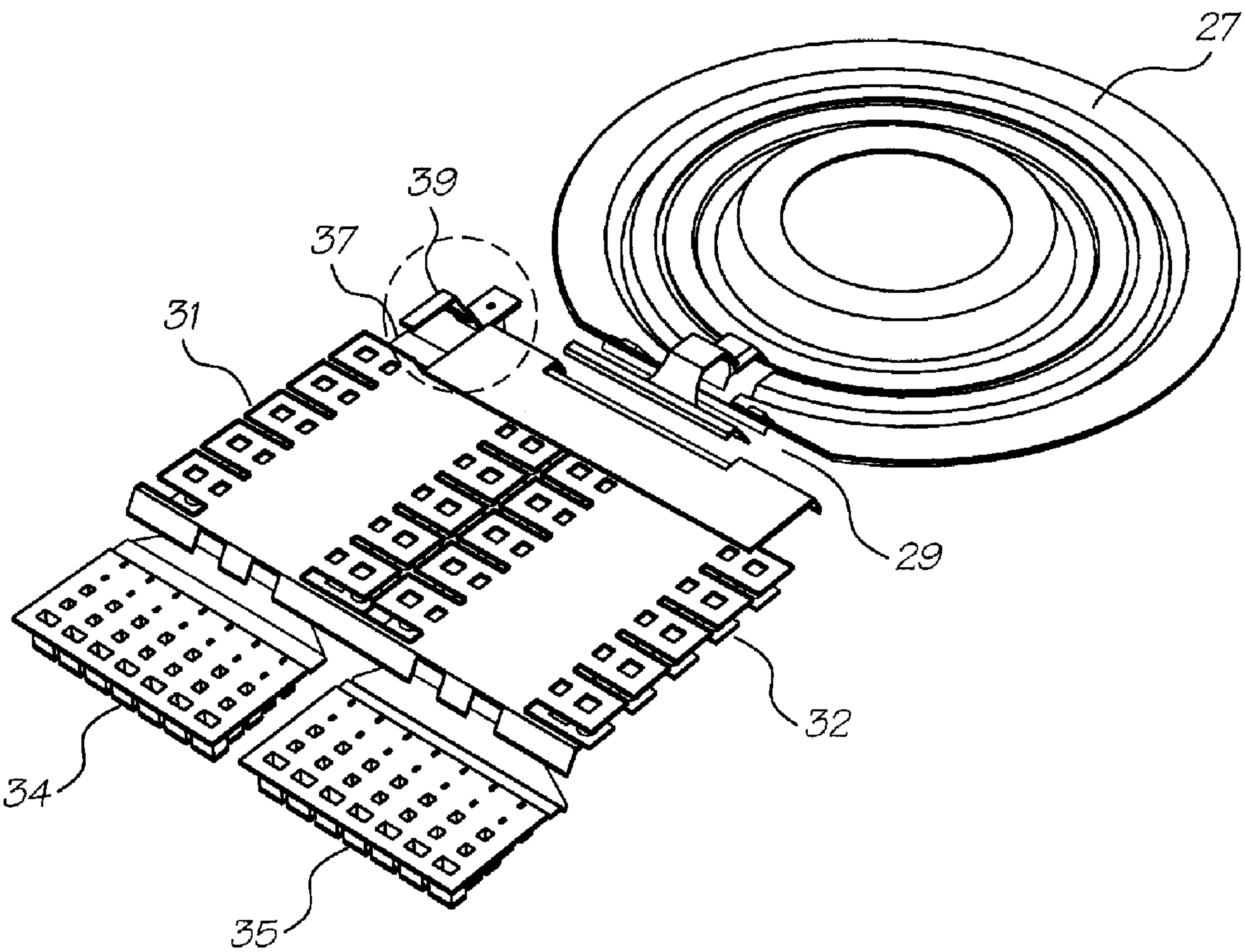
(51) **Cl.Int./Int.Cl.** *B81B 7/04* (2006.01), *B41J 2/045* (2006.01), *B41J 2/125* (2006.01), *B41J 2/14* (2006.01), *B81B 5/00* (2006.01), *B81B 7/02* (2006.01)

(72) **Inventeur/Inventor:**
SILVERBROOK, KIA, AU

(73) **Propriétaire/Owner:**
SILVERBROOK RESEARCH PTY LTD, AU

(74) **Agent:** RIDOUT & MAYBEE LLP

(54) Titre : DETECTEUR DE MOUVEMENT DANS UN DISPOSITIF ELECTROMECANIQUE
(54) Title: MOVEMENT SENSOR IN A MICRO ELECTRO-MECHANICAL DEVICE



(57) Abrégé/Abstract:
A micro electro-mechanical device embodied within an ink ejection nozzle having an actuating arm that is caused to move an ink displacing paddle (27) when heat inducing electric current is passed through the actuating arm. The device incorporates a

(57) Abrégé(suite)/Abstract(continued):

movement sensor (37, 39) that comprises a moving contact element (37) that is formed integrally with the actuating arm, a fixed contact element (39) that is formed integrally with a support structure of the device and electrical elements formed within the support structure for detecting contact that is made between the fixed contact element (39) and the moving contact element (37). The movement sensor (37, 39) is provided for the purpose of facilitating testing of the device under various operating conditions.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
11 January 2001 (11.01.2001)

PCT

(10) **International Publication Number**
WO 01/02289 A1

(51) **International Patent Classification**[7]: **B81B 7/04**, B41J 2/125

(21) **International Application Number:** PCT/AU00/00582

(22) **International Filing Date:** 24 May 2000 (24.05.2000)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
PQ 1309 30 June 1999 (30.06.1999) AU

(71) **Applicant** *(for all designated States except US)*: **SILVERBROOK RESEARCH PTY. LTD.** [AU/AU]; 393 Darling Street, Balmain, New South Wales 2041 (AU).

(72) **Inventor; and**
(75) **Inventor/Applicant** *(for US only)*: **SILVERBROOK, Kia** [AU/AU]; Silverbrook Research Pty. Ltd., 393 Darling Street, Balmain, New South Wales 2041 (AU).

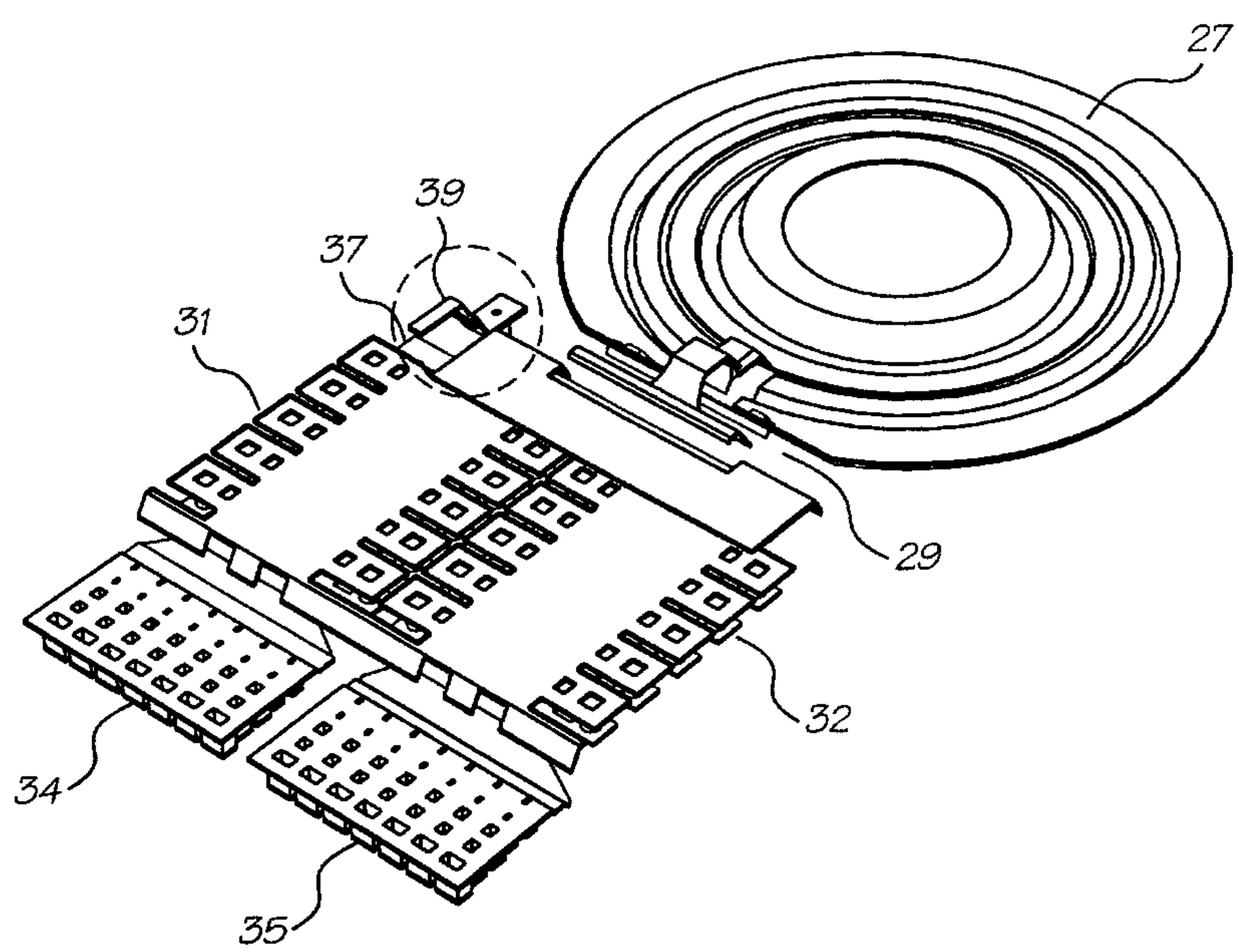
(81) **Designated States** *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** MOVEMENT SENSOR IN A MICRO ELECTRO-MECHANICAL DEVICE



(57) **Abstract:** A micro electro-mechanical device embodied within an ink ejection nozzle having an actuating arm that is caused to move an ink displacing paddle (27) when heat inducing electric current is passed through the actuating arm. The device incorporates a movement sensor (37, 39) that comprises a moving contact element (37) that is formed integrally with the actuating arm, a fixed contact element (39) that is formed integrally with a support structure of the device and electrical elements formed within the support structure for detecting contact that is made between the fixed contact element (39) and the moving contact element (37). The movement sensor (37, 39) is provided for the purpose of facilitating testing of the device under various operating conditions.

WO 01/02289 A1

"MOVEMENT SENSOR IN A MICRO ELECTRO-MECHANICAL DEVICE"

FIELD OF THE INVENTION

This invention relates to an integrated movement sensor within a micro electro-mechanical (MEM) device. The invention has application in ink ejection nozzles of the type that are fabricated by integrating the technologies applicable to micro electro-mechanical systems (MEMS) and complementary metal-oxide semiconductor ("CMOS") integrated circuits, and the invention is hereinafter described in the context of that application. However, it will be understood that the invention does have broader application, to a movement sensor within various types of MEM devices.

BACKGROUND OF THE INVENTION

A high speed pagewidth inkjet printer has recently been developed by the present Applicant. This typically employs in the order of 51200 inkjet nozzles to print on A4 size paper to provide photographic quality image printing at 1600 dpi. In order to achieve this nozzle density, the nozzles are fabricated by integrating MEMS-CMOS technology and in this context reference may be made to International Patent Publication No. WO 2000/064804 filed on April 20, 2000 by the present Applicant entitled "Thermal Actuator".

A difficulty that flows from the fabrication of such a printer is that there is no convenient way of ensuring that all nozzles that extend across the printhead or, indeed, that are located on a given chip will perform identically, and this problem is exacerbated when chips that are obtained from different wafers may need to be assembled into a given printhead. Also, having fabricated a complete printhead from a plurality of chips, it is an inkjet nozzle as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:-

Figure 1 shows a highly magnified cross-sectional elevation view of a portion of the inkjet nozzle,

Figure 2 shows a plan view of the inkjet nozzle of Figure 1,

Figure 3 shows a perspective view of an outer portion of an actuating arm and an ink ejecting paddle or of the inkjet nozzle, the actuating arm and paddle being illustrated independently of other elements of the nozzle,

Figure 4 shows an arrangement similar to that of Figure 3 but in respect of an inner portion of the actuating arm,

Figure 5 shows an arrangement similar to that of Figures 3 and 4 but in respect of the complete actuating arm incorporating the outer and inner portions shown in Figures 3 and 4,

Figure 6 shows a detailed portion of a movement sensor arrangement that is shown encircled in Figure 5,

Figure 7 shows a sectional elevation view of the nozzle of Figure 1 but prior to charging with ink,

Figure 8 shows a sectional elevation view of the nozzle of Figure 7 but with the actuating arm and paddle actuated to a test position,

Figure 9 shows ink ejection from the nozzle when actuated under test conditions,

Figure 10 shows a blocked condition of the nozzle when the actuating arm and paddle are actuated to an extent that normally would be sufficient to eject ink from the nozzle,

Figure 11 shows a schematic representation of a portion of an electrical circuit that is embodied within the nozzle,

Figure 12 shows an excitation-time diagram applicable to normal (ink ejecting) actuation of the nozzle actuating arm,

Figure 13 shows an excitation-time diagram applicable to test actuation of the nozzle actuating arm,

Figure 14 shows comparative displacement-time curves applicable to the excitation-time diagrams shown in Figures 12 and 13,

Figure 15 shows an excitation-time diagram applicable to various testing and calibration procedures to which the nozzle might be subjected,

Figure 16 shows a temperature-time diagram that is applicable to the nozzle actuating arm and which corresponds with the excitation-time diagram of Figure 15, and

Figure 17 shows a deflection-time diagram that is applicable to the nozzle actuator and which corresponds with the excitation/heating-time diagrams of Figures 15 and 16.

DETAILED DESCRIPTION OF THE INVENTION

As illustrated with approximately 3000x magnification in Figure 1 and other relevant drawing figures, a single inkjet nozzle device is shown as a portion of a chip that is fabricated by integrating MEMS and CMOS technologies. The complete nozzle device includes a support structure having a silicon substrate 20, a metal oxide semiconductor layer 21, a passivation layer 22, and a non-corrosive dielectric coating/chamber-defining layer 23. Reference may be made to the above identified International Patent Application No. PCT/AU00/00338 by the present Applicant entitled "Thermal Actuator" (Our Docket No. MJ08), which corresponds to US Patent Application Serial number to be advised, for a detailed disclosure of the fabrication of the nozzle device.

The nozzle device incorporates an ink chamber 24 which is connected to a source (not shown) of ink and, located above the chamber, a nozzle chamber 25. A nozzle opening 26 is provided in the chamber-defining layer 23 to permit displacement of ink droplets toward paper or other medium (not shown) onto which ink is to be deposited. A paddle 27 is located between the two chambers 24 and 25 and, when in its quiescent position, as indicated in Figures 1 and 7, the paddle 27 effectively divides the two chambers 24 and 25.

The paddle 27 is coupled to an actuating arm 28 by a paddle extension 29 and a bridging portion 30 of the dielectric coating 23.

The actuating arm 28 is formed (i.e. deposited during fabrication of the device) to be pivotable with respect to the support structure or substrate 20. That is, the actuating arm has a first end that is coupled to the support structure and a second end 38 that is movable outwardly with respect to the support structure. The actuating arm 28 comprises outer and inner arm portions 31 and 32. The outer arm portion 31 is illustrated in detail and in isolation from other components of the nozzle device in the perspective view shown in Figure 3. The inner arm portion 32 is illustrated in a similar way in Figure 4. The complete actuating arm 28 is illustrated in perspective in Figure 5, as well as in Figures 1, 7, 8, 9 and 10.

The inner portion 32 of the actuating arm 28 is formed from an titanium-aluminum-nitride ((Ti,Al)N reactively sputtered) deposit during formation of the nozzle device and it is connected electrically to a current source 33, as illustrated schematically in Figure 11, within the CMOS structure. The electrical connection is made to end terminals 34 and 35, and application of an excitation (drive) voltage to the terminals results in current flow through the inner portion only of the actuating arm 28. The current flow causes resistance heating within the inner portion 32 of the actuating arm and consequential elongation of that portion of the arm.

The outer arm portion 31 of the actuating arm 28 is mechanically coupled to but electrically isolated from the inner arm portion 32 by posts 36. No current-induced heating occurs within the outer arm portion 31 and, as a consequence, voltage induced current flow through the inner arm portion 32 causes bending of the complete actuating arm 28 in the manner indicated in Figures 8, 9 and 10 of the drawings. This bending of the actuating arm 28 is equivalent to pivotal movement of the arm with respect to the substrate 20 and it results in displacement of the paddle 27 within the chambers 24 and 25.

An integrated movement sensor is provided within the device in order to determine the degree or rate of pivotal movement of the actuating arm 28 and, hence, of the paddle 27.

The movement sensor comprises a moving contact element 37 that is formed integrally with the inner portion 32 of the actuating arm 28 and which is electrically active when current is passing through the inner portion of the actuating arm. The moving contact element 37 is positioned adjacent the second end 38 of the technologies. The complete nozzle device includes a support structure having a silicon substrate 20, a metal oxide semiconductor layer 21, a passivation layer 22, and a non-corrosive dielectric coating/chamber-defining layer 23. Reference may be made to the above identified International Patent Publication No. WO 2000/064804 filed on April 20, 2000 by the present Applicant entitled "Thermal Actuator" (Our Docket No. MJ08), for a detailed disclosure of the fabrication of the nozzle device.

The nozzle device incorporates an ink chamber 24 which is connected to a source (not shown) of ink and, located above the chamber, a nozzle chamber 25. A nozzle opening 26 is provided in the chamber-defining layer 23 to permit displacement of ink droplets toward paper or other medium (not shown) onto which ink is to be deposited. A paddle 27 is located between the two chambers 24 and 25 and, when in its quiescent position, as indicated in Figures 1 and 7, the paddle 27 effectively divides the two chambers 24 and 25.

The paddle 27 is coupled to an actuating arm 28 by a paddle extension 29 and a bridging portion 30 of the dielectric coating 23.

The actuating arm 28 is formed (i.e. deposited during fabrication of the device) to be pivotable with respect to the support structure or substrate 20. That is, the actuating arm has a first end that is coupled to the support structure and a second end 38 that is movable outwardly with respect to the support structure. The actuating arm 28 comprises outer and inner arm portions 31 and 32. The outer arm portion 31 is illustrated in detail and in isolation from other components of the nozzle device in the perspective view shown in Figure 3. The inner arm portion 32 is illustrated in a similar way in Figure 4. The complete actuating arm 28 is illustrated in perspective in Figure 5, as well as in Figures 1, 7, 8, 9 and 10.

The inner portion 32 of the actuating arm 28 is formed from a titanium-aluminum-nitride ((Ti,Al)N reactively sputtered) deposit during formation of the nozzle device and it is connected electrically to a current source 33, as illustrated schematically in Figure 11, within the CMOS structure. The electrical connection is made to end terminals 34 and 35, and application of an excitation (drive) voltage to the terminals results in current flow through the inner portion only of the actuating arm 28. The current flow causes resistance heating within the inner portion 32 of the actuating arm and consequential elongation of that portion of the arm.

The outer arm portion 31 of the actuating arm 28 is mechanically coupled to but electrically isolated from the inner arm portion 32 by posts 36. No current-induced heating occurs within the outer arm portion 31 and, as a consequence, voltage induced current flow through the inner arm portion 32 causes bending of the complete actuating arm 28 in the manner indicated in Figures 8, 9 and 10 of the drawings. This bending of the actuating arm 28 is equivalent to pivotal movement of the arm with respect to the substrate 20 and it results in displacement of the paddle 27 within the chambers 24 and 25.

An integrated movement sensor is provided within the device in order to determine the degree or rate of pivotal movement of the actuating arm 28 and, hence, of the paddle 27.

The movement sensor comprises a moving contact element 37 that is formed integrally with the inner portion 32 of the actuating arm 28 and which is electrically active when current is passing through the inner portion of the actuating arm. The moving contact element 37 is positioned adjacent the second end 38 of the

I claim:

1. A micro electro-mechanical device comprising:

a support structure,

an actuating arm having a first end coupled to the support structure and a second end that is movable with respect to the support structure, the actuating arm being formed in part from an electrically resistive material and being arranged to conduct heat inducing electrical current from a current source within the support structure to effect movement of the actuating arm, and

a movement sensor incorporated in the device, the movement sensor comprising –

a moving contact element formed integrally with the actuating arm adjacent the second end of the actuating arm,

a fixed contact element formed integrally with the support structure and positioned to be contacted by the moving contact element when the actuating arm moves to a predetermined extent under the influence of the heat inducing electrical current, and

electrical circuit elements formed within the support structure for detecting contact between the fixed contact element and the moving contact element.

2. The device as claimed in claim 1 wherein the actuating arm is arranged such that the second end of the actuating arm moves outwardly with respect to the support structure with passage of heat inducing electric current through the actuating arm and moves inwardly upon termination of current flow through the actuating arm.

3. The device as claimed in claim 2 wherein the actuating arm comprises an inner arm portion that is formed from the electrically resistive material and an outer arm portion that is mechanically coupled to but electrically isolated from the inner arm portion.

4. The device as claimed in claim 3 and embodied in a liquid ejection nozzle having a liquid receiving chamber from which the liquid is ejected with outward movement of the actuating arm.

5. The device as claimed in claim 3 and embodied in an ink ejection nozzle having an ink receiving chamber from which the ink is ejected with outward movement of the actuating arm.

6. The device as claimed in claim 5 wherein the actuating arm is coupled to a paddle that is positioned within the chamber and wherein the paddle is movable by the actuating arm to expel the ink through a nozzle opening that communicates with the chamber.

7. The device as claimed in claim 6 wherein the fixed contact element is positioned to be contacted by the moving contact element when the actuating arm is moved to an extent greater than that necessary to effect displacement of the ink from the chamber.

8. The device as claimed in claim 6 wherein the moving contact element is formed as a lateral projection of one side of the inner portion of the actuating arm.

9. The device as claimed in claim 1 wherein the electrical circuit elements are embodied in CMOS structures within the support structure.

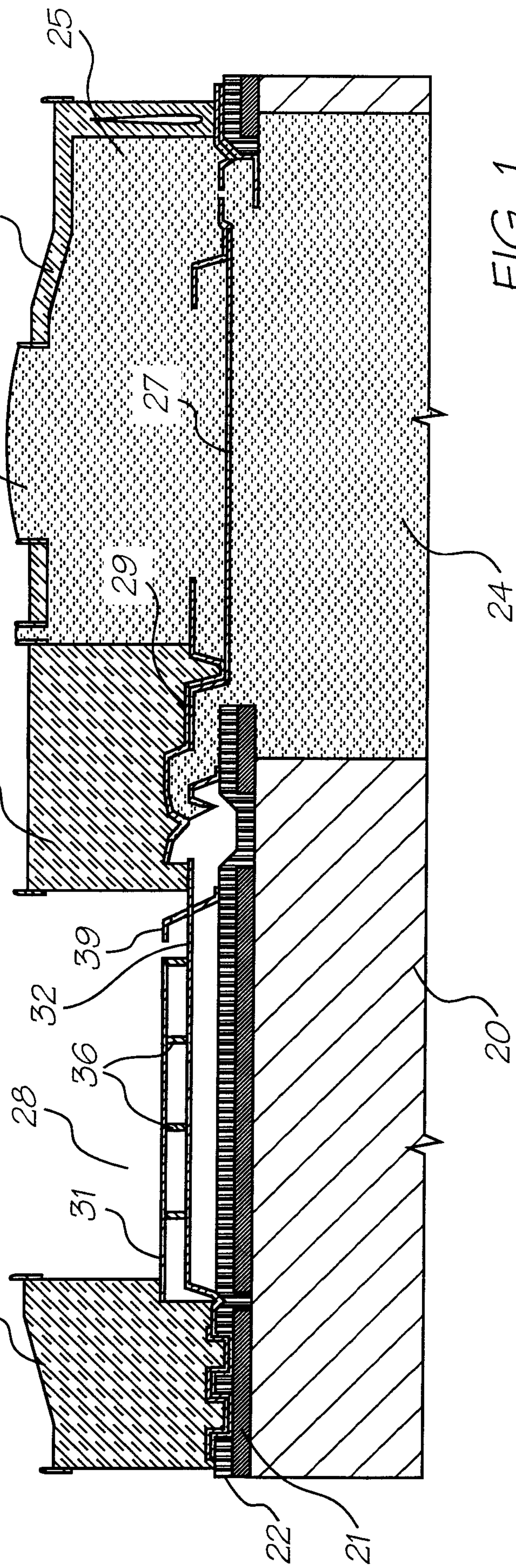


FIG. 1

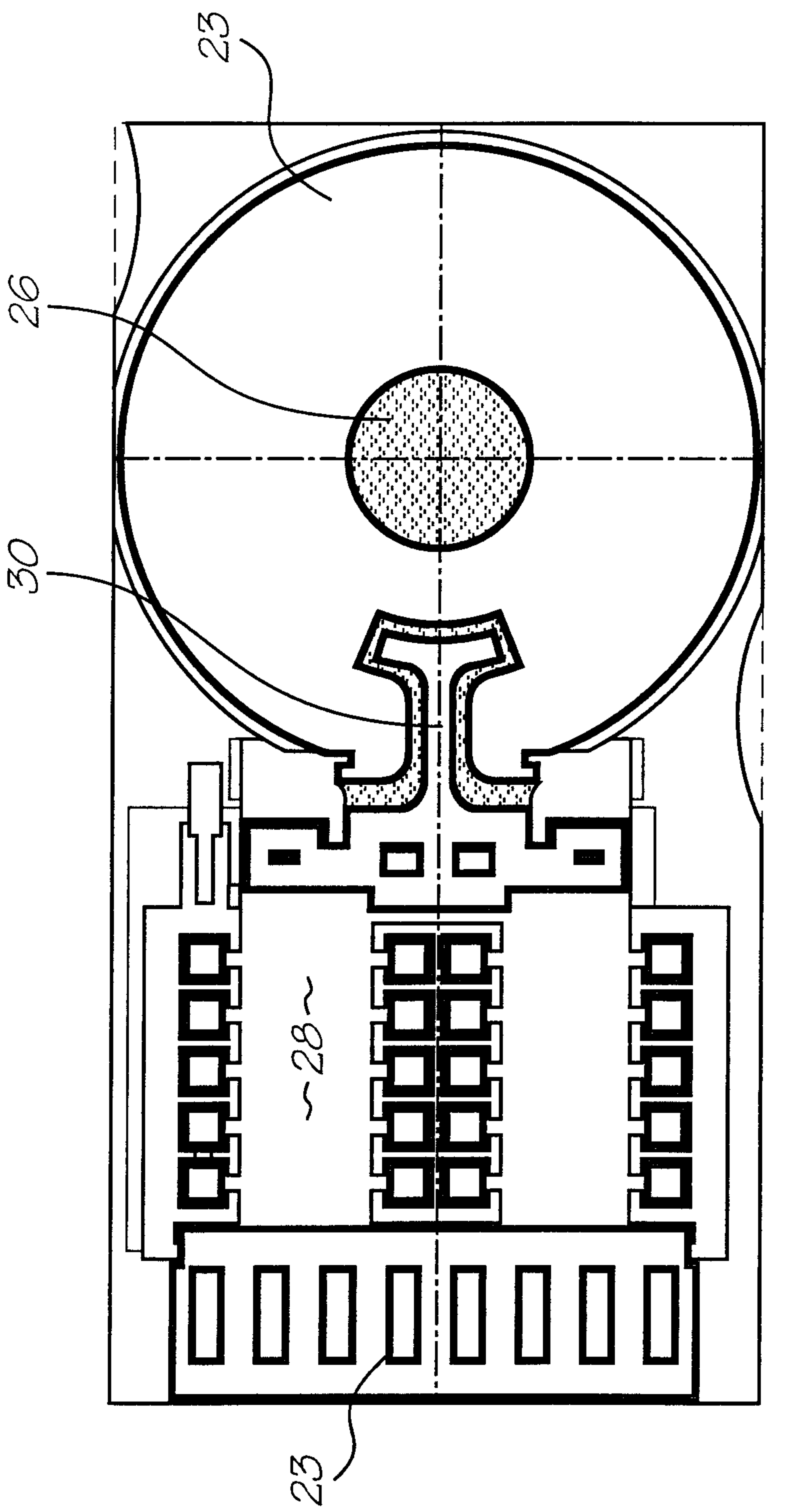


FIG. 2

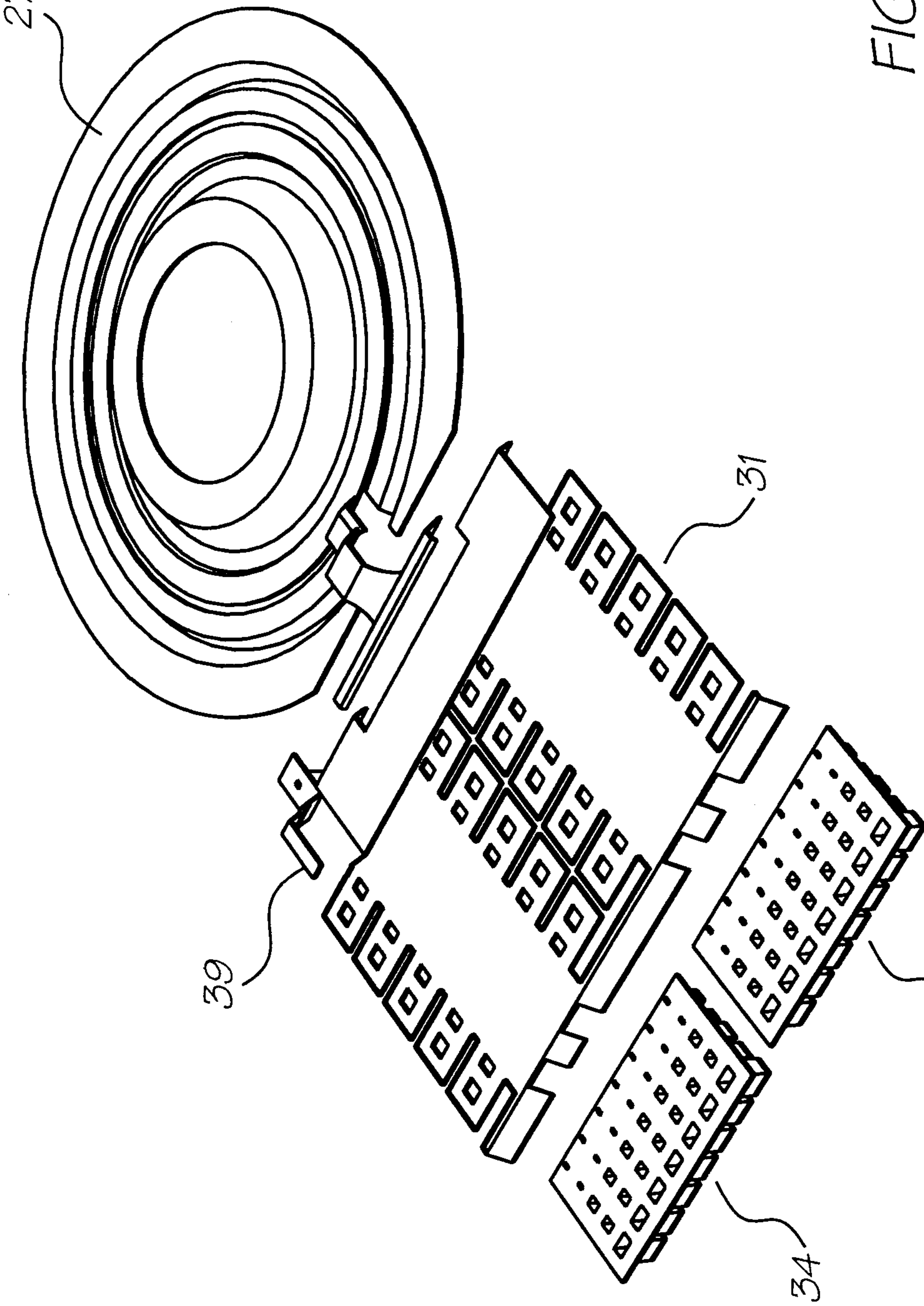


FIG. 3

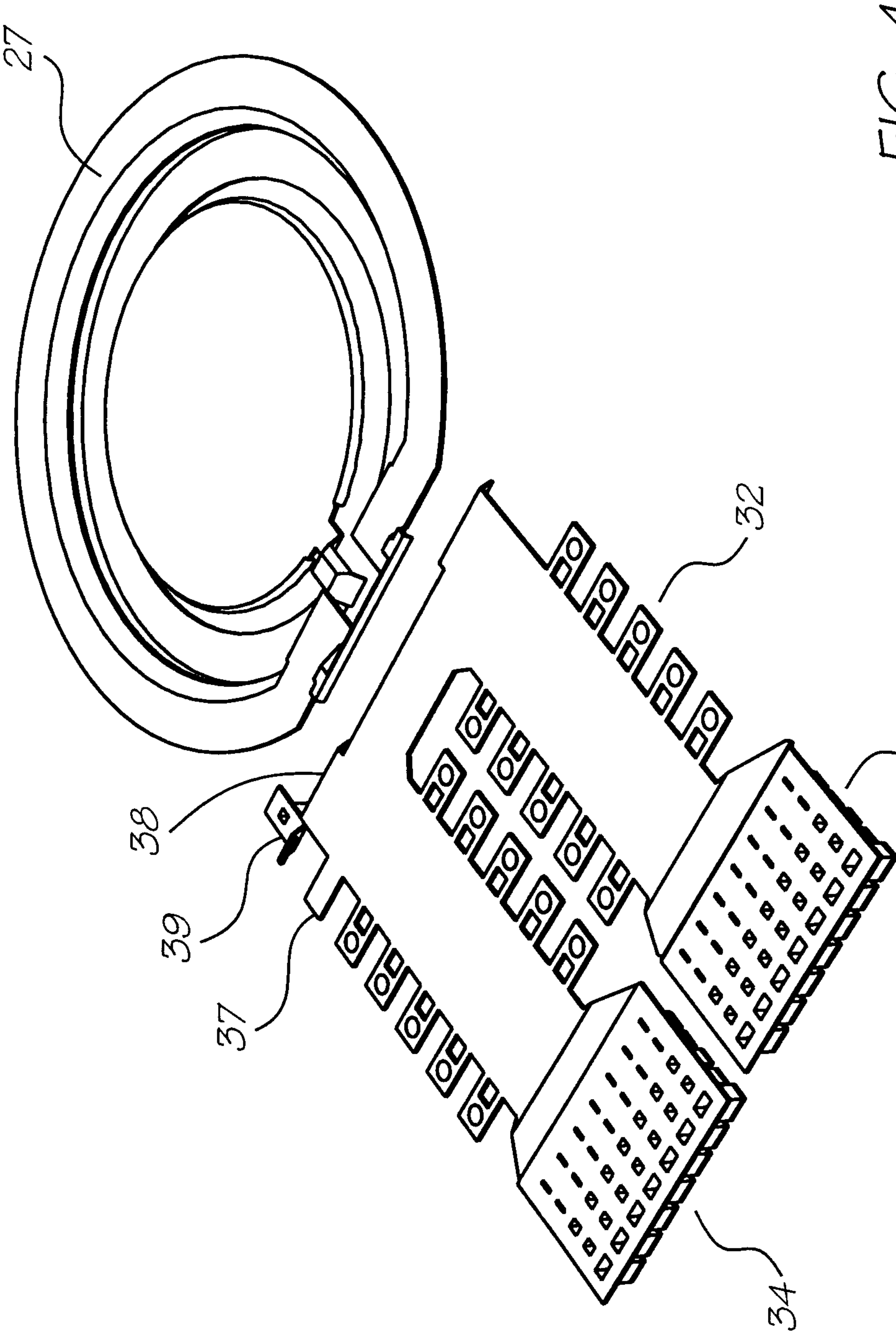


FIG. 4

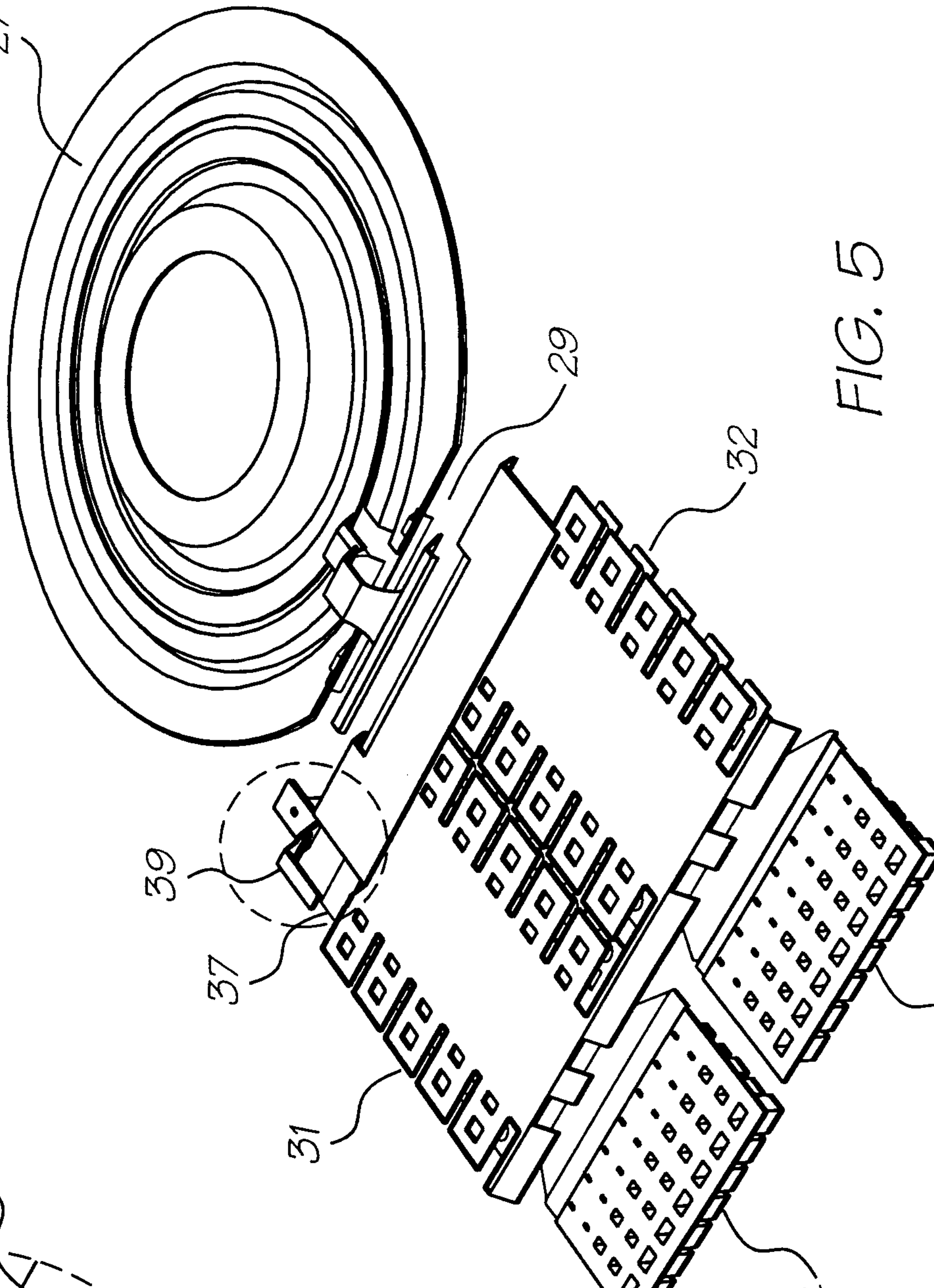


FIG. 5

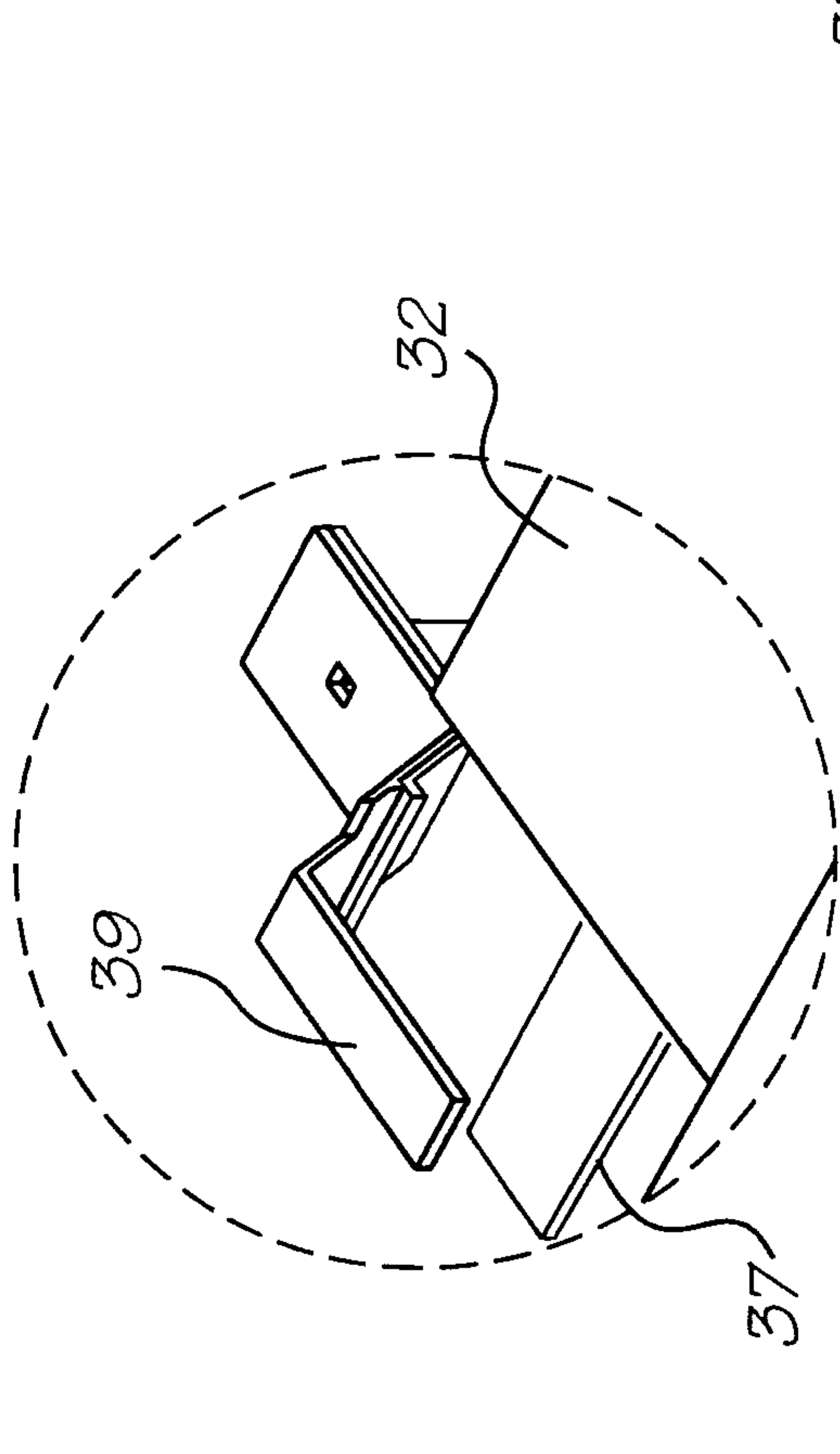


FIG. 6

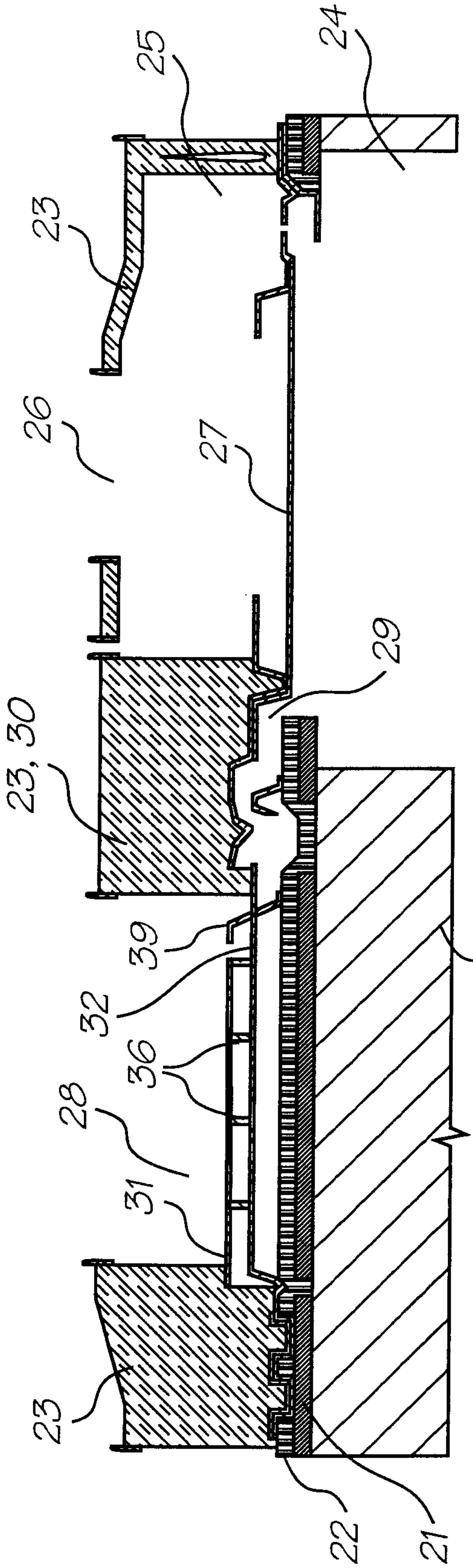


FIG. 7

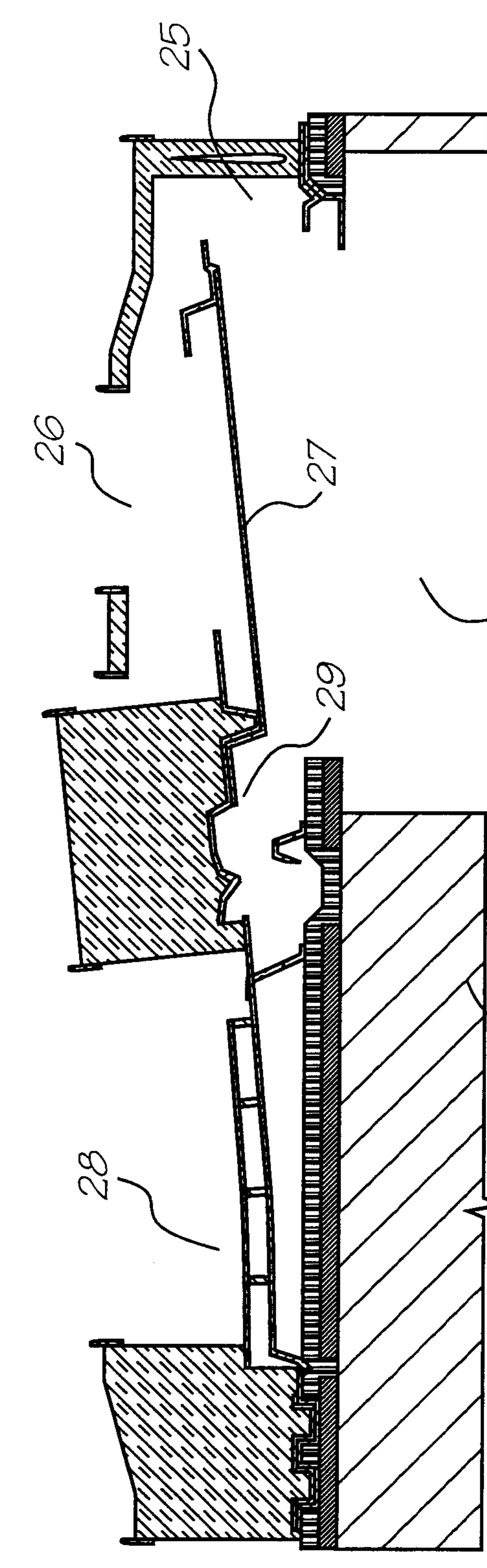


FIG. 8

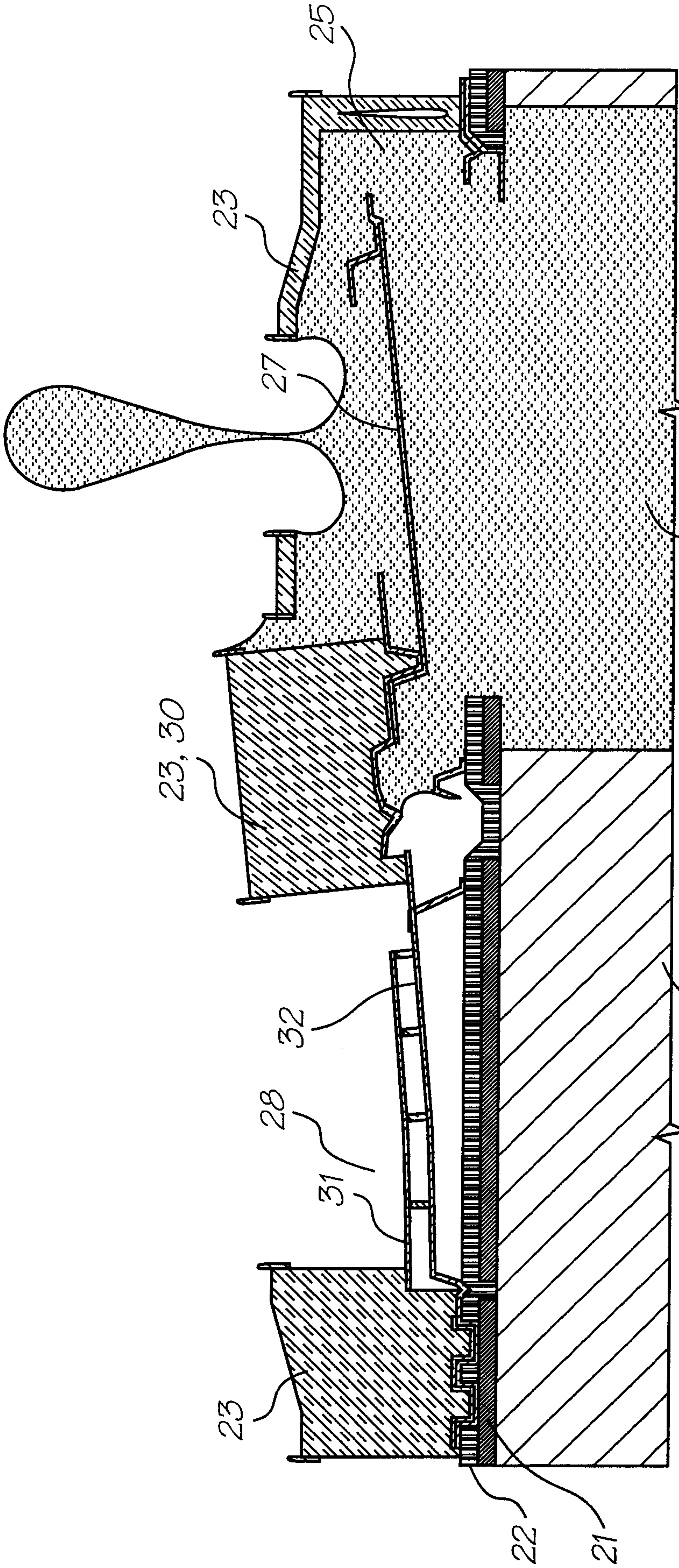


FIG. 9

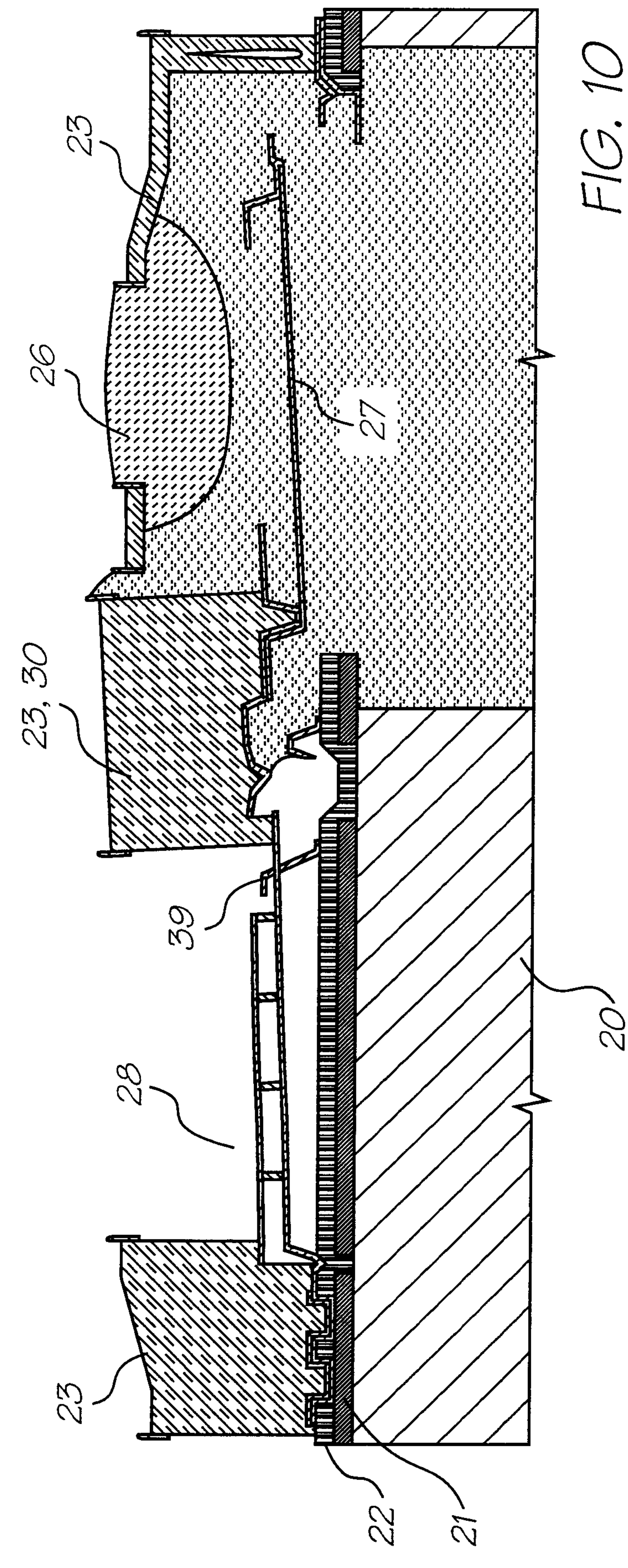


FIG. 10

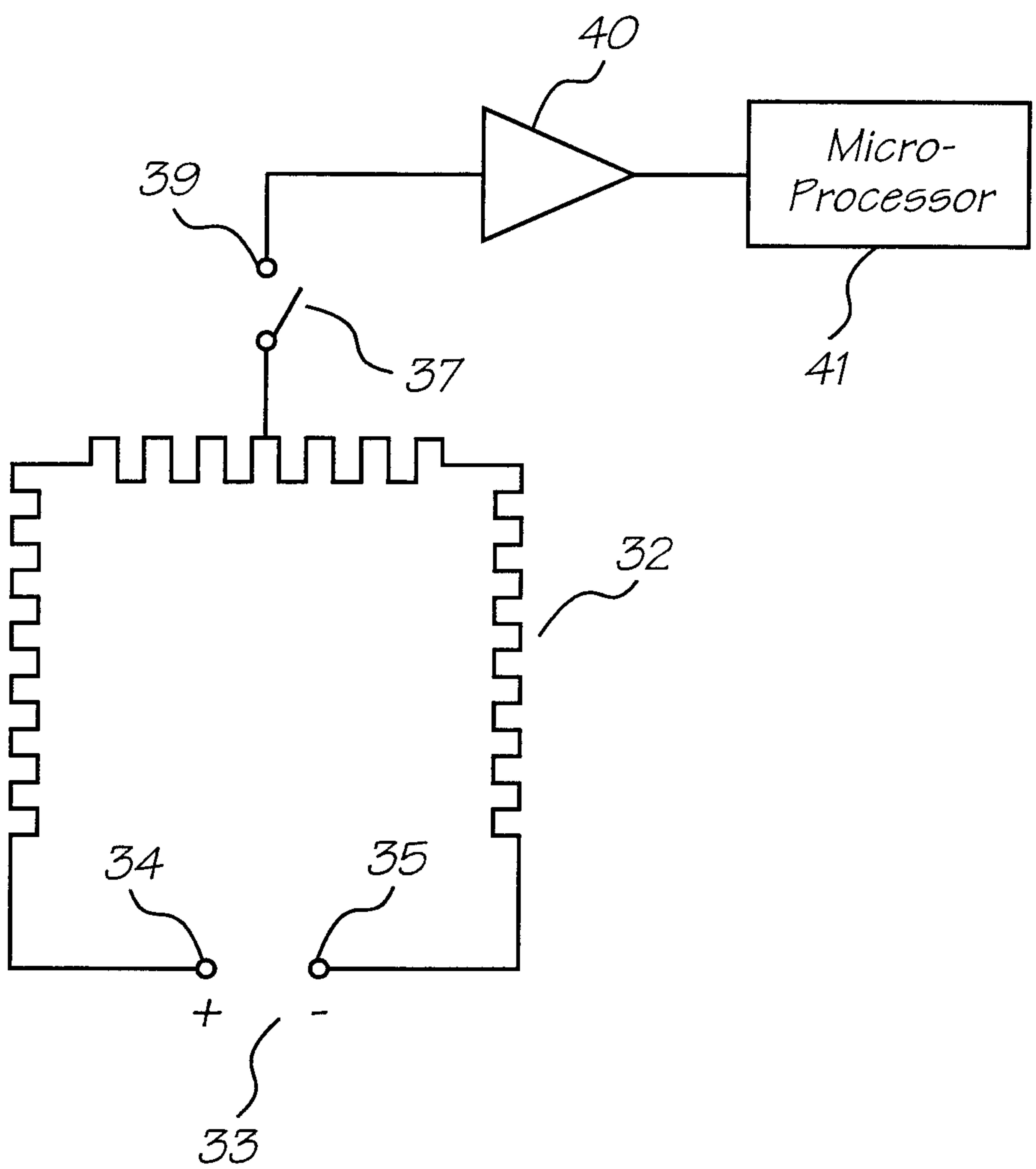


FIG. 11

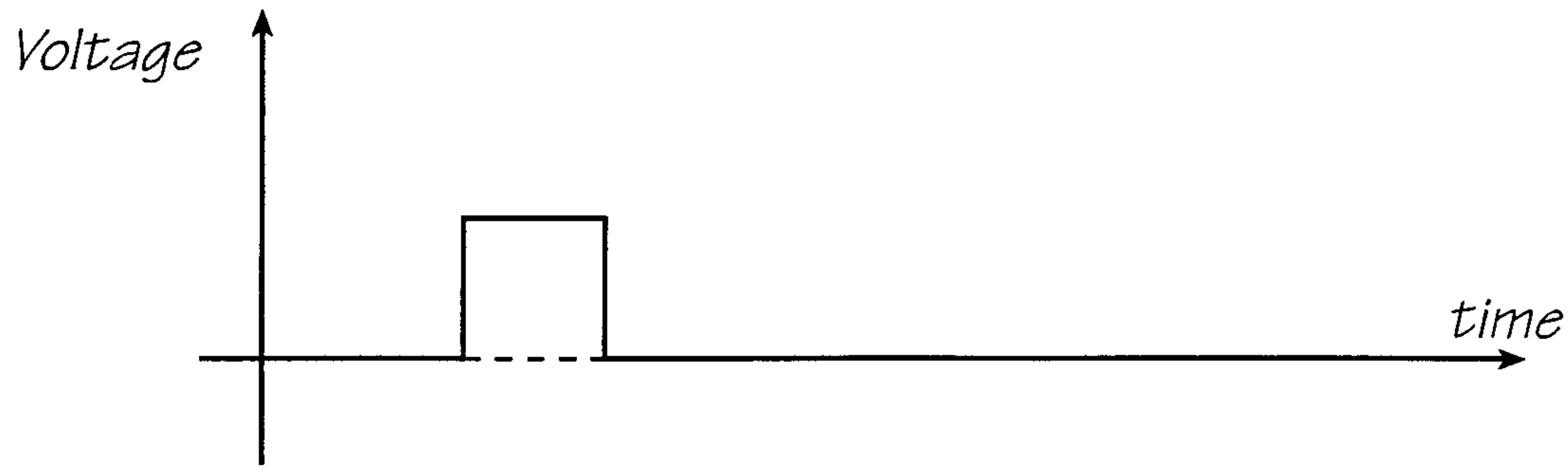


FIG. 12

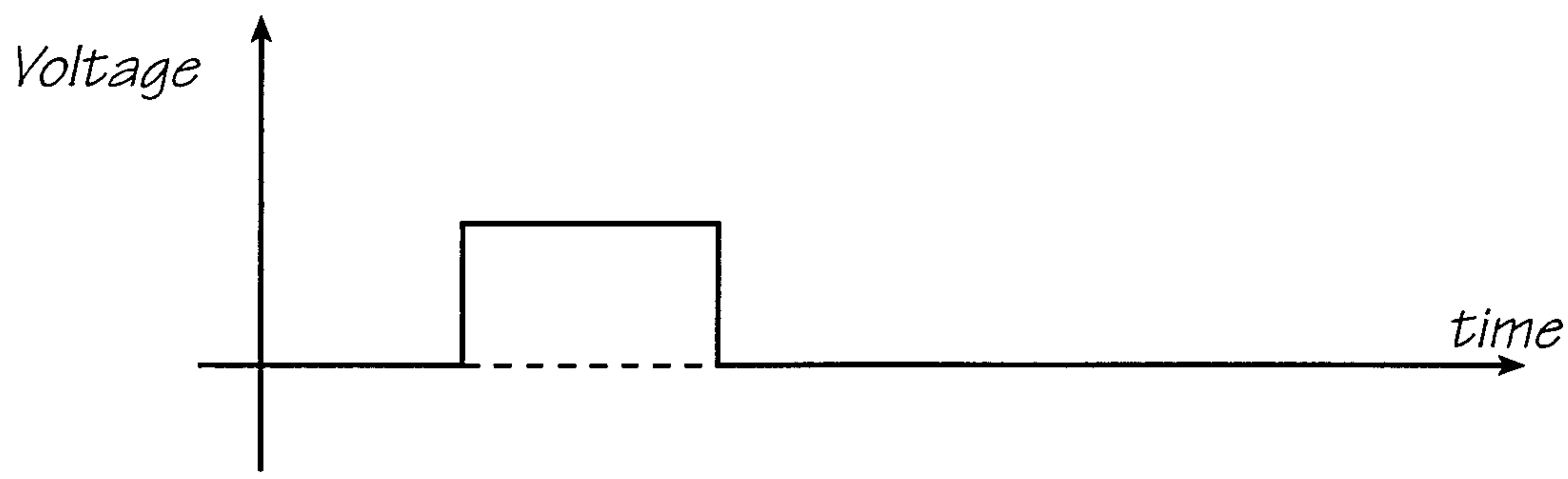


FIG. 13

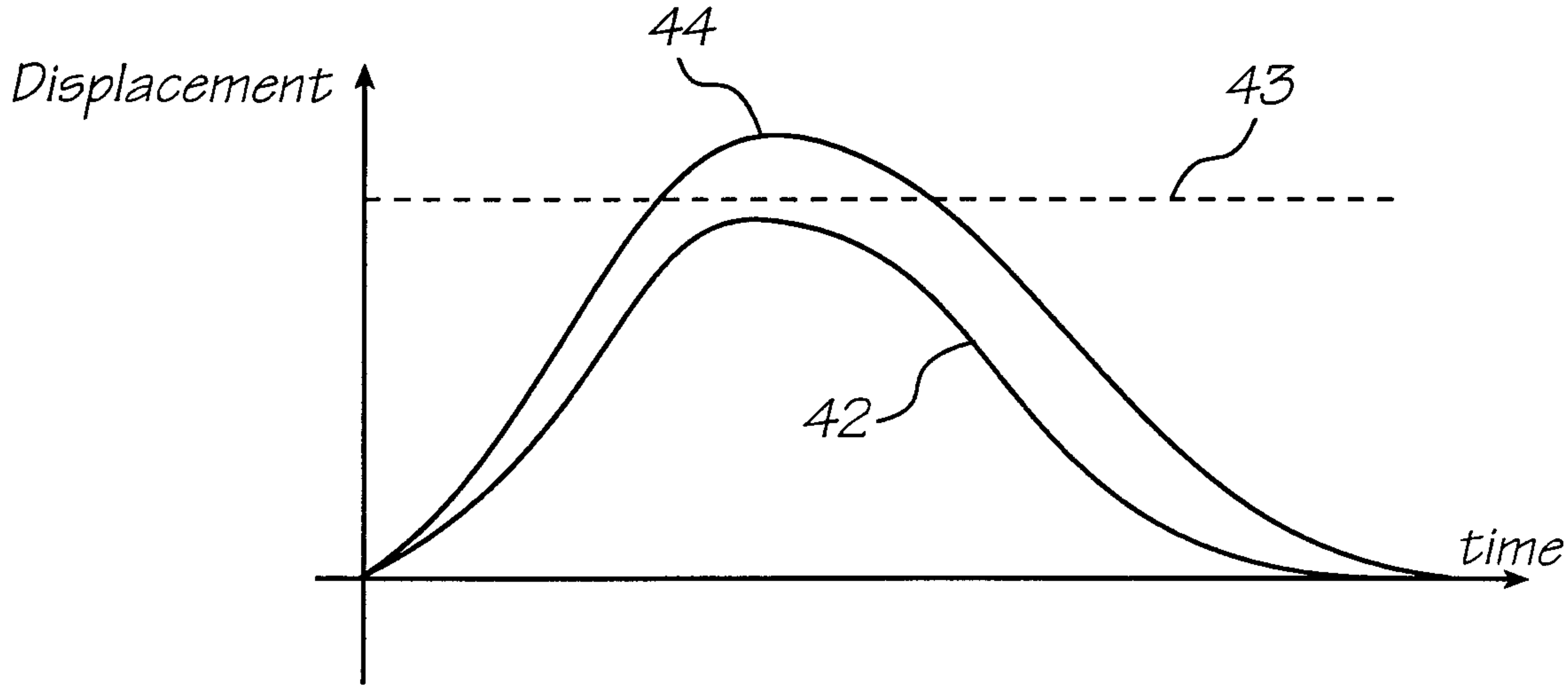


FIG. 14

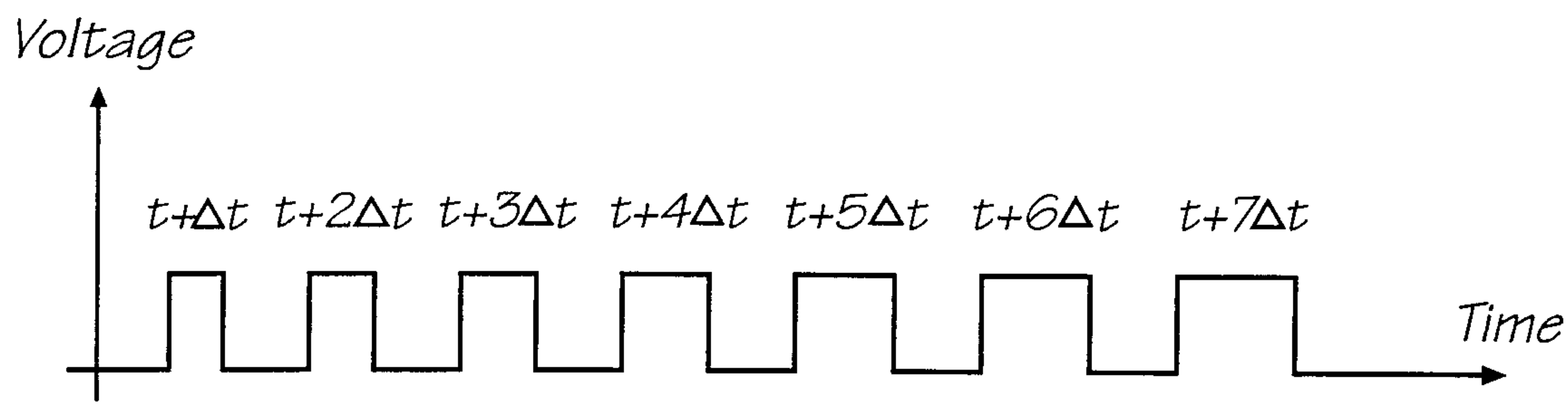


FIG. 15

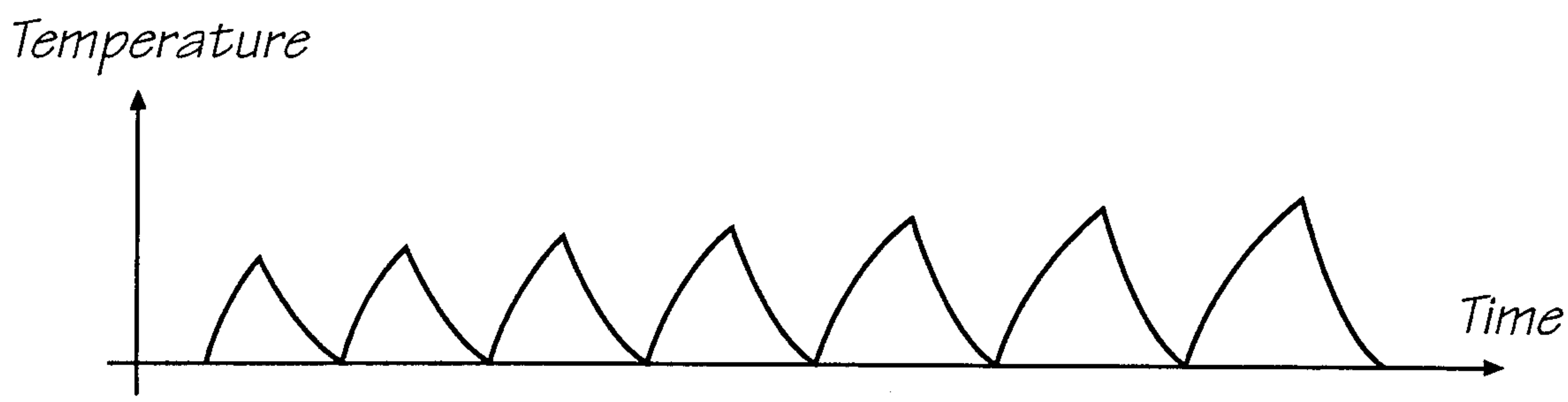


FIG. 16

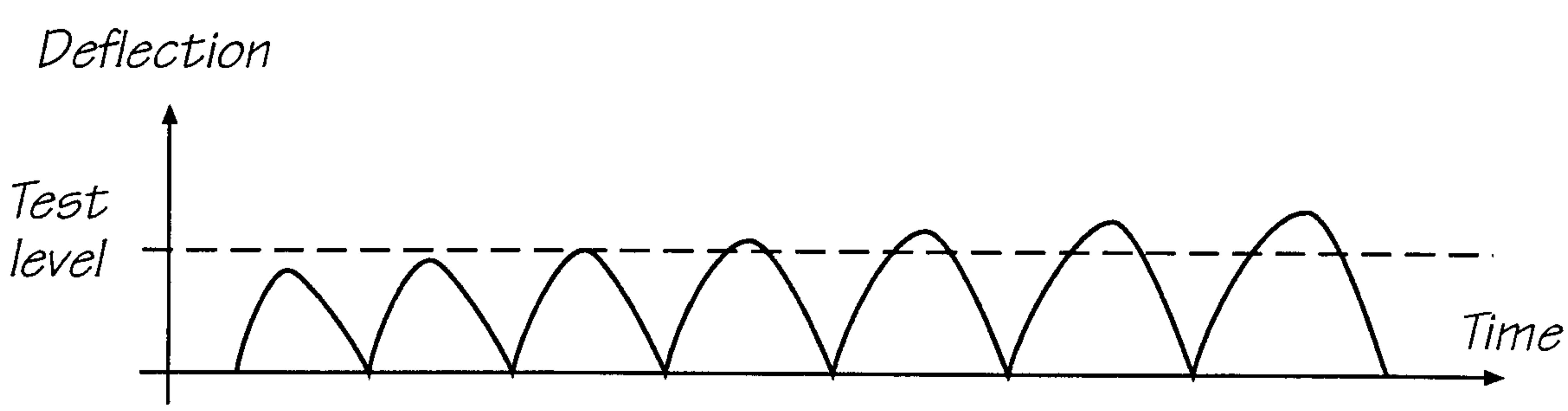
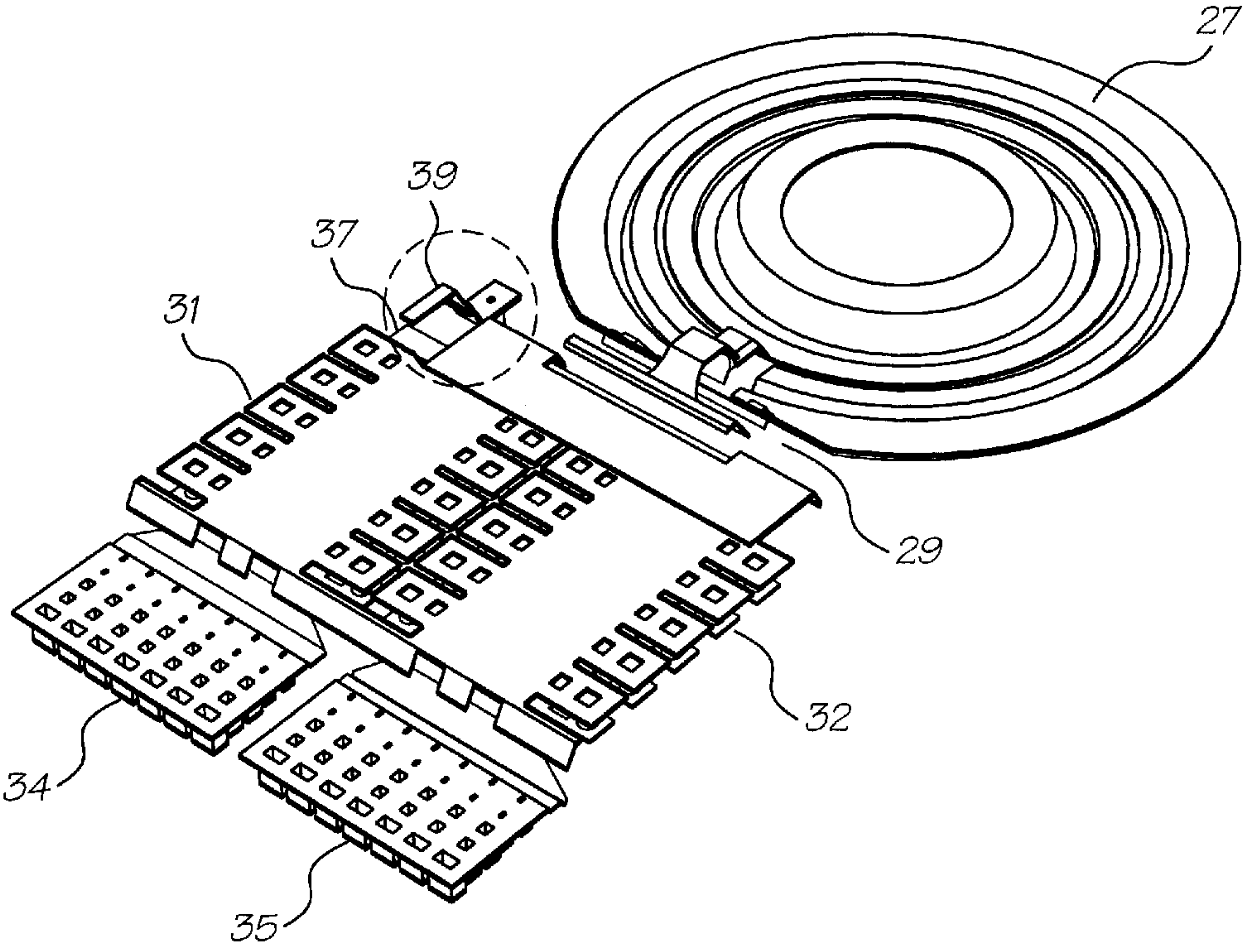


FIG. 17


27
39
37
31
29
32
34
35