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(54) Lead frame for electroacoustic transducer and electroacoustic transducer

(57) A lead frame (1) for an electroacoustic transducer, forming leads of the electroacoustic transducer, comprising a metal sheet (2) made of a metal having elongation 20% or higher, a nickel undercoat deposit (3) of a thickness in the range from 0.01 to 2.0 μm formed on the metal sheet (2) by plating in a nickel plating bath containing no brightening agent, and a solder deposit (4) of a thickness in the range from 1.0 to 10 μm formed on the surface of the nickel undercoat deposit (3) by plating in a tin-lead plating bath containing no brightening agent. With the lead frame (1) formed by plating the metal sheet (2) as stated above, micro-cracking occurring in the bent corners of the metal sheet (2) and the solder deposit (4), when the outer leads of the lead frame (1) are bent at an angle of 90°, can be prevented.

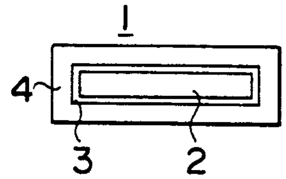

FIG. 3

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Description

This invention relates to a lead frame used for connection of electronic devices, more particularly, internal and external connections of an electroacoustic transducer such as a sounder, a speaker, a microphone, an earphone, a pickup, a magnetic head and the like.

By way of example, a sounder, which is a kind of electroacoustic transducer, is described hereafter.

A lead frame 1 as shown in Fig. 4 is formed by etching or punching a metal sheet. Leads, 6A, 6B, 6C, and 6D, of the lead frame are inner leads, on which a base is integrally formed, as shown by the phantom line in Fig. 4, with a base member having a pole piece (not shown) using synthetic resin; after connecting the end of a coil wound around the pole piece on the base to one of the inner leads, a case made of synthetic resin for forming an acoustic resonator is joined with the base such that an electroacoustic transducer device is enclosed therein. Also, the lead frame has other leads, 7A, 7B, 7C, and 7D, which are outer leads and are bent at an angle of 90° to form leads for connection with external circuits, completing an electroacoustic transducer. Reference numeral 5 in Fig. 4 indicates guide holes, through which finishing work of the lead frame 1 and molding work on the surface of the lead frame 1 are provided. The leads for connection with the external circuits are important parts to be soldered to a printed board for surface-mounting.

Various alloys (hereafter referred to as "metal") including Cu-Zn based alloys (for example, one containing 30% Zn, or one containing 40% Zn), and Cu-Sn based alloys (for example, one containing 4% Sn, 0.2% P, and balance Cu) have recently come into use for forming a lead frame of an electroacoustic transducer as stated above.

In the case of the Cu-Zn based alloys and Cu-Sn based alloys mentioned as above, metals having elongation in the range from 5 to 50% have been in use for forming metal sheets as material for the lead frame to prevent cracking from occurring when bending the metal sheets.

More specifically, a Cu-Zn based alloy containing 30% Zn formed in the shape of a strip which is undercoated by Cu to a thickness of 1 μm and then bright tin-lead plated to a thickness in the range from 5 to 7 μm on the surface of the Cu undercoat is in use for forming the lead frames; the reason for application of a bright plating method in this instance being to improve the solderability of the metal sheet. Also, other alloys, for example, a Cu-Sn-P alloy containing 4% Sn and 0.2% P which is undercoated by nickel to a thickness in the range from 2 to 5 μm and then bright tin-lead plated to a thickness from 5 to 7 μm on the surface of the Ni undercoat is in use as well.

When the lead frame formed by the metal sheet thus plated is resin sealed and outer leads thereof are bent at an angle of 90° in the final stage of processing, micro-cracking occurs in the bent corners of the lead frame causing nonwetting of solder in the bent region to proceed with time and subsequently resulting in poor solderability when the lead frame is mounted on a printed board.

Another problem with Cu-Zn based alloys is that use of the metal for forming the lead frame will cause zinc to be precipitated and diffused in a tin-lead deposit when the metal is solder plated, resulting in significant deterioration of solder wettability.

Similarly, when the outer leads of the lead frame formed by bright-solder-plating the metal sheet of a Cu-Sn based alloy are bent at an angle of 90°, micro-cracking occurs in a tin-lead deposit, even though no micro-cracking occurs in the metal sheet, resulting in poor solderability when connecting the outer leads to the leads of external devices for mounting the lead frame on a printed board.

Such poor solderability stated as above at the time of mounting the lead frame poses a serious problem in respect of reliability of an electroacoustic transducer.

It has become apparent from the examination of the causes of defects with electroacoustic transducers that solder melted when a lead frame is mounted on a printed board is not flowing into cracks, resulting in defective connections, which is one of the causes.

In view of the problems stated as above, preferably the present invention provides a lead frame to which economical plating is applied and which can be put to use for fabricating a highly reliable electroacoustic transducer. The lead frame of the invention is characterized in that it is formed from a metal sheet of a metal having elongation 20% or higher and its surface or at least its lead region is undercoated in a nickel plating bath containing no brightening agent and a nickel undercoat deposit thus formed is further plated on in a tin-lead plating bath containing no brightening agent.

The plating according to the invention is applied in a nickel plating bath and a tin-lead plating bath, respectively, neither of which contains a brightening agent comprising organic compounds such as thiourea, saccharin, grape sugar, and the like or inorganic compounds such as thiosulfate and the like; the reason for such a practice being that plating a metal sheet in a plating bath containing a brightening agent turns the surface of metallic deposit brighter and into a fine structure, making the metallic deposit susceptible to cracking when the lead frame is worked by bending. Plating applied in a plating solution containing no brightening agent is hereafter referred to as "dull plating".

An ordinary nickel plating bath, watts nickel bath, semi-bright nickel plating bath, nickel sulfamate plating bath, and the like are available for nickel plating. However, the watts nickel bath is particularly preferable. A tin-lead borofluoride plating bath, methansulfonic acid plating bath, and the like are available for solder plating, but the methansulfonic acid plating bath is preferable.

Further, the metal sheet in the shape of a strip of the invention is specified to use an alloy having elongation 20% or higher because if a metal sheet formed by a metal having elongation less than 20% is worked by press working or etching and then plated on, cracking occurs in the corners of the leads when the metal sheet is bent, resulting in nonwetting of solder due to oxidation of an undercoat deposit proceeding with time.

That is, a lead frame 1 according to the invention is illustrated in Fig. 3. The lead frame 1 of the invention is obtained by forming a metal sheet 2 of an alloy having elongation 20% or higher into the shape of the lead frame 1 by press working or etching, applying dull nickel plating on the surface of the metal sheet 2 to form a nickel undercoat deposit 3 of a thickness in the range from 0.01 to 2.0 μm, preferably, from 0.05 to 0.3 μm, and further solder plating the surface of the nickel deposit forming a dull tin-lead deposit, i.e., solder deposit 4 of a thickness in the range from 1 to 10 μm, preferably, from 5 to 7 μm as shown in Fig. 3. Such nickel plating and solder plating should be applied to the entire surface of the lead frame 1 or at least the leads thereof; metallic deposit of a desired thickness can be formed by electroplating and for solder plating, use of solder consisting of 90% Sn and 10% Pb is particularly preferable.

Metals preferably chosen as material for the metal sheet 2 according to the invention are Fe-Ni based alloys containing 35.5 to 36.5% Ni, containing 40.5 to 41.5% Ni, and containing 49.5 to 51.5% Ni, and Cu-alloys such as brass, phosphor bronze, and phosphor bronze for springs. However, other metals are also suitable for the purpose if they have elongation 20% or higher, good affinity with a Ni deposit undercoated, and good wettability by solder.

Fe-Ni based alloys having elongation 20% or higher can be obtained by a process wherein a draft of temper rolling after recrystallization annealing is set at 10% or lower; further treatment by stress-relieving annealing applied after the temper rolling may enhance elongation still higher, but stress-relieving annealing at temperatures between 500° and 600° C is preferable to avoid a decline in strength; elongation 20% or higher is obtainable by providing annealing for refining at temperatures between 600° and 700° C after rolling, however, fluctuation in the quality of the metal sheet 2 treated with temper rolling is less in magnitude than that of the metal sheet 2 treated with annealing for refining.

Cu-alloys can attain elongation 20% or higher by setting a draft of temper rolling at 20% or lower in the case of brass, 15% or lower in the case of common grade phosphor bronze, and 25% or lower in the case of phosphor bronze for springs.

The lead frame 1 of the invention is constituted as described in the foregoing such that cracking which will occur when the lead portion of the metal sheet 2 is bent at an angle of 90° can be prevented by use of a metal having elongation 20% or higher, diffusion of constituent elements of the metal sheet 2 can be prevented by nickel plating the surface of the lead portion which is to be surface-mounted on a printed board, and micro-cracking of metallic deposits formed by plating can be prevented from occurring when the metal sheet 2 is bent at an angle of 90° by dull plating the surface of the metal sheet 2 with nickel and tin-lead, respectively.

A thickness of the nickel undercoat deposit 3 formed by dull nickel plating needs to be in the range from 0.01 to 2 μm because if it is less than 0.01 μm, the nickel deposit will lose its effect as a barrier to diffusion of alloying elements and impurity elements contained in the metal sheet 2 which will occur when the metal sheet 2 is heated for synthetic resin sealing while if it exceeds 2 μm, the nickel deposit will be less effective and uneconomical; therefore, the nickel deposit thickness in the range from 0.05 to 0.3 μm is preferable.

If the conventional method of bright nickel plating is applied, a nickel deposit electroplated on the metal sheet 2 becomes harder than the metal sheet 2 and its workability becomes poorer because the nickel deposit turns microcrystalline and many distortions are formed on its surface. As a result, cracking occurs when outer leads are being bent, resulting in defective leads.

In particular, requirements for the lead frame 1 of an electroacoustic transducer are very severe such that the radius (r) of curvature must be 0.5 mm or less for bending the outer leads, and a ratio of the radius to the metal sheet thickness (t), r/t, must be 2.5 or less. Thus, excellent workability is required of a metallic deposit formed by plating and this is why the present invention has adopted a dull nickel plating method.

A tin-lead deposit thickness in the range from 1 to 10 μm is preferable because if it is less than 1 μm, soldering strength is insufficient to mount the lead frame 1 on a printed board while if it exceeds 10 μm, the deposit thickness is excessive and uneconomical. Therefore, a tin-lead deposit thickness in the range from 5 to 7 μm is preferable. The invention has adopted a dull solder plating method for the same reason as in the case of the nickel plating.

The above and other objects, features, and advantages of the invention will be apparent from the following detailed description of the preferred embodiments of the invention in conjunction with the accompanying drawings.

Fig. 1 is a chart (Table 1) showing the structure and characteristics of exemplary lead frames embodying the invention.

Fig, 2 is a chart (Table 2) showing the structure and characteristics of exemplary lead frames for comparative study.

Fig. 3 is a sectional view of the lead frame for an electroacoustic transducer according to the invention.

Fig. 4 is a plan view of a metal sheet after press working for the lead frame for an electroacoustic transducer.

The present invention will be described in further detail referring to the preferred embodiments stated hereafter.

The preferred composition and condition of the dull plating bath according to the invention are as follows:

A. the composition of the dull nickel plating bath

nickel sulfate :	200 g/L to 250g/L
nickel chloride :	35 g/L to 45 g/L
boric acid :	20 g/L to 30 g/L
pH :	4 to 5
temperature of plating bath:	40° C to 55° C
electric current density :	1 A/dm^2 to 8A/dm^2

B. the composition of the dull tin-lead bath

tin (II) borofluoride :	80 g/L to 120 g/L
lead borofluoride :	20 g/L to 40 g/L
free fluoroboric acid :	80 g/L to 120 g/L
free boric acid :	20 g/L to 30 g/L
B naphtol :	0.5 g/L to 3 g/L
formalin :	8 g/L to 15 g/L
pH :	4 to 5
temperature of plating bath :	15° C to 30° C
electric current density :	1A/dm^2 to 6A/dm^2

Testpieces each in the form of a strip, 10 mm in width, and 100 mm in length, were prepared by cutting, in the direction of rolling, metal sheets 2 made of 0.2 mm thick metals having elongation 20% comprising Fe-alloys containing 36% Ni, 42% Ni, and 50% Ni, respectively, and copper alloys comprising brass and phosphor bronze specified by JIS H 3110 and phosphor bronze for spring specified by JIS H 3130. The testpieces, referred to hereafter as embodiments 1 to 6 of the invention, were subjected to following tests for evaluation:

the test condition under which dull nickel plating is conducted

(1)	composition of plating bath	
	nickel sulfate :	240 g/L
	nickel chloride :	45 g/L
	boric acid :	30 g/L
	pH :	5.0
(2)	temperature of plating bath :	50° C
(3)	electric current density :	5A/dm^2

the test condition under which dull solder plating is conducted

(1)	composition of plating bath	
	tin (II) borofluoride :	80 g/L
	lead borofluoride :	10 g/L
	free fluoroboric acid :	100 g/L
	free boric acid :	25 g/L
	B naphtol :	1 g/L
	formalin :	20 g/L
	pH :	5.0
(2)	temperature of plating bath :	25° C
(3)	electric current density :	3A/dm^2

Additional testpieces in a strip form, each having the same dimensions as that of the testpieces stated above, that is, 0.2 mm in thickness, 10 mm in width, and 100 mm in length, were prepared for comparative study by cutting metals of the same kinds as stated above but having elongation less than 20%. These test- pieces were subjected to the following evaluation tests:

test condition under which bright nickel plating is conducted

(1)	composition of plating bath	
	nickel sulfate :	300 g/L
	nickel chloride :	50 g/L
	boric acid :	40 g/L
	brightening agent (saccharin) :	1.5 g/L
	pH :	4.5
(2)	temperature of plating bath :	50° C
(3)	electric current density :	5A/dm^2

test condition under which bright solder plating is conducted

(1)	composition of plating bath	
	tinn (II) borofluoride :	150 g/L
	lead borofluoride :	50 g/L
	free fluoroboric acid :	100 g/L
	free boric acid :	25 g/L
	B naphtol :	1 g/L
	formalin :	20 g/L
	brightening agent :	60 g/L
	(aldehyde amine based)	
	pH :	5.0
(2)	temperature of plating bath :	25° C
(3)	electric current density :	3A/dm^2

The composition of the metals from which the testpieces were made are as follows:

Fe-36% Ni Alloy: 36.1% Ni, 0.3% Mn, 0.1% Si, 0.003% C, balance Fe
Fe-42% Ni Alloy: 41.6% Ni, 0.5% Mn, 0.3% Si, 0.004% C, balance Fe
Fe-50% Ni Alloy: 49.8% Ni, 0.6% Mn, 0.4% Si, 0.003% C, balance Fe

phosphor bronze (1) :	3.8% Sn, 0.18% P, balance Cu
phosphor bronze (2) :	4.8% Sn, 0.20% P, balance Cu
phosphor bronze (3) :	6.1% Sn, 0.19% P, balance Cu
phosphor bronze (4) :	7.9% Sn, 0.21% P, balance Cu
70/30 brass (1) :	30.5% Zn, balance Cu
70/30 brass (2) :	35.8% Zn, balance Cu
70/30 brass (3) :	37.5% Zn, balance Cu
phosphor bronze for springs :	7.9% Sn, 0.20% P, balance Cu

Evaluation tests were conducted on the above testpieces in simulation of plating and actual surface-mounting on printed boards.

(1) metallic deposit adhesion :

After undercoating as predetermined and solder (90% Sn-10%Pb) plating on metal sheets 2, the testpieces were bent (Radius at 0.2 mm) at an angle of 90° to the line in parallel with the rolling direction of the metal sheet 2 to observe whether or not metallic deposits peel off.

(2) metallic deposit solderability :

After applying rosin-alcohol based flux to testpieces undercoated as predetermined and solder plated, the testpieces were immersed in a 60%SN-40% Pb plating bath kept at 230 C° for 5 seconds to observe a solder wetting area.

(3) solderability after heat resistance test :

Testpieces were prepared by undercoating as predetermined and then solder plating metal sheets 2; subsequently, the testpieces were bent at an angle of 90° to the line in parallel with the rolling direction of metal sheets 2 and heated in an atmosphere at 150° C for 24 hours and then solder plated in a manner described in (2) above. The results of respective tests are shown in Tables 1 and 2.

Respective properties were rated as follows:

metallic deposit adhesion: the testpieces were bent at an angle of 90° to check metallic deposits peeling off.
metallic deposit solderability: rated "satisfactory" if a solder wetting area is 95% or higher, and "unsatisfactory" if the same is less than 95%.
solderability after heat resistance test: rated in the same manner as above.

As is evident from Tables 1 and 2, the embodiments No. 1 to No. 6 turned out to be highly reliable when actually mounted on the printed board in comparison with other testpieces No. 7 to No. 12. Also, as in the case of test piece No. 12 where phosphor bronze for springs having elongation 20% or higher was used, the results of a 90° bending test shows that cracking was observed in the bent corners of the nickel deposit when the test piece was bright nickel plated and another test simulating actual mounting of the lead frame 1 on the printed board shows poor wettability by solder and low reliability of the test piece.

As stated in detail in the foregoing, highly reliable electroacoustic transducers can be fabricated by use of the lead frame 1 of the invention taking full advantage of high elongation ratio of its metal sheet 2 and characteristics of solder plating. Furthermore, the lead frame 1 is expected to be quite effective for use in electronic devices where high elongation ratio of metal sheets 2 and solder plating are required and severe working by bending needs to be applied.

It is to be understood that the present invention is not limited in its application to the scope of the preferred embodiments stated above and that the lead frame 1 of the invention is of course applied with equal utility to not only electroacoustic transducers but also various other equipments.

Claims

1. A lead frame (1) for an electroacoustic transducer, forming leads of the electroacoustic transducer, comprising a metal sheet (2) made of a metal having elongation 20% or higher, a nickel undercoat deposit (3) of a thickness in the range from 0.01 to 2.0 μm formed on the metal sheet (2) by plating in a nickel plating bath containing no brightening agent, and a solder deposit (4) of a thickness in the range from 1.0 to 10 μm formed on the surface of the nickel undercoat deposit (3) by plating in a tin-lead plating bath containing no brightening agent.

2. A lead frame (1) for an electroacoustic transducer according to claim 1 wherein said metal sheet (2) is formed by working a metal selected from a group of metals comprising Fe-Ni based alloys, brass, phosphor bronze, and phosphor bronze for use in springs.

3. A lead frame (1) for an electroacoustic transducer according to claim 1 wherein said metal sheet (2) is formed by working a Fe-Ni based alloy temper rolled at a draft of 10% or less after recrystallization annealing.

4. A lead frame (1) for an electroacoustic transducer according to claim 1 wherein said metal sheet (2) is formed by working a brass temper rolled at a draft of 20% or less after recrystallization annealing.

5. A lead frame (1) for an electroacoustic transducer according to claim 1 wherein said metal sheet (2) is formed by working a common phosphor bronze temper rolled at a draft of 15% or less after recrystallization annealing.

6. A lead frame (1) for an electroacoustic transducer according to claim 1 wherein said metal sheet (2) is formed by working a phosphor bronze for use in springs after temper rolling at a draft of 25% or less after recrystallization annealing.

7. An electroacoustic transducer comprising said lead frame (1) for an electroacoustic transducer according to claims 1, 2, 3, 4, 5, or 6 for use as leads.

Table 1

No.	Metal Sheet (grade)	Elongation (%)	Undercoating		Solder Plating		Evaluation		
			thickness (μm)	plating method	thickness (μm)	plating method	metallic deposit adhesion (peeling)	solderability	solderability
1	Fe alloy (Ni 36%)	25	0.05	dull Ni electroplating	6.4	dull electroplating	none	satisfactory	satisfactory
2a	Phosphor bronze (1)	31	0.1	dull Ni electroplating	4.3	dull electroplating	none	satisfactory	satisfactory
2b	Phosphor bronze (2)	23	0.1	dull Ni electroplating	4.3	dull electroplating	none	satisfactory	satisfactory
2c	Phosphor bronze (3)	31	0.1	dull Ni electroplating	4.3	dull electroplating	none	satisfactory	satisfactory
2d	Phosphor bronze (4)	27	0.1	dull Ni electroplating	4.3	dull electroplating	none	satisfactory	satisfactory
3	Fe alloy (Ni 42%)	28	0.07	dull Ni electroplating	7.0	dull electroplating	none	satisfactory	satisfactory
4	Fe alloy (Ni 50%)	22	0.15	dull Ni electroplating	3.7	dull electroplating	none	satisfactory	satisfactory
5a	70/30 brass (1)	37	0.1	dull Ni electroplating	6.1	dull electroplating	none	satisfactory	satisfactory
5b	70/30 brass (2)	31	0.1	dull Ni electroplating	6.1	dull electroplating	none	satisfactory	satisfactory
5c	70/30 brass (3)	30	0.1	dull Ni electroplating	6.1	dull electroplating	none	satisfactory	satisfactory
6	Phosphor bronze for springs	40	0.5	dull Ni electroplating	5.2	dull electroplating	none	satisfactory	satisfactory

FIG. 1

Table 2

No.	Metal Sheet (grade)	Elongation (%)	Undercoating		Solder Plating		Evaluation		
			thickness (µm)	plating method	thickness (µm)	plating method	metallic deposit adhesion (peeling)	solderability	solderability after heat resistance test
7a	Fe alloy (Ni 36%)	7	0.03	bright Ni electroplating	5.8	dull electroplating	yes	unsatisfac-tory	unsatisfac-tory
7b	Fe alloy (Ni 36%)	11	0.03	bright Ni electroplating	5.8	dull electroplating	yes	unsatisfac-tory	unsatisfac-tory
8a	Phosphor bronze (1)	15	0.1	dull Cu electroplating	4.4	bright electroplating	yes	unsatisfac-tory	unsatisfac-tory
8b	Phosphor bronze (2)	13	0.1	dull Cu electroplating	4.4	bright electroplating	yes	unsatisfac-tory	unsatisfac-tory
8c	Phosphor bronze (3)	14	0.1	dull Cu electroplating	4.4	bright electroplating	yes	unsatisfac-tory	unsatisfac-tory
8d	Phosphor bronze (4)	12	0.1	dull Cu electroplating	4.4	bright electroplating	yes	unsatisfac-tory	unsatisfac-tory
9a	Fe alloy (Ni 42%)	11	0.05	dull Ni electroplating	6.0	bright electroplating	yes	unsatisfac-tory	unsatisfac-tory
9b	Fe alloy (Ni 42%)	13	0.05	dull Ni electroplating	6.0	bright electroplating	yes	unsatisfac-tory	unsatisfac-tory
10a	Fe alloy (Ni 50%)	4	0.1	dull Ni electroplating	0.5	bright electroplating	yes	unsatisfac-tory	unsatisfac-tory
10b	Fe alloy (Ni 50%)	9	0.1	dull Ni electroplating	0.5	bright electroplating	yes	unsatisfac-tory	unsatisfac-tory
11a	70/30 brass (1)	18	0.6	bright Cu electroplating	6.5	dull electroplating	yes	unsatisfac-tory	unsatisfac-tory
11b	70/30 brass (2)	15	0.6	bright Cu electroplating	6.5	dull electroplating	yes	unsatisfac-tory	unsatisfac-tory
11c	70/30 brass (3)	16	0.6	bright Cu electroplating	6.5	dull electroplating	yes	unsatisfac-tory	unsatisfac-tory
12a	Phosphor bronze for spring	25	0.7	bright Ni electroplating	5.0	bright electroplating	yes	unsatisfac-tory	unsatisfac-tory
12b	Phosphor bronze for spring	17	0.7	bright Ni electroplating	5.0	bright electroplating	yes	unsatisfac-tory	unsatisfac-tory

FIG. 2

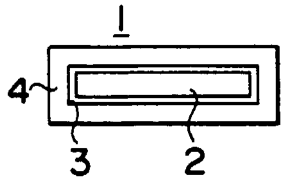

FIG. 3

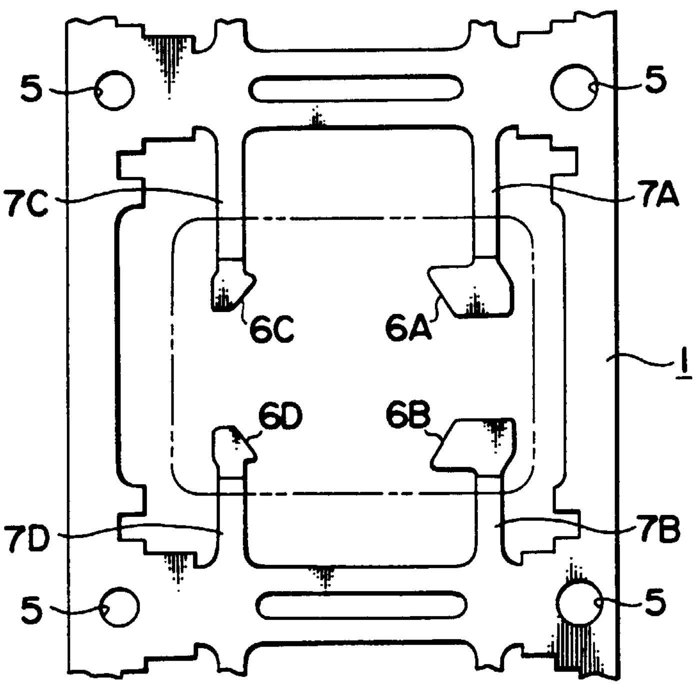

FIG. 4