One of the currently widely used plastic packages for two-lead semiconductor devices, such as diodes - particularly rectifiers (currents of up to about 1 A and reverse voltages of about 100 V to 2 kV) -, varistors or thermistors, has the shape of a cylinder with leads projecting in the same axis. The semiconductor die and the inner ends of its leads are hermetically embedded in the plastic, e.g., a thermoplastic or a thermosetting plastic, and thus protected from physical damage and chemical influences, such as the entrance of moisture.

In the fabrication of such semiconductor devices with a plastic package, the manufacture of the die starts with a semiconductor wafer on which several 100 to several 1000 identical dies are fabricated, and the leads for the semiconductor device are designed as so-called head leads, i.e., leads having a thickened, e.g., upset, portion at one end, the "head". Between the two heads, the die is attached by soldering, for example.

To achieve a high throughput, a large number of untinned head leads is fed into magazines, a die is positioned on

each of the heads, and the heads of other head leads fed into a further magazine are placed on the dies. In a furnace, each of the dies is then connected with its two associated head leads by soldering. If the finished semiconductor device is to have a high reverse voltage, the soldered dies are etched and covered with a suitable plastic.

Next, the semiconductor devices are transferred into molds where they are embedded in plastic. Only then are the leads of the individual semiconductor devices tinned, which is done by barrel tinning to achieve a high throughput.Then, however, the leads, which are bent during the tinning process, must be axially aligned again in suitable straightening devices. Only then are they tested, taped, and lettered.

Conventional straightening devices have an hourly throughput of about 20,000 semiconductor devices. As the prices of semiconductor devices are still falling, this throughput rate is much too low if low-cost volume production is to be achieved.

Although the manufacturing process described is a well-proved high-volume process, efforts are being made to modify it, particularly ith a view to further reducing the manufacturing costs, and to provide semiconductor devices which can be made at even lower cost.

U.S. Patent 3,127,285 discloses a diode whose semiconductor crystal is disposed between two ribbon-shaped, axially aligned leads, with each of the active regions of the semiconductor crystal connected to one of the leads. A protective, hermetic plastic coating surrounds the crystal and extends beyond the base of the leads.

European Patent 0 154 562 discloses a rectifier arrangement consisting of four semiconductor crystals (diodes) arranged in a stack between coaxial leads. The latter are offset and deformed to a paddle shape at the ends, between which the diodes are mounted.

Accordingly, the object of the invention as claimed is to provide a semiconductor device which has a plastic package that is of a different design than the hitherto widely used plastic packages to achieve a cost reduction. The design of the leads is to differ from the conventional design, too. In the method, the above-described

step of straightening the leads is to be eliminated. The same applies to the tinning following the molding or embedding. It is also within the scope of the object of the invention to provide an apparatus with which a higher hourly throughput of semiconductor devices is attainable.

One of the fundamental ideas of the invention is to manufacture the plastic package, hitherto formed by embedding or molding the die, as a can-shaped housing, henceforth called "can", in a separate step, which offers the advantage of greater freedom in the choice of the starting plastic and the temperatures and pressures to be used in the packaging process, for example, and to fill the can with a plastic compound, such as a cast resin, after insertion of the die.

Another fundamental idea of the invention is the completely different starting point for the manufacture of the leads, namely to form the latter from a wire unwinding from a spool, to run this wire through a major part of the manufacturing stages unseparated, and to separate it into the individual semiconductor devices only after formation of the plastic package, i.e., the mounting of the cans.

The invention offers the following advantages. A low-cost plastic may be used for the cans. The presses for

producing the can-shaped housings can be simpler in construction and, thus, smaller than the presses used so far. The need for the straightening device described is eliminated, so that a higher hourly throughput is possible. No polarity-determining device followed by a turnover device is necessary, so that the semiconductor devices can be taped in the same direction without the turnover device, since the dies can be brought from the semiconductor wafer to the positions between the leads with a predetermined polarity, which can be maintained until the taping takes place.

The invention will now be explained in greater detail with reference to the accompanying drawings, in which:

Fig. 1 is a perspective view of a preferred embodiment of the semiconductor device according to the invention;

Fig. 2 shows the course of the manufacture of a preferred embodiment of the invention, and

Fig. 3 shows an embodiment of the various stations of the apparatus according to the invention in a highly schematic representation.

The perspective view of Fig. 1 shows an embodiment of a finished semiconductor device according to the invention which comprises the cylindrical, can-shaped housing 1, henceforth called "can" for short, and the two leads 3.

At the front end 1b of the can 1, the filled-in and cured cast resin 2 can be seen. The rear lead 3 in Fig. 1 was passed through the bottom 1a of the can 1, from which it projects.

The eight illustrations of Fig. 2 show successive stages of the manufacture of a preferred embodiment of the invention, namely a semiconductor device with leads of circular cross section. This embodiment is particularly suitable for the above-mentioned rectifiers with the specified electrical characteristics. The piece of wire 30 shown in Fig. 2a is the one on which the steps necessary to form the inner lead ends for attaching the die are performed.

Fig. 2b shows how the offset portion 6, which is shaped like a z in a preferred embodiment of the invention, is formed on the wire 30 of Fig. 2a by means of a suitable tool. It is also readily possible to form a single offset, in which case the offset extends continuously from the left-hand beginning to the right-hand end of the offset portion 6, so that the piece of wire is approximately shaped like a tray.

Simultaneously with the formation of the offset, the wire 30 is flattened in the area of action of the offsetting tool, so that flat mounting surfaces 51, 52 for a semiconductor die are obtained. The distance d between the wire axis x and the mounting surfaces 51, 52 should be approximately equal to half the thickness of the die.

Fig. 2c shows how the die 4 is placed with one of its major surfaces, 41, on one of the mounting surfaces, 51 (Fig. 2b), near the offset point 61. Fig. 2d shows that the middle portion 63 is cut out to obtain the inner lead ends 60, 70. Fig. 2e shows the condition after the free lead end 70 obtained by cutting off the middle portion 63 has been moved onto the die 4 and joined to the other major surface 42 of the latter.

As shown in Fig. 2f, the can 1 is then slipped over the lead 32 until it occupies the position shown in Fig. 2g, i.e., until the inner lead ends 60, 70 are completely within the can, with the leads 31, 32 projecting axially therefrom. The internal dimensions of the can and the dimensions of the lead ends 60, 70 must be so adapted to one another that the offset points 61, 62 (Fig. 2c) lie completely within the can 1. Furthermore, the internal width of the can 1 must be adapted to the external dimensions of the inner lead ends 60, 70 with the die 4 lying therebetween, or the hole in the bottom 1a must be adapted to the diameter of the lead 32, such that a slight force fit is obtained, so that the can 1 will not fall off during the subsequent process steps.

Fig. 2h shows the cast resin 2 in the can 1, which fills up the entire hollow space of the can 1 and, thus, hermetically seals the die 4.

Instead of a round wire, a wire of square or rectangular section can be used. In that case, no mounting surfaces 51, 52 need be formed, of course.

The sequence of operations in the manufacture of a plurality of ready-to-sell semiconductor devices is as follows. The leads 31, 32 are formed from wires coming from the spool 39 (Fig. 3). In a preferred embodiment of the invention, the wire has already been tinned, but it may also be tinned after unwinding from the spool 31. After the wire has been straightened and/or stretched, equally spaced offset portions 6 are formed, which may have the preferred z-shape shown in the embodiment of Fig. 2; the spacing of the offset portions follows from the desired length of the leads on the finished semiconductor device taking into account the length of the removed middle portion 63. If the wire 30 is of circular section, its surface will be flattened in the offset portion during the offsetting process so as to form a flat mounting surface for the die. The latter is then attached with one of its major surfaces, 41, to the offset portion near one of the offset points, 61. The middle portion 63 is cut out; if only one offset is present, it suffices to simply divide the offset portion 6 in the middle. In the latter case, the resulting free offset portion is then moved onto the other major surface 42 of the die 4 by axially rotating the lead 32 with the die 4 through 180° and then moving the free offset portion onto the die. The major surface 42 of the die 4 is then joined to this free offset portion. In a preferred variant of the method, the joints are made by soldering using a hydrogen flame for each die which burns in an excess of hydrogen, either in two separate, successive steps for the two major surfaces 41, 42 or in a single, simultaneous step, so that no flux is necessary to solder the metallized major surfaces 41, 42 of

the die 4 to the tinned wire 30. The wires to be soldered may also be heated on a hot plate, or instead of soldering, a conductive adhesive may be used. The can 1 is then slipped over the lead ends 60, 70 provided with the die 4, after which the necessary quantitity of cast resin 2 is filled in and cured. Finally, the mechanically finished semiconductor devices are tested, and those lying in a predetermined "go" range are taped and subsequently lettered, while those found defective are discarded, and those which are "other than go" are taped, too, and lettered otherwise.

Fig. 3 is a highly schematic representation showing the construction of an apparatus according to the invention for manufacturing semiconductor devices according to the invention by the method described. The manufacture starts with the spools of wire 39 from which the wires 30 run to the straightening station 40 and the stretching station 50, which straighten and stretch each of the wires 30. This straightening and stretching is done only once during the entire manufacturing process of the semiconductor devices, namely at the beginning of the process, so to speak, and the subsequent stations and process steps are so designed and performed as to leave the straightness of the wires unchanged. The straightening and stretching stations 40, 50 contain a corresponding substation for each of the wires 30, which is not shown in Fig. 3; the convergence of the seven wires 30 at the inlet end of the straightening station 40, which are shown at the left in Fig. 3, is to illustrate only that all wires enter the station 40.

After leaving the stretching station 50, the wires enter the offsetting station 65, of which Fig. 3 shows the two offsetting punches 66, 67, which, if the wires 30 are circular in section, simultaneously form the mounting surfaces 51, 52 (Fig. 2b) since their ends coming into contact with the wire have a corresponding flat shape. By the two offsetting punches 66, 67, the z-shaped offset shown in Fig. 2b is formed on the wire 30. If only the above-explained single offset is to be formed, one of the two offsetting punches 66, 67 can be dispensed with.

The offsetting station 65 naturally contains as many offsetting punches or pairs of offsetting punches as there are wires to be worked simultaneously, i.e., about 100, for example. Instead of the offsetting punches, a suitable rolling device can be used for all wires.

After leaving the offsetting station 65, the offset wire enters the die placement station 75, in which a die is placed on the offset portion or, if a z-shaped offset was formed, on one of the offset portions. This, too, takes place simultaneously for all wires, i.e., dies are placed on each of the above-mentioned about 100 wires simultaneously, such that in all dies, the same semiconductor region is connected with the respective wire, e.g., the N-type region. In the case of the above-mentioned tinned wires, it is advantageous to provide the two semiconductor regions of the dies already on the semiconductor wafer with a metal layer, e.g., by vapor deposition, which permits the semiconductor region to be soldered to the tin coating. Metals suitable for this

purpose are gold, palladium, and silver, for example.

The simultaneous placement of the about 100 dies on the wires may proceed as follows. The semiconductor wafer, scribed by sawing as usual, is diced with the orientation of the dies being retained, and the individual dies are transferred into a magazine, from which they are placed, e.g., by means of suction pipettes, on an alignment plate, where their lateral edges are aligned parallel to each other and brought to exactly the same distance between them. This process can be easily automated by means of an optical monitoring facility. The aligned dies are then placed on the mounting surfaces of the wires by a further set of suction pipettes.

The placement station 75 is followed by the first cutting and feed station 80, in which the offset portion 6 (Fig. 2b) is cut through, or in which the middle portion 63 (Fig. 2c) is cut out of the offset wire. After the cutting operation, the "left" free offset portion 70 thus obtained is moved onto the die 4 by causing the wire to perform a corresponding forward movement, while the "right" wire is held in place.

The station 80 is followed by the die attachment station 85, in which the two major surfaces 41, 42 of the die 4 (Figs. 2c, d) are soldered to the tinned wire. This is done, for example, by means of the above-mentioned individual hydrogen flames operating in an excess of hydrogen, so that the tin is reduced by the excess hydrogen and no flux is necessary, whose residues would have to be

removed in a subsequent cleaning process. The invention thus has the additional advantage that throughout the attachment of the leads, no chemical steps are necessary.

The station 85 is followed by the second cutting station 90, in which the, e.g., 100 wires are cut through simultaneously. At this point, the separation into a prestage of the finished semiconductor devices takes place, namely into the manufacturing stage in which the cans 1 are slipped over the inner lead ends 60, 70 (Figs. 2e to h) and filled with cast resin.

The cans, which were previously fed, e.g., in hundreds, into the magazine 99 in the station 95, are slipped over the inner lead ends in the can-mounting station 100. The respective arrangements 32, 60, 70, 31 are inserted into the cans, as shown in Figs. 2f to h. To facilitate the insertion into the can 60, the latter is chamferred at its opening 1b. Behind the second cutting station 90, the direction of conveyance changes by 90°, and the respective magazine 99, now containing the canned semiconductor devices, is conveyed to the plastic-compound-filling station 105, in front of which the direction of conveyance is again changed by 90°, so that the openings 1a of the cans 1 are arranged below the outlets of the filling station 105. The number of the outlets is equal to the number of cans in each magazine, i.e., about 100, for example. To simplify the illustration, however, only one outlet 106 is shown in Fig. 3.

In the magazine 99, the now nearly finished semiconductor devices are transferred to the curing station 110, which consists of a heating portion 111 and a cooling portion 112. The magazines 99 are taken from the outlet of the cooling portion 112 and emptied into the filler inlet of the testing station 115. Since Fig. 3 is divided into two halves, the curing station 110 is shown both in the upper half and the lower half; this only serves to facilitate an understanding of the invention and does not mean that two curing stations are present.

The testing and sorting station 115 shown in the embodiment of Fig. 3 tests and sorts the about 100 semiconductor devices simultaneously, but only in three groups, thus comprising only the "no-go" container 116, the container 117 for semiconductor devices having properties other than the set "go" condition, and the outlet 118 for the devices lying in the "go" range (= prime type devices). After the semiconductor devices which are "no-go" and "other than go" have been sorted out, the "go" devices, handled in parallel up to this point, are transferred serially, i.e., successively in time, to the taping station 120 and thence to the lettering station 125. In the reeling station 130, the tape 120 equipped with the lettered, ready-to-sell devices, is finally wound on the reels 131.

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Claims

1. A semiconductor device comprising two coaxial leads (3) and a prefabricated semiconductor die (4) attached between those sides of the inner ends (60, 70) of the leads (3) which face toward each other, characterized by a prefabricated, can-shaped, preferably circular-cylinder-shaped, plastic housing (1) which is filled with a plastic compound, preferably a cast resin (2), and through whose bottom (1a) passes one of the leads, with the inner ends (60, 70) of the leads (3) inserted in the housing (1).

2. A semiconductor device as claimed in claim 1, comprising at least one lead (31; 32) offset within the housing (1).

3. A semiconductor device as claimed in claim 1 or 2, comprising leads (31, 32) having their respective inner ends (60, 70) deformed, on the side connected with the semiconductor die (4), into mounting surfaces (51, 52) for the semiconductor die (4).

4. A method of manufacturing a plurality of ready-to-sell semiconductor devices as claimed in claims 1 to 3 wherein

a) leads (31, 32) stem from a spool of wire (39) whose, preferably tinned, wire, after being straightened and/or stretched, is provided with equally spaced

offset portions (6) and, at the same time, with mounting surfaces (51, 52);

b) one major surface (41) of a semiconductor die (4) is attached to the mounting surfaces (51) near an offset point (61);

c) the offset portion (6) is divided approximately in the middle, and the mounting surface (52) of the resulting free offset portion is moved onto the semiconductor die (4) and attached to the other major surface (42) of the latter;

d) the semiconductor die (4) with the lead ends (60, 70) is inserted into a prefabricated, can-shaped plastic housing (1), and a necessary quantity of plastic compound is then filled in and subsequently cured, and

e) the now mechanically finished semiconductor devices are tested, and those lying in a predetermined "go" range are taped and subsequently lettered.

5. A method as claimed in claim 4 wherein by double offsetting, two successive offset portions (68, 69) are formed whose middle portion (63) is removed in step c).

6. A method as claimed in claims 4 and 5 wherein steps a) to c) are performed simultaneously on a plurality of wires stemming from the same plurality of spools, preferably on about 100 wires, and wherein step d) is performed simultaneously on the same number of housings in a single operation.

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7. A method as claimed in claim 6 wherein by soldering with a hydrogen flame burning in an excess of hydrogen, either both major surfaces (41, 42) of each semiconductor die (4) are soldered simultaneously or one major surface (41) is soldered in a first cycle step and the other major surface (42) in a subsequent cycle step.

8. Apparatus for carrying out the method claimed in claim 6 or 7, comprising the following stations arranged in the direction of conveyance:

- a straightening station and/or a stretching station (40, 50),

- an offsetting station (65) which also forms the mounting surfaces (51, 52) if necessary,

- a die placement station (75),

- a first cutting and feed station (80),

- a die attachment station (85),

- a second cutting station (90),

- a station (95) for feeding the can-shaped housing (1) into a magazine (99),

- a housing-mounting station (100),

- a plastic-compound-filling station (105),

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- a curing station (110),

- a testing and sorting station (115),

- a taping station (120),

a lettering station (125), and

- a reeling station (130) for the tape (121) equipped with the ready-to-sell semiconductor devices.

9. A apparatus as claimed in claim 8 wherein the direction of conveyance changes by 90^{o} behind the second cutting station and in front of the plastic-compound-filling station.