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Title: A method of encapsulating an integrated circuit on a support, an apparatus for performing the method, and an electronic assembly obtained by use of the method.

The invention relates to a method of encapsulating an integrated circuit on a support, an apparatus for performing the method, and an electronic assembly obtained by use of the method

Electronic assemblies are known which incorporate at least one integrated circuit carried on a support such as a printed circuit enabling electrical interconnection between the integrated circuit and other electronic assemblies, so as to set up a system in operational condition. By integrated circuit, is meant a device which carries out predetermined electronic functions, which are more or less complex, and which is formed from a bar of semiconductor material of small size; which is still called a chip in many applications. The predetermined functions carried out by a chip can be relatively simple, such as the function of amplification, or more complex since, depending upon the degree of integration, a single chip can form on its own a complete microprocessor including its work and program storage.

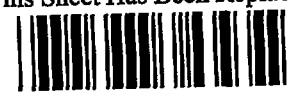
An integrated circuit therefore constitutes an electronic circuit of which certain points, still called terminals, must be interconnected with the exterior. To this end, wire conductors of very small cross section connect the terminals to the rest of the electronic system.

In many applications, the assembly formed by the chip and the wires is enclosed in a housing out of which extend the beam leads for connection with the exterior. A first end of each of the wires is connected to a terminal of the integrated circuit and the other end is connected to a particular beam lead of the housing, so that when the housing is mounted on a printed circuit, the electronic device can then carry out its functions. An electronic system may comprise several printed circuits, each of which carries several housings and / or other components.

In other applications, it is not possible for reasons of size, to use integrated circuits or chips enclosed in a housing. This is the case, for example, for the integrated circuits used in cards with electronic microcircuits, still known under the name of chip cards or memory cards, according to the function carried out by the microcircuit. These cards are used in systems of confidential processing of data, for example in the fields of banking, telephony or other fields.

In such a case, the integrated circuit is fixed on one face of a support which bears, on its other face, pads for contact with the exterior. The wires of the integrated circuit are connected to the contact pads of the support, which then forms a printed circuit, and the assembly thus formed is placed in a recess in a sheet of flexible material which constitutes the body of the card, the integrated circuit being contained firmly within the body, and the contact pads being at the level of one of the main faces of the body of the card.

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In such a case, in order to protect the integrated circuit, even though it is not possible to use a housing, it is usual that, before placing the integrated circuit and its printed circuit support in the body of the card, the integrated circuit and the wires for connection to the contact pads of the printed circuit are encapsulated in a material such as a protective resin.

The encapsulation enables the chip and the wires to be protected during subsequent handling, in particular during the phase of installation in the body of the card. In fact, a chip presents an area of a few square millimetres and a thickness which is measured in microns, of 350 microns on average, which corresponds to extreme values included in the range from 100 to 500 microns on average, and accordingly is relatively fragile. It is therefore necessary to avoid physical damage to it, which would make it unusable, and also contact with microscopic dust or particles which would cause modification of the electronic functioning of the circuit. It will be noted, at this stage, that the role of a housing in the applications described above is similar.

In the particular case of the application to memory cards, the contact pads of the printed circuit used as support for the chip are brought into electrical relationship with the rest of the system, for example by means of the terminals of a connector specific to the card.

It will be understood that other applications can be considered where the chip is not enclosed in a housing, for example applications in which circuits are used without housings in order to increase the number of integrated circuits carried on a single printed circuit. In fact, when an integrated circuit is enclosed in a housing, it should be remembered that the volume of the housing occupies some cubic millimetres, whereas the chip occupies a few hundredths of a cubic millimetre, and it follows that the size of the housing is disproportionate relative to the size of the chip. These disproportionate sizes are necessary in order to enable the contact beam leads fixed to the housing to be of sufficient size to have a suitable rigidity, especially during handling.

Thus, in certain applications, both in order that the chip and its wires may be protected from external attack and not damaged, and also in order that electronic insulation can be ensured, it is known to encapsulate the assembly formed by the chip and its wires in resin or in another insulating material. In addition, the encapsulation improves or ensures mounting of the chip on its support.

A first known method of encapsulation consists of pulverising onto the assembly formed by the chip and its wires an encapsulation material which is polymerisable at room temperature.

This method presents the following disadvantages : on one hand, it does not enable the shape and thickness of the encapsulation to be easily controlled and, on the other hand, the wire conductors extending away from the chip act like a net which prevents the material diffusing properly, so that it can happen that part of the chip or its wires are not encapsulated or even, on

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account of the net effect, that air bubbles remain in the encapsulation, resulting in mechanical weakness and / or in poor protection.

Another method enables the shape of the encapsulation to be controlled. It consists of performing the encapsulation by transfer moulding; to this end, a mould having the final shape desired for the encapsulation, and into which opens out at least one duct for injection of the encapsulation product, is placed in contact with the support, totally enclosing the chip and the wires, in such a way as to define the volume to be encapsulated, and the encapsulation product is injected into the interior of the mould through the injection duct, before it is hardened, for example by cold or hot polymerisation.

Even if this method presents the advantage of enabling the encapsulation to be obtained in the finished shape, it presents other disadvantages, however. On one hand, it requires a fairly complex and costly equipment to be provided, since the volumes of the product to be injected are very small, of the order of a few cubic millimetres, and very precise machining of the mould must be performed, with small tolerances, and similarly it is necessary to produce injection ducts of very small cross section. In addition, the product is injected in the liquid or solid or semi-solid condition, so that in order to fill the mould cavity correctly, the injection requires a certain pressure; it can happen that the injected product, because of its speed of penetration into the cavity, will displace the integrated circuit and / or the wires, and accordingly will damage the electronic assembly to be encapsulated. Consequently, the encapsulated assembly is unusable, even if the encapsulation presents the shape and the dimensions desired.

Also, the presence of an injection duct implies special maintenance, since the cross section of the duct is of very small area, of the order of a few hundredths of square millimetres, and it is necessary to perform a regular check of this duct to avoid it being blocked. It follows that, overall, this method does not enable a satisfactory encapsulation to be obtained in all circumstances and in addition the apparatus for performing the method requires particular operations of maintenance and upkeep.

An object of the invention is to avoid these disadvantages, and the invention relates to a method which enables encapsulation of an integrated circuit carried on a support such as a printed circuit, the integrated circuit comprising wires for connection with the external environment, the encapsulation enabling the integrated circuit and at least part of the wires to be enclosed in a protective volume of a given shape and dimensions, the performance of the method not leading to damage or displacement of the assembly formed by the integrated circuit and its wires for connection with the exterior, the said method requiring apparatus which is very simple to produce and use.

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In accordance with the invention, a method of encapsulating on its support with the use of a hardenable material an electronic assembly formed from an integrated circuit and at least part of its wires for contact with the exterior, the said assembly being carried by a face of the said support, is characterised in that it consists on one hand of positioning the support and the electronic assembly in such a way that the said face of the support carrying the integrated circuit and its wires for contact is disposed in a substantially horizontal plane, at a level higher than the other planes of the support, the support thus forming the base of the encapsulation, of positioning on the said face of the support, around the electronic assembly, a frame whose dimensions and shape correspond to the dimensions and shape of the outer edge of the encapsulation adjacent to the base, the periphery of an opening of the frame being pressed flat on the support, the frame remaining accessible through its other opening opposite to the first opening, and in that it consists on the other hand of putting into the frame, through its accessible opening, the necessary quantity of encapsulation material to obtain the final encapsulation, the said material being chosen among those which are capable of adopting a liquid state between the moment when they are put into the frame and before their hardening, so that, while it is in the liquid state, the material spreads under gravity into the whole of the frame and adopts the shape of the interior edge of the frame by capillary action, the encapsulation thus taking its final shape before hardening, and in that the material is hardened, and in that the frame is removed after hardening of the material.

The invention is therefore particularly advantageous since it requires for its performance a very simple apparatus; the frame used to circumscribe the encapsulation can be produced by drilling or milling a suitable material and it is possible to consider the production of apparatus enabling the simultaneous encapsulation of several electronic assemblies, and that with very low cost. The presence of a frame prevents the encapsulation material, while it is in the liquid phase, from spreading anarchically over the whole of the support, and the fact that the frame is accessible through one of its open sides, for putting the material in place, makes it possible for the material to be deposited without it being necessary to apply an injection pressure, thus avoiding the risks of damage to the electronic assembly.

In addition, the use of a frame favours the performance of encapsulation using various materials.

Thus, it is possible to use an encapsulation material which is placed in the frame while it is in the liquid condition, its hardening or its polymerisation, when the material is a resin, being performed at room temperature. It is still possible to use thermo-setting or hot cured material, without the existence of the opening at the top of the frame causing any problem for the curing. In fact, as indicated previously, the quantities of encapsulation material required are tiny (of the order of a few hundredths of cubic millimetres), so that the cross sectional area of the opening is very small (of the order of a few square millimetres) and it follows that, during the phase of

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polymerisation or heat hardening, the thermal losses between the encapsulation material and the exterior are very small, and a suitable temperature in the interior of the encapsulation material can be achieved to obtain the polymerisation without it be necessary to close the frame. Performing encapsulation of larger volumes, or even of housings, would require that the frame be closed during a hot curing phase, in order to reduce the thermal exchanges with the exterior and to optimise the reaction.

In an embodiment of an apparatus in accordance with the invention using a thermo-setting or hot curing material, heater elements are provided in the structure of which the frame is made in heat conductive material.

In a variant, the heater elements are omitted, and the temperature is obtained by heating the apparatus.

In another variant, advantage is taken of the presence of the opening to expose the encapsulation material to a source of external radiation, such as laser or infrared radiation, for example, and the apparatus is preferably made in this case from an insulating material in order to avoid thermal losses through the apparatus itself.

Other features and advantages of the invention will appear from the following description, given with reference to the accompanying figures 1 to 9F, which give a non limitative illustration of various apparatus for performing the invention and / or various electronic assemblies to which the invention is applicable.

Figure 1 illustrates a strip forming a support 1 which carries on one of its faces several integrated circuits 2, 3, 4 which are each designed to form an active electronic element of an electronic microcircuit card. The other face of the strip bears, substantially opposite each of the integrated circuits 2, 3, 4, contact pads (21, 22, ... 27, 28, 31, 32 ... 37, 38, 41, 42 ... 47, 48) shown in dashed lines and designed to provide the interconnection, once the microcircuit cards are finished, between the microcircuits contained in each of the integrated circuits and the rest of the system utilising the memory cards.

Some of the contact pads opposite an integrated circuit are connected to the corresponding circuit through electrical lead wires (210 ... 215, 310 ... 315, 410 ... 415). In this figure, each integrated circuit is shown having the form of a rectangular parallelepiped and the wire conductors all project from the same face of each integrated circuit which, in this example, is the face of the circuit opposite to that through which they are in contact with the carrier strip. It will be understood that this figure has a purely illustrative role and that the wire conductors may project from other places on each of the integrated circuits, and in particular from the sides, or else from the face of each integrated circuit which contacts the carrier strip 1.

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The connection between a wire conductor and the corresponding pad disposed on the other face of the strip is achieved in a manner which is known per se, either by means of a metallised hole drilled through the strip, or by any other suitable means already known in the art.

Around each integrated circuit 2, 3, 4 and the contact pads which correspond to each of them, is shown in continuous lines a circular area which represents, by way of illustration and not limitation, the position where it is cut out after the encapsulation has been finished, in order to separate from the strip each of the electronic assemblies formed by an integrated circuit, its contact pads, and the lead wires between the circuit and the said pads, an assembly thus separated from the strip forming what is commonly called a button which is placed in a recess in the microcircuit card.

The production of a complete card does not form part of the present invention, all the more so as the method is applicable to encapsulating circuits intended for all applications which are known or can be imagined, as well as the cards.

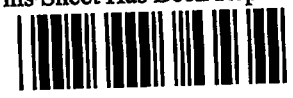
In addition, in Figure 1, within each of the circular areas, a frame is shown in broken lines which surrounds the integrated circuits and the corresponding wire conductors. This frame in broken lines represents the position of the encapsulation on the face of the strip carrying the integrated circuits.

In the example, the cross section of the encapsulation is rectangular. It is to be understood that this is not limitative and that the cross section of the encapsulation at the level of the strip may take any other shape, for example square, circular, oval, square or rectangular with rounded or truncated corners, etc..

In addition, it will be recalled that Figure 1 illustrates the case where the integrated circuits 2, 3, 4 are mounted on a bearer strip, in such a way as to form subsequently the active elements of a microcircuit card. It will be understood that this example is not limitative and that in particular the integrated circuits may be mounted on a more complex printed circuit which, instead of comprising simple contact pads for interconnection with the exterior, may also comprise conductive bands enabling connections to be made between several integrated circuits thus formed, and also the connection between one or more integrated circuits and other active or passive electronic elements, the circuit not necessarily being intended for use on a card, in this case.

In addition, in the example illustrated, the conductive pads are disposed on the second face of the bearer strip 1, that is to say the face opposite the face bearing the integrated circuits 2, 3, 4 and the corresponding wire conductors. It will be understood that it is possible to design

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devices in which an integrated circuit and its wire conductors are carried on the face of a support which also carries the conductive bands or pads.

Lastly, in Figure 1 is illustrated a strip bearing three integrated circuits. Once again, it should be noted that the method of the invention is applicable to the encapsulation of a greater or lesser number of integrated circuits borne on the same support and whose position and / or shape may also be very variable. In fact, here the integrated circuits are aligned on the same longitudinal axis of the strip, but cases are also possible in which the circuits are not mounted on the same axis nor disposed in the same direction. This is the case, for example, when the support forms a more complex printed circuit, so that different integrated circuits linked together by means of the small complex printed circuit form an electronic assembly which accumulates and / or combines the functions of each of the integrated circuits that it carries. In this case, apparatus for performing the method of the invention will be provided in such a way as to enable encapsulation of the integrated circuits one after the other, or simultaneously, as will be explained below.

In Figure 2, are illustrated in perspective part of the elements of Figure 1, namely part of the bearer strip 1, and one of the integrated circuits 2, its connector wires 210, 211 ... 214, 215, with the contact pads not shown this time and positioned on the other face of the strip or support 1. This figure makes clear that in this example the wire conductors project from the face of the integrated circuit opposite to that which is disposed on the support 1. In dashed lines, a possible final shape is shown for the encapsulation 5 of such an electronic assembly formed by the chip and its associated wire conductors. It will be observed that, if the thickness of the electronic assembly measured between the face of the support 1 on which it is disposed and the point or points of the assembly which are the furthest away from this face has a given value "h" then the overall thickness "e" of the encapsulation and its shape must be such that the whole of the electronic assembly defined previously must be incorporated in the encapsulation. Thus, in the example illustrated, the encapsulation has a parallelepiped shape and it follows that its thickness "e" must be greater than the thickness "h" of the electronic assembly and that its cross sectional area must be greater than the orthogonal projection of the electronic assembly onto the said face of the support.

Figure 3 shows the principle of an apparatus for performing the method of the invention and enabling electronic assemblies to be encapsulated unitarily.

A frame 6 is formed in a block or bar 7 from a material which is suitable for receiving the encapsulation material without being damaged. The frame 6 is manufactured in such a way that it can be disposed on the face of the support 1 bearing the integrated circuit 2 and the wires 210, 211 ... 214, 215 for contact between the integrated circuit and the exterior.

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In the following description, the expression "height" or "thickness" of the electronic assembly is to be understood as being the dimension between the plane of the support 1 bearing the electronic assembly and the plane parallel to the said plane of the support, the furthest away from the latter plane which has at least one point in common with an element of the electronic assembly. Thus, in the example illustrated, it will be observed that the wire conductors project from the face of the integrated circuit 2 opposite to its face carried on the support 1, so that the height of the electronic assembly is the distance between the said face of the support 1 and the furthest point of the conductors relative to the said face of the support.

By extension, the height or thickness of the encapsulation is the dimension of the encapsulation measured from the support in a direction normal to the support, and lastly the height, or thickness or depth of the frame 6 is measured from the plane common to the support and to the frame.

As will be seen in Figure 3, the frame is disposed on the support in such a way as to surround the electronic assembly to be encapsulated and, in accordance with the present invention, before the encapsulation material is placed in the frame 6, on one hand the support 1 is positioned in such a way that its face bearing the electronic assembly to be encapsulated is horizontal and that the frame is accessible from above this horizontal plane. Additionally, before the encapsulation material is placed inside the frame, it is arranged that a sufficient pressure is exerted between the frame 6 and the support 1 for sealing to be ensured, so as to avoid the encapsulation material, while it is in a liquid condition, being able to spread outside the frame between the edges of the frame and the support.

The fact that the support is positioned in a horizontal plane with the electronic assembly 2 and the conductors above it enables the encapsulation material, when it is in the liquid condition, to spread out under gravity within the frame, in such a way as to surround totally and adequately the electronic assembly and so that by capillary action it pours over the whole of the frame.

Generally speaking, the support 1 is made of a material which is relatively flexible (for example epoxy glass), so that in a preferred embodiment of the method of the invention, it is arranged for the support 1 to be disposed on an underlying base plate 8, and for the support 1 to be clamped between the base plate and the frame in such a way as to ensure sealing between the frame and the support.

As has been explained in the preamble of the present specification, the encapsulation material may be thermo-setting or hot curable or even a material which is deposited in liquid condition and which hardens or polymerises at room temperature.

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In all cases, the material of which the frame is made must be chosen so that it will not adhere with the encapsulation material, and the frame must be formed in such a way that when the encapsulation material will have hardened or will have been cured, no element of the frame is able to project into the mass of the encapsulation material and cause damage to the encapsulation material when the frame is removed. It is for this reason that the frame is formed in such a way that its edges are perpendicular to the plane of the support, defining then an encapsulation in the shape of a rectangular parallelepiped, as shown in Figure 3, or else that the cross sectional area of the opening of the frame at its base, that is to say at the plane of its junction with the support 1, is greater than the cross sectional area of the upper opening of the frame, that is to say the opening through which the encapsulation material is inserted, so that the cross sectional area of the frame is smaller at its top that at its bottom. This is illustrated in Figures 4A and 4B which show in section along AA in Figure 3, two opposite edges 61, 63 of the frame which converge in two different ways. In the case of Figure 4A, the edges 61, 63 are planar in shape and converge towards each other so that the cross sectional area of the opening of the frame reduces uniformly between the bottom and the top, whereas in the case of Figure 4B, the said edges 61 and 63 are curved inwards, so as to converge towards the top of the frame.

In the case where the encapsulation material used is a resin or a thermo-setting or hot curable material, the apparatus for performing the method, and in particular the material of which the bar comprising the frame or frames is formed will be different according to the methods used for bringing the encapsulation material to its hardening temperature.

In fact, as was explained in the preamble to the present specification, it is possible to arrange for direct heating, by presenting the encapsulation material to a suitable source of radiation. In this case, the source of radiation is placed above the opening of the frame through which the encapsulation material is inserted and, in this case, the material of which the bar comprising the frame or frames is formed is preferably an insulating material in order to avoid energy being lost in the bulk material. Thus, in such a case, the material of which the bar is made may be chosen to be a ceramic material.

When this method of heating is used and the bar 7 comprises several frames for performing simultaneous encapsulation of several electronic assemblies, the heating equipment may comprise a single source of radiation which is displaced relatively to face each frame, or else several sources of radiation, for example one facing each frame, so that the hardening of the different encapsulations can occur simultaneously.

Alternatively, the encapsulation material is brought to the hardening temperature by applying energy through the intermediary of the material of which the bar 7 is made. In such a case, it is necessary for the material to be a good heat conductor and it is chosen to be either an

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alloy or a metal which withstands the temperature of polymerisation or hardening. In this case, the temperature required at the level of the frame can be obtained either by subjecting the bar directly to a source of radiation, the dissemination of the heat then being obtained within the bulk of the bar bearing the frame or frames due to its conductive characteristics or else by using heater elements disposed within the bulk of the bar. These heater elements are shown symbolically in Figure 3 by the spiral 9, incorporated in the bulk of the bar 7.

In another variant, heating by direct exposure of the encapsulation material to a source of radiation is combined with application of heat in the bulk of the bar which, in this case, is then made of a conductive material.

In this case, two alternatives are possible. The first consists of using a source of radiation placed facing the opening or openings in the bar, and which has sufficient power to heat the bulk of the bar evenly; the second consists in placing the heater elements in the bar and exposing each opening to a radiation source which is more limited.

Lastly, it should be noted that when the chosen encapsulated material hardens or cures at room temperature, it is of little importance whether the material that the bar is made of is insulating or conductive.

The manner in which the encapsulation material is put in place will be explained subsequently, since it is equally applicable to the alternatives illustrated with respect to the following figures.

Figure 5 shows apparatus for performing the method of the invention which can be used for the simultaneous encapsulation of a number greater than one of electronic assemblies each of which consists of an integrated circuit and a certain number of wire conductors for connection between the integrated circuit and the exterior. Of course, the number, the shape and the relative positions of the assemblies may be different, as described above.

The apparatus described is therefore particularly used for encapsulation of electronic assemblies carried by the same support 1, as described with respect to Figure 1.

The apparatus is formed in the following way : a bar 70 has a specific number of openings 600, 601 ... 607, 608 which pass right through the bar in the direction of its thickness and each of which comprises a frame for the encapsulation of electronic assemblies 100, 101, 102 ... 107, 108 carried by the support 1.

It will be observed that in this figure the thickness of the bar in which the openings are formed is disproportionate relative to the dimensions of the electronic assemblies carried by the

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bearer strip. The reason for this lack of proportion will be explained with respect to the description of Figures 6A and 6B which show partial sectional views along BB of two variant embodiments of the bar 70 of Figure 5, and enable the way in which the openings are made to be seen.

Preferably, a base plate 80 is provided whose upper face 81 is planar to receive the support 1 for the electronic assemblies 100, 101 ... 107, 108. The lower face 70A of the bar 70, in which the openings are formed, is also planar so that the support 1 for the electronic assemblies can be pressed between the lower face of the bar and the upper face of the base plate, while the encapsulation material is in the recesses, so that sealing can be ensured at the plane of the junction between the frames formed in the bar 70 and the face of the support 1 onto which the said lower face 70A of the bar is applied. It follows that no leakage of the encapsulation material can occur when it is liquid.

Preferably, means are provided to enable proper positioning of the support 1 relative to the bar 70 comprising the openings 600, 601 ... 607, 608 in which the frames defining the shape of the encapsulation are formed.

In the example shown, two pins 82, 83 are provided on the upper face 81 of the base plate, and which fit into corresponding orifices 71, 72 formed at each end of the bar 70 bearing the openings. In addition, two other pins 84, 85 are provided on the upper face 81 of the base plate 80, to be inserted into two corresponding orifices 109, 110 formed in the support 1 of the electronic assemblies 100, 101 ... 107, 108.

Thus, in order to encapsulate a set of assemblies carried by the same support, it is only necessary to position the said support correctly on the base plate 80 by means of the pins 84, 85 provided on the base plate and the corresponding orifices 109, 110 provided in the support 1, and then to position the bar 70 on the base plate by means of the pins 82, 83 of the base plate 80 and the corresponding orifices 71, 72 of the bar 70. Since the support is then correctly positioned on the base plate as is the bar as well, it follows that the electronic assemblies are correctly positioned relative to the openings in the said bar.

Other means can be provided for providing the alignment, but they do not form part of the present invention. In particular, it may be unnecessary to position the bar correctly relative to the base plate, to the extent that direct alignment means are provided between the bar and the support 1 for the electronic assemblies. In fact, the pins 84, 85 which are disposed, in the case shown in Figure 5, on the upper face 81 of the base plate 80 could be replaced by pins placed on the lower face of the bar 70.

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Also, the means for exerting pressure between the bar 70 and the base plate 80, in order to trap the support 1 for the electronic assemblies, has not been shown. Suitable means which might be used include hydraulic, mechanical or other press means.

Figure 6A is a partial view in section along BB of Figure 5, showing more particularly the shape that the openings formed in the bar 70 can take. This figure also makes apparent the relative positions which are occupied by the different parts of the apparatus when it is ready for the operation of encapsulation.

Thus it will be seen that the support 1 bearing the different electronic assemblies 100 ... 108 is clamped between the bar 70 and the base plate 80 and that a seal is obtained at the periphery of the openings in the bar 70 at the level of the surface mating with the support for the electronic assemblies.

It will also be noted in this figure like in figure 5 that the overall thickness of the bar 70, that is to say its dimension measured in a direction perpendicular to its face 70A which will come into contact with the support 1 for the electronic assemblies, is substantially greater than the thickness "h" of the said electronic assemblies. Now, as was explained in the preamble to the present specification, the invention is applicable to producing encapsulations of very small dimensions and volumes : in particular it is applicable to encapsulating electronic circuits which are designed to be incorporated into memory cards. Now, for such applications, the overall thickness of the encapsulation may be situated in the range from 150 microns to 600 or 700 microns, the electronic assembly having a thickness of the order of a few hundreds of microns. It follows that the frame used for the encapsulation may have a maximum thickness or depth of the order of 700 microns, that is to say a thickness or a depth corresponding to the maximum thickness of the encapsulation. It will be readily understood that a bar 70 which enables the simultaneous encapsulation of several electronic assemblies, and which is provided with a corresponding number of openings, and which had a thickness "e" which merely corresponded to the thickness required for each frame would not have sufficient rigidity to be properly pressed flat against the support, so that when the encapsulation material is in the liquid condition, it would filter out between the bar and the support if sealing was not properly ensured.

For this reason, the bar is given an overall thickness which is substantially greater than that required to form the frame defining the thickness "e" and the cross section of each encapsulation, so as to give it enough rigidity for sufficient pressure to be exerted between the support 1 and the bar 70.

In addition, each opening 600, 601 ... 608 is formed in two different parts 600A ... 608A and 600B ... 608B respectively.

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The part 600A, 608A of each of the openings 600, 608 defines the frame needed for encapsulation. It extends therefore from the lower face 70A of the bar 70 which will come into contact with the support during the encapsulation operation and therefore is given the shape and size of the outer edges of the encapsulation adjacent to the support 1. In particular, this first part has a depth "e" equal to the desired final thickness for each encapsulation. This part may be made in accordance with any one of the different embodiments illustrated with regard to figures 3, 4A and 4B, that is to say that it can be so made that the outer edges of the encapsulation adjacent to the support are perpendicular to the support, or else that a certain degree of convergence appears at greater distances from the support, in order to assist in the removal of the bar after hardening of the encapsulation material.

The first part 600A, 608A terminates within the thickness of the bar 70 in a flat area 600C, 608C which is parallel to the face of the bar which will come into contact with the support 1, the presence of this flat area causing a sudden increase in the cross sectional area of the opening in the thickness of the bar 70, and the second part 600B, 608B of each opening is included between this flat area and the second face 70B of the bar opposite to the face which will come into contact with the support.

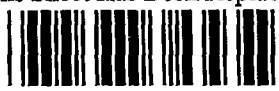
In an embodiment illustrated in Figure 6A, the cross sectional area of the second part of the recess widens between the part which is common with the flat area 600C, 608C and where it opens into the second face 70B of the bar 70. This widening assists in the positioning of the encapsulation material into each recess, since it will be appreciated that in many applications the cross sectional area of the encapsulation, measured at the level of the support 1, is a few tens of square millimetres and, for a square section encapsulation, this corresponds at the base to a side of the order of 5 millimetres; the widening of the cross section area helps maintenance and cleaning of the bar 70 on one hand and above all, during the performance of the encapsulation process, it helps in putting the encapsulation material in position within the opening, since this is thus made more accessible.

In addition, it should be noted that, in a similar manner to that described with regard to the description of figure 3, the choice of the encapsulation material and of the way in which it is hardened or cured governs the choice of the material of which the bar is made in which the different openings are formed.

In particular, if the material is a material which is hardened or cured by heat, and the curing is performed by exposing each of the openings to a source of suitable radiation, such as laser radiation or the like, then it is preferable to make the bar 70 in an insulating material such as a ceramic, in order to avoid losses of energy in the bulk of this material. On the other hand, a material which is heat conductive should be chosen in the case where it is desired that the heat of

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the bar be transmitted to the encapsulation material. In this latter case, the heat may be transmitted by exposing the bar to a source of radiation, or else by providing heater elements in the bulk of the bar 70.

Figure 6B illustrates an alternative embodiment of the bar 70 which is formed from two different members 700, 701 which may be placed one on top of the other, before the encapsulation material is placed therein.

The first member 700, of thickness "e", equal to that desired for the encapsulations, comprises the openings 600 ... 608A which define the frames for receiving the encapsulation material, and the second member 701 functions as an external reinforcement, and is provided with openings 600B ... 608B enabling the encapsulation material to be inserted. The cross section and the positioning of the openings 600B ... 608B are such that when the two members 700, 701 are in position relative to each other, the flat areas 600C ... 608C described with respect to figure 6A are present.

This structure in two parts assists the cleaning and the upkeep of the apparatus.

When the heater elements are provided in the bulk of the apparatus, they are disposed in the first part 700 and / or in the second part 701, the second part 701 being more convenient for receiving the heater elements, however, on account of its thickness being greater than the first member.

Figure 7 shows, in plan view, a preferred way of putting the encapsulation material in position when it is in a condition intermediate between the solid state and the liquid state at room temperature at the moment when it is placed within the frame. For it to become liquid, it is necessary to raise its temperature, this being the case for example with certain epoxy resins which polymerise at a temperature of 150° C after passing through a liquid phase at a temperature of approximately 50° C.

Figure 8 is a sectional view along CC of figure 7 showing the distribution of the encapsulation material in a vertical plane, before it goes through the liquid phase.

The process illustrated in figures 7 and 8 enables optimisation of the spreading out of the encapsulation material when it becomes liquid, so that it can spread out as quickly as possible over the whole of the volume defined by the frame and the electronic assembly. In accordance with the process illustrated in these figures 7 and 8, several drops 90, 91, 92, 93 of the encapsulation material in a semi liquid state are placed within the frame, so that the material will spread out properly when it becomes liquid, before hardening.

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Thus, by way of example, in figure 7 the electronic assembly 100 is formed by the integrated circuit 100A and by six wire conductors 100B, C, D, E, F, G and is placed on the support 1, with the wire conductors communicating additionally with the other face of the support through the intermediary of the holes 100H, I, J K, L, M. The wire conductors, as well as the holes, are spaced apart in threes on opposite sides of the integrated circuit 100A, and the drops of encapsulation material are preferably placed in the gap between two wire conductors, in such a way that the encapsulation material can spread out well around the wires when it becomes liquid. In this example, it is four drops of encapsulation material that are needed.

Preferably, the drops are of identical volume, such that the total volume of the drops used will correspond to the final volume of the encapsulation material to be placed within the frame.

Figure 8 shows, in vertical section along CC of figure 7, the distribution of the encapsulation material before it becomes liquid, when it is arranged as a number of drops. It will be understood that the proportions of the drawing are absolutely not to scale since, for example, for the production of electronic circuits which are designed to be incorporated into memory cards or microcircuit cards, the electronic assembly formed by the memory or the microcircuits which are incorporated in the chip has a thickness which is extremely small relative to the other dimensions. In fact, it will be recalled, the chip may have a thickness of a few microns, compared with a length and a width of a few millimetres. By way of example, a chip designed to be incorporated in a memory card or a microcircuit card may have its cross sectional area in the range from ten to thirty square millimetres, which corresponds to sides of the order of 5 millimetres, and its thickness may be as much as 100 to 500 microns, from which it follows that the total volume of the chip is of the order of 5 cubic millimetres. It follows that the thickness of the chip is on average 50 times smaller than its other dimensions, which would have been impossible to show in the drawing. The same applies to the dimensions of the frame forming the peripheral edge of the encapsulation which, in such a case, may have dimensions parallel to the support of the order of 7 millimetres each, which corresponds to an area of around 50 square millimetres, whereas its height or its thickness must be in the range from 150 to 700 microns, that is to say that it is on average 20 times smaller.

The same applies to the diameters of the drops of the encapsulation material placed on the electronic assembly 101 before they become liquid, since by way of example for an electronic assembly of square cross section with sides of 4 millimetres, for example, for a thickness of 200 microns that is to be encapsulated in a volume having a cross section of the order of 7 millimetres square and a thickness of 350 microns, it is necessary to provide a volume of encapsulation material of the order of 13 cubic millimetres which, if it is split into 4 drops of equal volume, requires each of the drops to have a diameter of the order of 2 millimetres, that is to say a diameter five times greater than the overall thickness of the frame.

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Thus, in Figure 8, two of the drops 90, 91 are to be seen in the case where four drops are provided.

Figures 9A, 9B, 9C, 9D show the importance which should be attached to the production of the active part of the frame, that is to say the part which defines the shape of the sides of the encapsulation adjacent to the support.

The shape and the size of the frame assume their full importance when the encapsulation product is in the liquid phase, since this is the moment when the final shape of the encapsulation is defined.

Figure 9A shows in section along AA of figure 3 an arrangement where the depth of the frame would be too big. In this figure, two opposite sides 62, 64 of the frame 6 formed in the bar 70 are to be seen. In addition, the sides 62, 64 of the frame are formed between a lower edge 7A of the frame and its upper edge 7B opposite the edge 7A. The edge 7A is the one which will be brought into contact with the support 1 of the electronic assembly during the phase of encapsulation. In the example shown in this figure 9A, the depth or the thickness of the frame, that is to say the distance between the angle which is common to the edge 7B and the sides 62, 64 of the frame, and the plane passing trough the lower edge 7A is substantially greater than the depth "e" which the encapsulation ought to have. It is observed that after putting the quantity of encapsulation material 900 which would enable the desired volume to be obtained, on account of the very small cross sectional area of the frame 6; the encapsulation material after it becomes liquid rises up the sides 62, 64 of the frame by capillary action as far as the angle formed between the upper edge 78 and the said sides, thus forming a concave meniscus. It follows that at the centre of the frame the level of the encapsulation material is quite insufficient, which can lead as shown in this figure 9A to incomplete encapsulation of the electronic assembly formed by the integrated circuit 2 and the connection wires which are not shown in this figure.

Figure 9B shows the case where the bar 70 in which is formed an opening 600 has a thickness which is greater than the final thickness "e" that the encapsulation is to have and in which the opening 600 is made in two parts, a first part 600A opening into the face 70A of the bar which will be brought into contact with the support, the said first part 600A defining a frame having a thickness "e" and dimensions corresponding to those of the final encapsulation, and the second part 600B having inclined walls, which thus results in the opening flaring out towards the second face 70B of the bar. The said inclined walls open out directly into the first part 600A, in such a way that the intersection between a wall of the first part 600A forming the frame and the adjacent wall of the second part 600B defines an obtuse angle: it can happen that by capillary action, as shown in this figure 9B, the encapsulation material 900 when it is in the liquid phase rises up along these

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walls of the second part 600B and that poor encapsulation or partial encapsulation is obtained for the electronic assembly formed by the integrated circuit 100A and the lead wires.

Figures 9C and 9D illustrate two variants which enable encapsulation to be obtained without the disadvantages illustrated with respect to figures 9A and 9B.

In figure 9C, the arrangement shown is in fact that which has been described with respect to figure 6 once the encapsulation material 900 has been placed therein and has become liquid. The bar 70 in which is formed the frame defining the shape of the edge adjacent to the support 1 and its height, has an overall thickness which is considerably greater than the desired final thickness for the encapsulation, so that it is necessary for the recess 600 to be made in at least two parts, a first part 600A forming the frame and opening directly into a first face 70A of the bar which is to be brought into contact with the support 1, and a second part 600B starting from the first part and opening into a second face 70B of the bar 70 opposite to the first face 70A. In addition, it is necessary for the separation between the walls of each of the two parts to be pronounced and sufficiently clear for the encapsulation product 900 when it has become liquid not to tend to rise up along the walls of the second part. For this reason, in accordance with the example illustrated by this variant, it is arranged that the frame 600A opens into the second part, and is connected to its walls, through the intermediary of a border 600C which extends in a plane parallel to the first face 70A of the bar and forms a flat area, as illustrated in figure 9C, or else forms a downwards slope between its intersection with the sides of the frame and its intersection with the walls of the second part 600B as shown in figure 9D. In this way, on account of the existence of the phenomena of capillary action and surface tension, when the encapsulation product is in the liquid condition, in no case can it spread onto the border 600C or the flat area, but it will stabilise at the intersection between the upper edge of the frame 600A and the border 600C or the flat area surrounding the said frame.

On account of the tolerances which may exist for the volume of encapsulation product placed within the frame, it may happen that there will be either just the required quantity, or a little too much of the product, or a quantity which is slightly insufficient. In the case where the quantity is slightly insufficient, the upper face of the encapsulation will take the shape of a concave meniscus when the product is in the liquid phase, the said meniscus springing from the intersection between the walls of the frame 600A and the border 600C or the flat area surrounding the said frame, as is shown in figure 9C. On the other hand, if somewhat too much of the encapsulation product 900 is placed within the frame 600A, then a convex meniscus will be formed which also springs from the intersection between the sides of the frame and the border 600C or the peripheral flat area, as shown in figure 9D. It will be noted, however, that the volume of encapsulation material can be controlled to within a few hundredths of a cubic millimetre, at the time when it is put in place, so that the deformation due to the concavity or the convexity is

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negligible. In fact, a dosing error of a tenth of a cubic millimetre too much or too little corresponds to a convexity or a concavity whose height or depth is of the order of 2 microns, which is negligible compared to 350 microns which is the average value of the height of the encapsulation. Such a convexity or concavity is practically invisible and of no consequence. It must therefore be admitted that the process of the invention enables perfect control of the shape and size of the encapsulation.

In figures 9C and 9D are shown cases where the peripheral walls of the frame, defining the shape of the encapsulation are perpendicular to the face 70A of the bar which is to be applied against the support; so that an encapsulation produced using such an arrangement will have a rectangular parallelepiped base.

Figures 9E and 9F show respectively variants of figures 9C and 9D in which the said walls of the frame, that is to say the first part 600A of the recess, are slightly inclined, the cross sectional area at the base being greater than the cross sectional area where it opens into the second part, in order to facilitate the removal of the bar after hardening of the encapsulation product.

Lastly, it should be noted that the alternatives illustrated by figures 9D and 9F are more difficult to implement, since it should be recalled that the height "e" between the plane of the support and the intersection between the walls of the frame 600A and the border 600C or the peripheral flat area may be very small, of the order of 300 microns, and it follows that machining an inclined border may pose particular manufacturing problems. In addition, very good results are obtained by using the alternatives illustrated by figures 9C or 9E, without it necessarily being required to attempt to produce the alternatives of figures 9D and 9F. These possibilities have simply being mentioned to show the importance that there is for the opening of the frame opposite to that which is to be brought into contact with the support 1 to be surrounded by a border whose shape and design are such that the encapsulation product when it is in the liquid phase is unable to spread over this edging but stays properly in the limits of the frame, without rising up in such a way as to leave part of the electronic assembly not encapsulated.

Preferably, the encapsulation apparatus (bar, heater means) is completed by a device for putting in place the required volume of encapsulation material.

In the case of a bar with several frames, it is either arranged that the frames are filled one after the other, the device for putting in place moving relative to the bar, or that the device can simultaneously fill all the frames of the same bar.

It will therefore also be understood from reading the foregoing that it is important for the implementation of the invention that the apparatus be positioned in such a way that the support is disposed in a horizontal plane, with the electronic assembly above the support, since the

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spreading of the encapsulation product is produced while it is in a liquid condition by using the phenomena of gravity and of capillary action and by profiting from the surface tensions which can occur at the surface of liquids in order to spread it out properly within the frame.

The invention is therefore especially advantageous, simple to implement and completely solves the problems of the prior art, since it enables an encapsulation to be obtained in the desired shape and size, the operation running absolutely no risk of damaging the electronic assembly that it is intended to encapsulate.

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CLAIMS

1. A method of encapsulating on its support (1) with the use of a hardenable material (900) an electronic assembly formed from an integrated circuit (2, 3, 4, 100 ... 108, 100A) and its wires (210 ... 215, 310 ... 315, 410 ... 415, 100B ... 100G) for contact with the exterior, which is carried by a face of the said support (1), characterised in that it consists on one hand of positioning the support (1) and the electronic assembly in such a way that the said face of the support (1) carrying the integrated circuit is disposed in a substantially horizontal plane, at a level higher than the other planes of the support, the base of the encapsulation thus being formed on the support, of positioning on the said face of the support, around the electronic assembly, a frame (6, 600A ... 608A) whose dimensions and shape correspond to the dimensions and shape of the outer edge of the encapsulation adjacent to the said face of the support, the periphery of a first opening of the frame being pressed flat on the support, the frame remaining accessible through its other opening opposite to the first opening, and in that it consists on the other hand of putting into the frame, through its accessible opening, the necessary quantity of encapsulation material (900) to obtain the final encapsulation, the said material being chosen among those which are capable of adopting a liquid state between the moment when they are put into the frame and before their hardening, so that, while it is in the liquid state, the material spreads under gravity into the whole of the frame and adopts the shape of the interior edge of the frame by capillary action, the encapsulation thus taking its final shape before hardening, and in that the material is hardened, and in that the frame is removed after hardening of the material.

2. A method of encapsulation according to claim 1, characterised in that it consists of depositing an encapsulation material (900) in liquid form, the said material being chosen among those which present the characteristic of polymerising or hardening at room temperature.

3. A method of encapsulation according to claim 1, characterised in that it consists of depositing a liquid encapsulation material presenting the characteristic of being polymerisable or hardenable by bringing it to a defined temperature which is higher than the temperature at which it was put in place, and implementing means for bringing the encapsulation material (900) to its polymerisation or hardening temperature.

4. A method of encapsulation according to claim 1, characterised in that the encapsulation material is viscous at the ambient temperature at which it is deposited and has the characteristic of being able to polymerise following a rise in temperature, while passing through a liquid phase between the ambient temperature and the said polymerisation temperature, and in that it consists of implementing means for raising the temperature of the said encapsulation material after it has been put in position within the frame.

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5. A method of encapsulation according to claim 3 or 4, characterised in that it consists of depositing the encapsulation material (900) in at least two different positions within the frame, in such a way as to assist it spreading over the electronic assembly when it reaches the liquid state.

6. A method of encapsulation according to any one of the preceding claims, characterised in that the encapsulation material (900) is chosen from among the epoxy resins.

7. Apparatus for performing the process according to any one of the claims 1 to 6, characterised in that it comprises a bar (7, 70) in which is formed at least one orifice (6, 600 ... 608) which opens into two of its opposed faces (7A, 7B, 70A, 70B), the distance between the two of which corresponds to the thickness of the bar, a first one of the said faces (7A, 70A) being arranged to come into contact with a support (1) for at least one electronic assembly during the encapsulation, in that the part at least of each orifice opening into the said first face (7A, 70A) which is to be brought into contact with the support forms a frame (6, 600A ... 608A) having its peripheral wall (61, 62, 63, 64) opening on one hand into a first edge formed by the said first face (7A, 70A) and on the other hand into a second edge (600C), and in that the shape of the said peripheral wall defines the exterior shape of the wall of the encapsulation adjacent to the support (1), and in that the height "e" of the frame, corresponding to the distance between the first (7A, 70A) and the second (78, 600C) edge, is equal to the desired thickness of the encapsulation, and in that none of the points on the second edge is at a distance orthogonal to the first face (7A, 70A) of the bar greater than the height "e" of the frame, and in that the dimensions of the frame are such that it defines a volume greater than that of an electronic assembly to be encapsulated, and in that the bar comprises as many orifices as the support comprises assemblies to be simultaneously encapsulated.

8. Apparatus according to claim 7, characterised in that the thickness of the bar (7, 70) corresponds to the desired thickness of the encapsulation, and in that the said second edge (600C) is formed by the second face (7B, 70B) of the bar (7, 70) opposite to the first face (7A, 70A).

9. Apparatus according to claim 7, characterised in that the bar (7, 70) has an overall thickness greater than the height of the frame, so as to give the bar sufficient strength when it is pressed against the support (1) for the electronic assembly, and in that each orifice is in two parts, a first part (600A ... 608A) forming a frame starting from the first face (7A, 70A) of the bar and terminating, within the thickness of the bar, in a border (600C ... 608C), defining the said second edge and a second part (600B ... 608B) starting from the second edge (600C ... 608C) and opening into the second face (7B, 70B) of the bar, the second part having at every point a cross sectional area greater than the cross sectional area of the first part, so as to facilitate putting the encapsulation material in position through the opening of the second part which opens into the second face of the bar.

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10. Apparatus according to claim 9, characterised in that the bar (7, 70) is formed from a one piece block of material.

11. Apparatus according to claim 9, characterised in that the bar (7, 70) is formed in two members (700, 701) which can be placed one on top of the other, a first one of which (700) has a thickness corresponding to the desired thickness of the encapsulation, the said first member (700) being provided with the first parts (600A ... 608A) of orifices forming the frames, and a second member (701) for reinforcement being provided with the second parts (600B ... 608B) of orifices.

12. Apparatus according to one of the claims 7 to 11 characterised in that it comprises a base plate (80) with a planar face (81), for receiving the face of the support (1) for at least one electronic assembly opposite to the face which carries each assembly, so that when the bar (70) is placed above the support (1), the support becomes clamped between the base plate and the bar, in order for the encapsulation liquid to be unable to flow between the bar and the support, and in that means (71, 72, 82, 83, 84, 85, 109, 110) are provided for properly positioning the base plate relative to the bar, and the support (1) relative to the bar, respectively.

13. Apparatus according to claim 12, characterised in that the means for correctly positioning the base plate (80), the support (1) and the bar (7, 70) are formed by pins (82, 83, 84, 85) and complementary orifices (71, 72, 109, 110).

14. Apparatus according to any one of the claims 7 to 13, characterised in that the bar is formed by a thermally conductive material and comprises, contained in the bulk of the material, heater elements (9) to enable hardening or polymerisation of the encapsulation material by heat.

15. Apparatus according to one of claims 7 to 13, characterised in that the bar is formed in a thermally conductive material such as a material having a metal base, to enable hardening or polymerisation of the encapsulation material at room temperature, or heat hardening or polymerisation by heating the bar, at least, with the aid of a suitable source of heat.

16. Apparatus according to any one of claims 7 to 13, characterised in that the bar (7, 70) is formed in a heat insulating material, such as a ceramic, in order to enable hardening or polymerisation of the encapsulation material at ambient temperature, or heat hardening or polymerisation by direct exposure of the encapsulation material to a suitable source of radiation.

17. Apparatus according to one of claims 14 to 16, characterised in that it comprises at least one external source of radiation, placed in such a way that the encapsulation material and / or the bar may be directly exposed thereto, in such a way that the encapsulation material is brought to its hardening or polymerisation temperature.

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18. An electronic assembly formed by an integrated circuit (2, 3, 4, 100A, 100 ... 108) and its wires for contact with the exterior, carried by a support (1), and encapsulated on the support by implementation of a method according to one of claims 1 to 6.

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