ABSTRACT

Dies that are attached to a die plate can be transferred to a substrate. An actuator can be used to cause a die to be released from the die plate and to come into contact with the substrate. For example, the die may cover a corresponding hole in the die plate. The actuator can move a pin into the hole in the die plate, thereby pushing the die from the die plate. The actuator may be actuated by an electromagnetic stimulus. For instance, a solenoid having windings around a tubular core may provide the electromagnetic stimulus to the actuator. Current may be provided to the windings of the solenoid to generate the electromagnetic stimulus that actuates the actuator. The actuator may be provided in the tubular core of the solenoid.
FIG. 1
BEGIN

PRODUCE WAFER HAVING MULTIPLE DIES

APPLY WAFER TO SUPPORT SURFACE

SEPARATE DIES

TRANSFER DIE FROM SUPPORT SURFACE TO TAG SUBSTRATE

POST PROCESS TAG SUBSTRATE

END

FIG. 3
FIG. 4A
Receive die plate having die attached to first surface thereof

Position first surface of die plate and substrate adjacent to each other

Apply electromagnetic stimulus to actuator to cause die to be released from die plate to come into contact with contact area

FIG. 7
TRANSFERRING DIE(S) FROM AN INTERMEDIATE SURFACE TO A SUBSTRATE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The following applications of common assignee are herein incorporated by reference in their entireties:


BACKGROUND OF THE INVENTION

[0005] 1. Field of the Invention

[0006] The present invention relates generally to the assembly of electronic devices. More particularly, the present invention relates to the transfer of integrated circuit (IC) dies to surfaces in high volumes.

[0007] 2. Related Art

[0008] Pick and place techniques are often used to assemble electronic devices. Such techniques involve a manipulator, such as a robot arm, to remove integrated circuit (IC) chips or dies from a wafer and place them into a die carrier. The dies are subsequently mounted onto a substrate with other electronic components, such as antennas, capacitors, resistors, and inductors to form an electronic device.

[0009] Pick and place techniques involve complex robotic components and control systems that handle only one die at a time. This has a drawback of limiting throughput volume. Furthermore, pick and place techniques have limited placement accuracy, and have a minimum die size requirement.

[0010] One type of electronic device that may be assembled using pick and place techniques is an RFID "tag." An RFID tag may be affixed to an item whose presence is to be detected and/or monitored. The presence of an RFID tag, and therefore the presence of the item to which the tag is affixed, may be checked and monitored by devices known as "readers."

[0011] As market demand increases for products such as RFID tags, and as die sizes shrink, high assembly throughput rates and low production costs are crucial in creating commercially viable products. Accordingly, what is needed is a method and apparatus for high volume assembly of electronic devices, such as RFID tags, that overcomes these limitations.

SUMMARY OF THE INVENTION

[0012] The present invention is directed to methods, systems, and apparatuses for producing one or more electronic devices, such as RFID tags, that each include one or more dies. The dies each have one or more electrically conductive contact pads that provide for electrical connections to related electronics on a substrate.

[0013] According to embodiments of the present invention, electronic devices are formed at greater rates than conventionally possible. In one aspect, large quantities of dies can be transferred directly from a wafer to corresponding substrates of a web of substrates. In another aspect, large quantities of dies can be transferred from a support surface to corresponding substrates of a web of substrates. In another aspect, large quantities of dies can be transferred from a wafer or support surface to an intermediate surface, such as a die plate. The die plate may have cells formed in a surface thereof in which the dies reside. Otherwise, the dies can reside on a surface of the die plate. The dies of the die plate can then be transferred to corresponding substrates of a web of substrates.

[0014] In embodiments of the present invention, an integrated circuit die is transferred from a die plate to a substrate by electromagnetically stimulating an actuator. The die plate has a first surface having a die attached thereto. The die covers a corresponding hole through the die plate. An electromagnetic stimulus actuates the actuator, which releases the die from the die plate. For example, the actuator may include a pin that extends into the hole in the die plate and moves the die from the die plate into contact with the substrate.

[0015] The first surface of the die plate and the substrate may be positioned to be adjacent to each other such that the die is closely adjacent to a corresponding contact area on a first surface of the substrate.

[0016] A solenoid may be used to generate the electromagnetic stimulus. According to an embodiment, the solenoid includes windings around a tubular core, and the actuator is provided in the tubular core. A current may be provided in a first direction through the windings to generate an electromagnetic stimulus having a first polarity. The electromagnetic stimulus having the first polarity may cause the actuator to move toward the die. A current may be provided in a second direction that is opposite the first direction through the windings to generate an electromagnetic stimulus having a second polarity. According to an embodiment, the electromagnetic stimulus having the second polarity may cause the actuator to move away from the die. In another embodiment, the actuator may have a magnetic property at steady state that moves the actuator away from the die. In yet another embodiment, a spring may be attached to the actuator to move the actuator toward or away from the die.

[0017] These and other advantages and features will become readily apparent in view of the following detailed description of the invention. Note that the Summary and Abstract sections may set forth one or more, but not all exemplary embodiments of the present invention as contemplated by the inventor(s), and thus, are not intended to limit claims.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

[0018] The accompanying drawings, which are incorporated herein and form a part of the specification, illustrate the
The present invention and, together with the description, further serve to explain the principles of the invention and to enable a person skilled in the pertinent art to make and use the invention.

FIG. 1 shows a block diagram of an exemplary RFID tag, according to an embodiment of the present invention.

FIGS. 2A and 2B show plan and side views of an exemplary die, respectively.

FIGS. 2C and 2D show portions of a substrate with a die attached thereto, according to an example embodiment of the present invention.

FIG. 3 is a flowchart illustrating a device assembly process, according to embodiments of the present invention.

FIGS. 4A and 4B are plan and side views of a wafer having multiple dies affixed to a support surface, respectively.

FIG. 5 is a view of a wafer having separated dies affixed to a support surface.

FIG. 6 shows a system diagram illustrating example options for transfer of dies from wafers to substrates, according to embodiments of the present invention.

FIG. 7 is a flowchart of a method for transferring dies from an intermediate surface to a substrate using an electromagnetic stimulus, according to embodiments of the present invention.

FIG. 8 is a cross-sectional view of a die plate, according to an example embodiment of the present invention.

FIG. 9 is a plan view of the die plate shown in FIG. 8, according to an example embodiment of the present invention.

FIG. 10 is a cross-sectional view of the die plate shown in FIG. 8, in which dies are attached to a surface of the die plate, according to an example embodiment of the present invention.

FIG. 11 shows a system, according to an example embodiment of the present invention.

FIG. 12 shows the system of FIG. 11 in which an actuator causes a die to be detached from a die plate, according to an example embodiment of the present invention.

FIG. 13 shows the system of FIG. 11 having a plurality of actuators, according to an example embodiment of the present invention.

The present invention will now be described with reference to the accompanying drawings. In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements. The drawing in which an element first appears is indicated by the leftmost digit(s) in the reference number.

DETAILED DESCRIPTION OF THE INVENTION

1.0 Overview

The present invention provides improved processes and systems for assembling electronic devices, including RFID tags. The present invention provides improvements over previous processes. Conventional techniques include vision-based systems that pick and place dies one at a time onto substrates. The present invention can transfer multiple dies simultaneously. Vision-based pick and place systems are limited as far as the size of dies that may be handled, such as being limited to dies larger than 600 square microns (µm²). The present invention is applicable to dies having an area of 100 µm² and even smaller. Furthermore, yield is poor in conventional systems, where two or more dies may be accidentally picked up at a time, causing losses of additional dies. The present invention allows for improved yield values.

The present invention provides an advantage of simplicity. Conventional die transfer tape mechanisms may be used by the present invention. Furthermore, much higher fabrication rates are possible. Previous techniques processed 5-8 thousand units per hour. The present invention provides improvements in these rates by a factor of N. For example, embodiments of the present invention can process dies 5 times as fast as conventional techniques, at 100 times as fast as conventional techniques, and at even faster rates. Furthermore, because the present invention allows for flip-chip die attachment techniques, wire bonds are not necessary. However, in embodiments, the present invention is also applicable to wire bonded die configurations.

Elements of the embodiments described herein may be combined in any manner. Example RFID tags are described in section 1.1. Assembly embodiments for devices are described in section 1.2. More detailed assembly embodiments for devices are described in sections 2.0 and 3.0.

1.1 Example Electronic Device

The present invention is directed to techniques for producing electronic devices, such as RFID tags. For illustrative purposes, the description herein primarily relates to the production of RFID tags. However, the invention is also adaptable to the production of further electronic device types (e.g., electronic devices including one or more IC dies or other electrical components mounted thereto), as would be understood by persons skilled in the relevant art(s) from the teachings herein. Furthermore, for purposes of illustration, the description herein primarily describes attachment of dies to substrates. However, embodiments of the present invention are also applicable to the attachment of other types of electrical components to substrates, including any type of surface mount component (e.g., surface mount resistors, capacitors, inductors, diodes, etc.), as would be understood by persons skilled in the relevant art(s).

FIG. 1 shows a block diagram of an exemplary RFID tag 100, according to an embodiment of the present invention. As shown in FIG. 1, RFID tag 100 includes a die 104 and related electronics 106 located on a tag substrate 116. Related electronics 106 includes an antenna 114 in the present example. Die 104 can be mounted onto antenna 114 of related electronics 106, or on other locations of substrate 116. As is further described elsewhere herein, die 104 may be mounted in either a pads up or pads down orientation.

RFID tag 100 may be located in an area having a large number, population, or pool of RFID tags present. Tag 100 receives interrogation signals transmitted by one or
more tag readers. According to interrogation protocols, tag 100 responds to these signals. The response(s) of tag 100 includes information that the reader can use to identify the corresponding tag 100. Once the tag 100 is identified, the existence of tag 100 within a coverage area defined by the tag reader is ascertained.

RFID tag 100 may be used in various applications, such as inventory control, airport baggage monitoring, as well as security and surveillance applications. Thus, tag 100 can be affixed to items such as airline baggage, retail inventory, warehouse inventory, automobiles, compact discs (CDs), digital video discs (DVDs), video tapes, and other objects. Tag 100 enables location monitoring and real time tracking of such items.

In the present embodiment, die 104 is an integrated circuit that performs RFID operations, such as communicating with one or more tag readers (not shown) according to various interrogation protocols. Exemplary interrogation protocols are described in U.S. Pat. No. 6,002,344 issued Dec. 14, 1999 to Bandy et al., titled “System and Method for Electronic Inventory,” and U.S. patent application Ser. No. 10/072,885, filed on Feb. 12, 2002, both of which are incorporated by reference herein in their entirety. RFID dies of the present invention may communicate according to any RFID communication protocol(s), including binary traversal, slotted Aloha, Class 0, Class 1, Gen 2, and other protocols. Die 104 includes a plurality of contact pads that each provide an electrical connection with related electronics 106.

Related electronics 106 are connected to die 104 through a plurality of contact pads of IC die 104. In embodiments, related electronics 106 provide one or more capabilities, including RF reception and transmission capabilities, impedance matching, sensor functionality, power reception and storage functionality, as well as additional capabilities. Components of related electronics 106 can be mounted or formed on substrate 116 in any manner. For example, components of related electronics 106 can be printed onto a tag substrate 116 with materials, such as conductive inks. Examples of conductive inks include silver conductors 5000, 5021, and 5025, produced by DuPont Electronic Materials of Research Triangle Park, N.C. Other example materials or means suitable for printing related electronics 106 onto tag substrate 116 include polymeric dielectric composition 5018 and carbon-based PTC resistor paste 7282, which are also produced by DuPont Electronic Materials of Research Triangle Park, N.C. Other materials or means that may be used to deposit the component material onto the substrate would be apparent to persons skilled in the relevant art(s) from the teachings herein.

As shown in FIG. 1, tag substrate 116 has a first surface that accommodates die 104, related electronics 106, as well as further components of tag 100. Tag substrate 116 also has a second surface that is opposite the first surface. An adhesive material and/or backing can be included on the second surface. When present, an adhesive backing enables tag 100 to be attached to objects, such as books, containers, and consumer products. Tag substrate 116 is made from a material, such as polyester, paper, plastic, fabrics such as cloth, and/or other materials such as commercially available Tyvek®.

In some implementations of tags 100, tag substrate 116 can include an indentation, “cavity,” or “cell” (not shown in FIG. 1) that accommodates die 104. An example of such an implementation is included in a “pads up” orientation of die 104.

FIGS. 2A and 2B show plan and side views of an example die 104. Die 104 includes four contact pads 204a-d that provide electrical connections between related electronics 106 (not shown) and internal circuitry of die 104. Note that although four contact pads 204a-d are shown, any number of contact pads may be used, depending on a particular application. Contact pads 204 are typically made of an electrically conductive material during fabrication of the die. Contact pads 204 can be further built up if required by the assembly process, by the deposition of additional and/or other materials, such as gold or solder flux. Such post processing, or “bumping,” will be known to persons skilled in the relevant art(s).

FIG. 2C shows a portion of a substrate 116 with die 104 attached thereto, according to an example embodiment of the present invention. As shown in FIG. 2C, contact pads 204a-d of die 104 are coupled to respective contact areas 210a-d of substrate 116. Contact areas 210a-d provide electrical connections to related electronics 106. The arrangement of contact pads 204a-d in a rectangular (e.g., square) shape allows for flexibility in attachment of die 104 to substrate 116, and good mechanical adhesion. This arrangement allows for a range of tolerances for imperfect placement of IC die 104 on substrate 116, while still achieving acceptable electrical coupling between contact pads 204a-d and contact areas 210a-d. For example, FIG. 2D shows an imperfect placement of IC die 104 on substrate 116. However, even though IC die 104 has been improperly placed, acceptable electrical coupling is achieved between contact pads 204a-d and contact areas 210a-d.

Contact pads 204 can be attached to contact areas 210 of substrate 116 using any suitable conventional or other attachment mechanism, including solder, an adhesive material (including isotropic and anisotropic adhesives), mechanical pressure (e.g., being held in place by an encapsulating material), etc.

Note that although FIGS. 2A-2D show the layout of four contact pads 204a-d collectively forming a rectangular shape, a greater or lesser number of contact pads 204 may be used. Furthermore, contact pads 204a-d may be laid out in other shapes in other embodiments.

1.2 Device Assembly

The present invention is directed to continuous-roll assembly techniques and other techniques for assembling electronic devices, such as RFID tag 100. Such techniques involve a continuous web (or roll) of the material of the substrate 116 that is capable of being separated into a plurality of devices. Alternatively, separate sheets of the material can be used as discrete substrate webs that can be separated into a plurality of devices. As described herein, the manufactured one or more devices can then be post processed for individual use. For illustrative purposes, the techniques described herein are made with reference to assembly of tags, such as RFID tag 100. However, these techniques can be applied to other tag implementations and other suitable devices, as would be apparent to persons skilled in the relevant art(s) from the teachings herein.
The present invention advantageously eliminates the restriction of assembling electronic devices, such as RFID tags, one at a time, allowing multiple electronic devices to be assembled in parallel. The present invention provides a continuous-roll technique that is scalable and provides much higher throughput assembly rates than conventional pick and place techniques.

FIG. 3 shows a flowchart illustrating a process 300 for assembling tags 100. According to example embodiments of the present invention, FIG. 3 is described with continued reference to FIGS. 4A and 4B. However, process 300 is not limited to these embodiments.

Process 300 begins with a step 302. In step 302, a wafer 400 is produced. FIG. 4A illustrates a plan view of an exemplary wafer 400. As illustrated in FIG. 4A, a plurality of dies 104 are arranged in a plurality of rows 402a-n. In a step 304, wafer 400 is optionally applied to a support structure or surface 404. Support surface 404 includes an adhesive material to provide adhesiveness. For example, support surface 404 may be an adhesive tape that holds wafer 400 in place for subsequent processing. For instance, in example embodiments, support surface 404 can be a “green tape” or “blue tape,” as would be understood by persons skilled in the relevant art(s). FIG. 4D shows an example view of wafer 400 in contact with an example support surface 404. In some embodiments, wafer 400 is not attached to a support surface, and can be operated on directly.

In a step 306, the plurality of dies 104 on wafer 400 are separated or “singulated.” For example, step 306 may include scribing wafer 400 using a wafer saw, laser etching, or other singulation mechanism or process. FIG. 5 shows a view of wafer 400 having example separated dies 104 that are in contact with support surface 404. FIG. 5 shows a plurality of scribe lines 502a-f that indicate locations where dies 104 are separated.

In a step 308, the plurality of dies 104 is transferred to a substrate. For example, dies 104 can be transferred from support surface 404 to tag substrates 116. Alternatively, dies 104 can be directly transferred from wafer 400 to substrates 116. In an embodiment, step 308 may allow for “pads down” transfer. Alternatively, step 308 may allow for “pads up” transfer. As used herein the terms “pads up” and “pads down” denote alternative implementations of tags 100. In particular, these terms designate the orientation of connection pads 204 in relation to tag substrate 116. In a “pads up” orientation for tag 100, die 104 is transferred to tag substrate 116 with pads 204a-204d facing away from tag substrate 116. In a “pads down” orientation for tag 100, die 104 is transferred to tag substrate 116 with pads 204a-204d facing towards, and in contact with tag substrate 116.

Note that step 308 may include multiple die transfer iterations. For example, in step 308, dies 104 may be directly transferred from a wafer 400 to substrates 116. Alternatively, dies 104 may be transferred to an intermediate structure, and subsequently transferred to substrates 116. Example embodiments of such die transfer options are described below in reference to FIG. 6.

Note that steps 306 and 308 can be performed simultaneously in some embodiments. This is indicated in FIG. 3 by step 320, which includes both of steps 306 and 308.


In a step 310, post processing is performed. For example, during step 310, assembly of RFID tag(s) 100 is completed. Example post processing of tags that can occur during step 310 are provided as follows:

(a) Separating or singulating tag substrates 116 from the wafer using a wafer saw, laser etching, or other singulation mechanism or process. For examples, support surface 404 can be a “green tape” or “blue tape,” as would be understood by persons skilled in the relevant art(s). FIG. 4D shows an example view of wafer 400 in contact with an example support surface 404. In some embodiments, wafer 400 is not attached to a support surface, and can be operated on directly.

(b) Forming tag “labels.” A “label” is used generally to refer to an inlay that has been attached to a pressure sensitive adhesive (PSA) construction, or laminated and then cut and stacked for application through in-mould, wet glue or heat seal application processes, for example. A variety of label types are contemplated by the present invention. In an embodiment, a label includes an inlay attached to a release liner by pressure sensitive adhesive. The release liner may be coated with a low-to-non-stick material, such as silicone, so that it adheres to the pressure sensitive adhesive, but may be easily removed (e.g., by peeling away). After removing the release liner, the label may be attached to a surface of an object, or placed in the object, adhering to the object by the pressure sensitive adhesive. In an embodiment, a label may include a “face sheet”, which is a layer of paper, a film, and/or other material, attached to a surface of the inlay opposite the surface to which the pressure sensitive material attaches. The face sheet may have variable information printed thereon, including product identification regarding the object to which the label is attached, etc.

(c) Testing of the features and/or functionality of the tags.

FIG. 6 further describes example flows for step 308 of FIG. 3. FIG. 6 shows a high-level system diagram 600 that provides a representation of the different modes or paths of transferring dies from wafers to substrates. FIG. 6 shows a wafer 400, a substrate web 608, and a transfer surface 610. Two paths are shown in FIG. 6 for transferring dies, a first path 602, which is a direct path, and a second path 604, which is a path having intermediate steps.

For example, as shown in FIG. 6, first path 602 leads directly from wafer 400 to substrate web 608. In other words, dies can be transferred from wafer 400 to substrates of substrate web 608 directly, without the dies having first to
be transferred from wafer 400 to another surface or storage structure. However, as shown in path 604, at least two steps are required, path 604A and path 604B. For path 604A, dies are first transferred from wafer 400 to an intermediate transfer surface 610. The dies then are transferred from transfer surface 610 via path 604B to the substrates of web 608. Paths 602 and 604 each have their advantages. For example, path 602 can have fewer steps than path 604, but can have issues of die registration, and other difficulties. Path 604 typically has a larger number of steps than path 602, but transfer of dies from wafer 400 to a transfer surface 610 can make die transfer to the substrates of web 608 easier, as die registration may be easier.

Any of the intermediate transfer surfaces and final substrate surfaces may or may not have cells formed therein for dies to reside therein. Various processes described below may be used to transfer multiple dies simultaneously between first and second surfaces, according to embodiments of the present invention. In any of the processes described herein, dies may be transferred in either pads-up or pads-down orientations from one surface to another.

Elements of the die transfer processes described herein may be combined in any way, as would be understood by persons skilled in the relevant art(s). Example die transfer processes, and related example structures for performing these processes, are further described in the following subsections.

2.0 Die Transfer Embodiments

FIG. 7 shows a flowchart 700 of a method of transferring dies from an intermediate surface to a substrate using an electromagnetic stimulus (e.g., an electromagnetic field), according to embodiments of the present invention. The flowchart depicted in FIG. 7 is described with continued reference to FIGS. 8-13. However, flowchart 700 is not limited to those embodiments. Further operational and structural embodiments of the present invention will be apparent to persons skilled in the relevant arts based on the following discussion. Note that in alternative embodiments, steps shown in FIG. 7 can occur in an order other than that shown, and in some embodiments, not all steps shown are necessary.

Flowchart 700 begins at step 702. In step 702, a die plate is received having a die attached to a first surface thereof. For example, the die plate is die plate 802 shown in FIG. 8. FIG. 8 is a cross-sectional view of die plate 802, according to an example embodiment of the present invention. As shown in FIG. 8, die plate 802 has a plurality of holes 804 extending from a first surface 806 to a second surface 808 of die plate 802. Example embodiments of die plates are described in co-pending applications, U.S. Ser. No. 10/866,150, titled “Method, System, and Apparatus for Transfer of Dies Using a Die Plate Having Die Cavities,” (Appx. Dkt. 1689.0540000) and U.S. Ser. No. 10/866,253, titled “Method, System, and Apparatus for Transfer of Dies Using a Die Plate,” (Appx. Dkt. 1689.0550000), both of which are herein incorporated by reference in their entirety.

Although not shown in FIG. 8, die plate 802 can be supported by a die plate holder, which may include a clamp, or other mechanism for holding die plate 802. According to an embodiment, die plate 802 has a thickness, t, of 20 mill-inches (mils) or less. In another embodiment, die plate 802 has a thickness, t, of 10 mils or less. Die plate 802 may be fabricated in less than one hour and/or at a cost of less than $100.

FIG. 9 is a plan view of die plate 802, according to an example embodiment of the present invention. In FIG. 9, die plate 802 includes eight rows and eight columns of holes 804 for illustrative purposes. However, die plate 802 may have any number of rows and/or columns.

FIG. 10 is a cross-sectional view of die plate 802, in which dies 104a-d are attached to first surface 806 of die plate 802, according to an example embodiment of the present invention. An adhesive material may be used to adhere dies 104a-d to first surface 806.

In step 704, the first surface of the die plate and the substrate are positioned to be adjacent to each other. For example, FIG. 11 shows a system 1100 according to an example embodiment of the present invention. In FIG. 11, die plate 802 and substrate 1102 are positioned to be adjacent to each other such that contact pads 204a and 204b of die 104a are closely adjacent to corresponding contact areas 210a-b of substrate 1102. Note that die plate 802 and substrate 1102 in various embodiments can be positioned to varying degrees of closeness to each other, including distances other than that shown in FIG. 11.

In step 706, an electromagnetic stimulus is applied to an actuator to cause the die to be released from the die plate to come into contact with the contact area. FIG. 11 shows an example actuator 1150 that includes a first actuator element 1110 and a second actuator element 1130. In the embodiment of FIG. 11, first actuator element 1110 is shown as a cylindrical actuator body having a head 1122 and a pin 1112, and second actuator element 1130 is a solenoid coil surrounding the actuator body of first actuator element 1110. Head 1122 of first actuator element 1110 may be configured similarly to a head of a nail. In FIG. 11, system 1100 includes a pin plate 1104 having a hole 1120 into which first actuator element 1110 may be provided. Hole 1120 extends from a first surface 1116 of pin plate 1104 to a second surface 1118 of pin plate 1104. The coil of second actuator element 1130 surrounds hole 1120 in pin plate 1104.

In FIG. 11, first actuator element 1110 is shown to be magnetic. The magnetic poles of first actuator element 1110 are indicated by the symbols “N” and “S”. In the embodiment of FIG. 11, a magnetic property of first actuator element 1110 causes first actuator element 1110 and a plate 1114 to be in contact with each other in a steady state condition. Plate 1114 is present to limit the distance by which first actuator element 1110 can move from die plate 802. When present, plate 1114 may also provide environmental protection for actuator 1150. However, system 1100 need not necessarily include plate 1114.

As shown in FIG. 11, plate 1114 and first actuator element 1110 are magnetically coupled in the absence of an electromagnetic stimulus, for example. Opposing poles “N” and “S” of first actuator element 1110 generate a magnetic field that may react with a magnetic polarization of plate 1114 if plate 1114 is made from a magnetic metal. If plate 1114 has a polarization of “S”, then the “N” pole of first actuator element 1110 may be attracted toward plate 1114. For instance, the magnetic field generated by the opposing poles “N” and “S” of first actuator element 1110 may interact
with the polarization of plate 1114, thereby compelling first actuator element 1110 and plate 1114 to move toward each other. Arranging first actuator element 1110 and plate 1114 in relatively close proximity with each other may cause a magnetic force to move first actuator element 1110 and plate 1114 toward each other.

In FIG. 11, pin 1112 is moved through hole 804a of die plate 802 based on an electromagnetic stimulus. In embodiments, prior to actuation, pin 1112 may reside outside of hole 804a (as shown in FIG. 11) or may reside partially in hole 804a.

In the embodiment of FIG. 11, a second actuator element 1130 provides the electromagnetic stimulus (e.g., an electromagnetic field) for actuator 1150. For example, second actuator element 1130 may be a commercial off-the-shelf (COTS) solenoid or a custom designed solenoid. In FIG. 11, second actuator element 1130 includes windings 1108 around a tubular core 1106. Tubular core 1106 of second actuator element 1130 may have any cross-sectional shape (e.g., circular, square, rectangle, etc.).

Current (e.g., direct-current (DC) current) flows through windings 1108, generating the electromagnetic stimulus that stimulates actuator 1150. In the embodiment of FIG. 11, electromagnetic stimulation of actuator 1150 causes actuator 1150 to be moved toward die plate 802. For example, the electromagnetic stimulus may be associated with a magnetic force that counteracts the magnetic property of actuator 1150. The magnetic force may be an electromagnetic force, for instance.

In the embodiment of FIG. 11, application of the electromagnetic stimulus to actuator 1150 causes actuator 1150 to move pin 1112 through hole 804a, thereby pushing die 104a from surface 806 toward contact areas 210a-b. Thus, in an embodiment, current through windings 1108 causes first actuator element 1110 to move toward die plate 802, while a lack of current (or a reversal of current) causes actuator 1110 to move pin 1112 through hole 804a. In an alternative embodiment, current flowing through windings 1108 causes plate 1114 and actuator 1150 to be in contact with each other, and a disruption in the current flow causes actuator 1150 to move toward die plate 802, thereby moving pin 1112 through hole 804a.

According to an embodiment, the electromagnetic field generated by second actuator element 1130 maintains die plate 802 in contact with pin plate 1104. For example, the force of the electromagnetic field may be used to move die plate 802 and pin plate 1104 toward each other. The magnitude of the electromagnetic force is based on the amplitude of the current that flows through windings 1108. For instance, a current having a relatively high magnitude produces an electromagnetic force having a relatively high magnitude. A current having a relatively low magnitude produces an electromagnetic force having a relatively low magnitude. In another example, the electromagnetic field may inhibit or prevent die plate 802 from detaching from pin plate 1104 when pin 1112 detaches die 104a from die plate 802.

According to an embodiment, solenoid in FIG. 11 has a radius of 0.16" or less, and a height, h, in a range from 0.25" to 0.4". In an embodiment, the alignment of pin 1112 to hole 804a has a tolerance of 1 mil or less.

FIG. 12 shows actuator 1150 moving pin 1112 through hole 804a to detach die 104a from bottom surface 1116 of die plate 802, according to an example embodiment of the present invention. Actuator 1150 moves pin 1112 based on the electromagnetic stimulus generated by current flowing through windings 1108 of second actuator element 1130. In FIG. 12, pin 1112 moves die 104a to contact with substrate 1204a.

In embodiments, pin plate 1104 may include a plurality of actuators 1150, to transfer a plurality of dies simultaneously. For example, FIG. 13 shows system 1100 of FIG. 11 having a plurality of actuators 1150a-b, according to an example embodiment of the present invention. In FIG. 13, current flows through windings 1108a-b to stimulate respective first actuator elements 1110a-b, causing respective pins 1112a-b to transfer respective dies 104a and 104d from die plate 802. According to an embodiment, first actuator elements 1110a-b provide a known and/or controllable force to respective dies 104a and 104d. For example, each first actuator element 1110a-b may provide substantially the same predetermined force to respective pins 1112a-b, even if pins 1112a-b have different lengths.

Referring to FIG. 13, actuators 1110a-b may be stimulated simultaneously, consecutively, or selectively. For example, current may flow through windings 1108a-b at the same time or at different times.

In an embodiment, a computer system is used to control systems of the present invention. For example, the computer system may be configured to control movement of a die plate holder to position die plate 802 adjacent to substrate 1102. Furthermore, the computer system may be configured to control a substrate supply, which may be supplying substrates singly or in web format (i.e., sheets or continuous roll of substrates). Still further, the computer system may be configured to control a stimulus source to actuate the stimulus, and to direct the stimulus to various positions on die plate 802 to cause dies 104 to be transferred therefrom.

Furthermore, FIG. 13 also shows an adhesive material 1302a adhering contact pads 204 of die 104a to the corresponding contact areas 210 on the first surface of substrate 1204a. In an embodiment, adhesive material 1302 can be cured or otherwise treated to cause a die 104a to adhere to a substrate 1204. For example, the current that is applied to windings 1108a-b to cause respective actuators 1110 to move toward substrate 1102 may be maintained during the curing cycle. A pin 1112 can hold a respective die 104 in place with a predetermined force while adhesive material 1302 is cured using ultraviolet (UV) radiation, for example.

According to an embodiment, the electric and/or magnetic field generated by a second actuator element 1130 over time can be controlled, to maintain a downward force as desired for a particular application. For example, the electric and/or magnetic field generated by second actuator element 1130 can be controlled to avoid damaging integrated circuit dies, or to avoid causing first actuator element 1110 to become separated from pin plate 1104.

In another embodiment, pin 1112 is not included in first actuator element 1110. For example, pin 1112 may be included in a plate that is provided between first actuator element 1110 and die plate 802. In this embodiment, first
actuator element 1110 comes into contact with pin 1112 based on an electromagnetic stimulus, thereby moving pin 1112 through hole 804a to remove die 104a from die plate 802.

[0089] In yet another embodiment, first actuator element 1110 may be coupled to plate 1114 via a spring, and/or a spring may be present between head 1122 and the top surface of pin plate 1104, around the body of first actuator element 1110. For example, the spring may contract in a steady state condition and extend in response to an electromagnetic stimulus. In another example, the spring may be extended in a steady state condition and contracted in response to the electromagnetic stimulus.

3.0 Other Embodiments

[0090] FIGS. 1-13 are conceptual illustrations allowing an easy explanation of transferring die(s) from an intermediate surface to a substrate. It should be understood that embodiments of the present invention can be implemented in hard, firmware, software, or a combination thereof. In such an embodiment, the various components and steps are implemented in firmware, hardware, and/or software to perform the functions of the present invention. That is, the same piece of hardware, firmware, or module of software can perform one or more of the illustrated blocks (i.e., components or steps).

[0091] In this document, the terms “computer program medium” and “computer usable medium” are used to generally refer to media such as a removable storage unit, a hard disk installed in hard drive, and signals (i.e., electronic, electromagnetic, optical, or other types of signals capable of being received by a communications interface). These computer program products are means for providing software to a computer system. The invention, in an embodiment, is directed to such computer program products.

[0092] In an embodiment where aspects of the present invention are implemented using software, the software may be stored in a computer program product and loaded into a computer system using a removable storage drive, hard drive, or communications interface. The control logic (software), when executed by a processor, causes the processor to perform the functions of the invention as described herein.

[0093] According to an embodiment, a computer executes computer-readable instructions to control the release of die(s) from an intermediate surface, such as die plate 802, to a substrate. For instance, a roll of substrate material may be provided. The computer controls stimulation or actuation to cause one or more dies to be released from the intermediate surface to a first portion of the substrate. The roll of substrate may be advanced to provide a second portion of the substrate. The computer controls stimulation or actuation to cause one or more dies to be released from the intermediate surface to the second portion of the substrate, and so on. In an embodiment, the computer executes instructions to selectively actuate the actuator.

[0094] In another embodiment, aspects of the present invention are implemented primarily in hardware using, for example, hardware components such as application specific integrated circuits (ASIC's). Implementation of the hardware state machine so as to perform the functions described herein will be apparent to one skilled in the relevant art(s).

[0095] In yet another embodiment, the invention is implemented using a combination of both hardware and software.

4.0 Conclusion

[0096] While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example, and not limitation. It will be apparent to persons skilled in the relevant arts that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

1. A method of transferring a plurality of integrated circuit dies from a die plate to a substrate, comprising:

(a) receiving a die plate that has a first surface having a die attached thereto, wherein the die covers a hole through the die plate;

(b) positioning the first surface of the die plate and the substrate to be adjacent to each other such that the die is closely adjacent to a corresponding contact area on a first surface of the substrate; and

(c) applying a stimulus to an actuator to cause the die to be released from the die plate to come into contact with the contact area.

2. The method of claim 1, wherein step (c) includes:

moving a pin of the actuator through the hole in response to the stimulus, wherein moving the pin causes the die to be released from the die plate.

3. The method of claim 1, further comprising:

(d) providing a current to windings of a solenoid to generate the stimulus.

4. The method of claim 1, further comprising:

(d) generating a magnetic force in response to applying the stimulus, wherein the magnetic force causes the die to be released from the die plate.

5. The method of claim 1, further comprising:

(d) maintaining contact between the die plate and a pin plate that includes the actuator using the stimulus.

6. The method of claim 1, wherein step (a) includes:

receiving the die plate having a plurality of dies attached to the first surface of the die plate, the die plate having a plurality of holes therethrough, wherein each die of the plurality of dies covers a corresponding hole through the die plate.

7. The method of claim 6, further comprising:

(d) repeating step (c) for each die of the plurality of dies to cause each die to be released from the die plate to come into contact with a corresponding contact area on the substrate.

8. A method of transferring an integrated circuit die from a die plate to a substrate, comprising:

(a) aligning an actuator pin of an actuator and a hole in a die plate with each other, wherein the hole is covered by a die that is attached to a first surface of the die plate; and
(b) providing an electromagnetic stimulus to the actuator to cause the actuator pin to move into the hole and to detach the die from the first surface.

9. The method of claim 8, further comprising:

(c) providing a current to a solenoid having windings around a tubular core in which the actuator pin is provided to generate the electromagnetic stimulus.

10. The method of claim 8, wherein step (b) includes:

generating a magnetic force, thereby causing the die to be detached from the die plate.

11. The method of claim 8, wherein the electromagnetic stimulus maintains contact between the die plate and a pin plate that includes the actuator.

12. The method of claim 8, wherein step (a) includes:

receiving the die plate having a plurality of dies attached to the first surface of the die plate, the die plate having a plurality of holes therethrough, wherein each die of the plurality of dies covers a corresponding hole through the die plate.

13. The method of claim 12, further comprising:

(c) repeating step (b) for each die of the plurality of dies to cause each die to be detached from the first surface.

14. A system for transferring integrated circuit dies, comprising:

an actuator that includes:

a solenoid having windings around a tubular hollow core, and

an actuator pin positioned in the tubular hollow core; and

a die plate having a first surface to which a die is attached, wherein the die covers a corresponding hole through the die plate;

wherein the actuator is configured to move the pin through the hole to detach the die from the first surface of the die plate based on an electromagnetic stimulus generated by the solenoid.

15. The system of claim 14, further comprising:

a die plate holder configured to mount the die plate; and

a substrate supply configured to present a substrate, wherein the die plate holder is further configured to position the first surface of the die plate adjacent to the substrate such that the die is closely adjacent to a corresponding contact area on a first surface of the substrate.

16. The system of claim 14, further comprising:

a current source to provide a current to the windings to cause the pin to be moved toward the die.

17. The system of claim 14, further comprising a pin plate coupled to the die plate by the electromagnetic stimulus provided by the solenoid.

18. The system of claim 14, wherein the first surface of the die plate has a plurality of dies attached thereto, the die plate having a plurality of holes therethrough, and wherein each die of the plurality of dies covers a corresponding hole through the die plate.

19. The system of claim 14, wherein the actuator pin has a head.

20. The system of claim 14, wherein the actuator pin has opposing magnetic poles.

21. A system to transfer integrated circuit dies, comprising:

means for actuating a pin aligned with a hole in a die plate, wherein the hole is covered by a die that is attached to a first surface of the die plate; and

means for providing an electromagnetic stimulus to the means for actuating to cause the pin to move into the hole and to detach the die from the first surface.