

A SYSTEM AND METHOD FOR IMPROVED DIE FEED USING DUAL EJECTORS WITH ORIENTATION CORRECTION

5 TECHNICAL CONTRIBUTION

The present disclosure relates to die feed systems and methods. More particularly, the present disclosure relates to use of at least two ejectors in a die feed system for increased die pick and place throughput.

10 BACKGROUND

Taken from the first figure of U.S. Patent No. 7,637,714, **FIG. 1A** illustrates a prior art die feed system **01**. The die feed system **01** includes a wafer stage **03** holding a wafer **50**. The dies **52** on the wafer **50** are held in place with a mounting tape **51** and this mounting tape **51** is tensioned across a central opening (not shown in this figure).

15 Below the wafer **50**, in the central opening, an ejector assembly **04** with a pepper pot **47** is used to push a current die **53** partially from the mounting tape **51**, whereupon the current die **53** is picked and placed by a suction cup **22** attached to an arm **21** of a pick and place assembly **02**. Alignment of the current die **53** to the suction cup **22** is assisted by the camera unit **70** located above the wafer **50**.

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Prior art die feed systems **01**, as illustrated in **FIG. 1A**, use a single pepper pot and single arm for picking and placing. The first figure of Japanese Patent No. 2899291B2 illustrates two separate pepper pots; however these two pepper pots are used one at a time. The two pepper pots are different sizes so as to accommodate different die sizes.

25 If the dies of a wafer mounted on the wafer stage are smaller, then the smaller pepper pot is mounted for use. If the dies of a wafer mounted on the wafer stage are larger, then the larger pepper pot is mounted for use.

The dies on the prior art die feed system must be picked and placed from the mounting
30 tape to a substrate one at a time, resulting in significant time to complete a single wafer. What is needed is a die feed system with increased throughput for die pick and place, yet with sufficient simplicity to maintain a low capital and maintenance cost.

SUMMARY

A first embodiment of the invention is an improved die feed system for pick and place of a wafer with a plurality of dies, comprising: (a) a wafer stage; (b) an ejector assembly mounted within the central opening; (c) a pick and place assembly with a first and second arm movably mounted on the rigid frame configured for shuttling the dies from the wafer to a substrate stage for placement of the dies on a plurality of substrates; (d) a camera unit configured to create at least one wafer image; and (e) a control unit including a library with at least one wafer map and at least one die model, a processor, and a data bus that is in communication with the wafer stage, the ejector assembly, the pick and place assembly, and the camera unit. The wafer stage includes a tensioning ring configured to hold a mounting tape of the wafer in tension over a central opening in the wafer stage; and the wafer stage is movably mounted to a rigid frame. The ejector assembly includes at least a first and a second ejector mounted on a common base, and a rotation unit. Each ejector includes a pepper pot, an ejector pin, a top plate, an ejector actuator, and a stem.

In the first embodiment, the processor is configured to: (i) instruct the camera unit to image the wafer and align at least one of the wafer images with at least one wafer map; (ii) align at least one of the wafer images with the die model and identify a set of coordinates for each die, wherein the set of coordinates includes for each die an x-coordinate, a y-coordinate, and an angle theta; (iii) organize the dies into a series of pairs, each pair including a first die and a second die; (iv) in a first cycle, index the wafer stage to place the first pepper pot below the first die of each pair according to the x- and y-coordinates of the first die and rotate the first pepper pot to the angle theta of the first die with the rotation unit, then pick the first die by action of the first ejector and the first arm; (v) in a second cycle, index the wafer stage to place the second pepper pot below the second die of each pair according to the x- and y-coordinates of the second die and rotate the second pepper pot to the angle theta of the second die with the rotation unit, then pick the second die by action of the second ejector and the second arm, wherein the first and second cycles are offset in phase; and (vi) repeat the first and second cycles of steps (iv) and (v) respectively for the series of pairs of dies until a completion status is indicated by the control unit.

A second embodiment of the invention is a method for improved die feed for pick and place of a wafer with a plurality of dies, comprising the steps of: (a) loading the wafer on a wafer stage; (b) tensioning a mounting tape of the wafer over a central opening in the wafer stage using a tensioning ring, wherein the wafer stage is movably mounted to a rigid frame; (c) providing an ejector assembly mounted within the central opening, wherein: (i) the ejector assembly includes at least a first and a second ejector mounted on a common base, and a rotation unit; and (ii) each ejector includes a pepper pot, an ejector pin, a top plate, an ejector actuator, and a stem; (d) providing a pick and place assembly with a first and second arm movably mounted on the rigid frame configured for shuttling the dies from the wafer to a substrate stage for placement of the dies on a plurality of substrates; (e) providing a camera unit configured to create at least one wafer image; (f) providing a control unit including a library with at least one wafer map and at least one die model, a processor, and a data bus that is in communication with the wafer stage, the ejector assembly, the pick and place assembly, and the camera unit; (g) controlling via the processor the steps to: (i) instruct the camera unit to image the wafer and align at least one of the wafer images with at least one wafer map; (ii) align at least one of the wafer images with the die model and identify a set of coordinates for each die, wherein the set of coordinates includes for each die an x-coordinate, a y-coordinate, and an angle theta; (iii) organize the dies into a series of pairs, each pair including a first die and a second die; (iv) in a first cycle, index the wafer stage to place the first pepper pot below the first die of each pair according to the x- and y-coordinates of the first die and rotate the first pepper pot to the angle theta of the first die with the rotation unit, then pick the first die by action of the first ejector and the first arm; (v) in a second cycle, index the wafer stage to place the second pepper pot below the second die of each pair according to the x- and y-coordinates of the second die and rotate the second pepper pot to the angle theta of the second die with the rotation unit, then pick the second die by action of the second ejector and the second arm, wherein the first and second cycles are offset in phase; and (vi) repeat the first and second cycles of steps (iv) and (v) respectively for the series of pairs of dies until a completion status is indicated by the control unit.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present disclosure are described herein with reference to the drawings in which:

5 **FIG. 1A** is a simplified illustration of the prior art die feed system.

FIG. 1B is a side view of the die feed system in an embodiment of the invention.

10 **FIG. 1C** is a perspective view of the die feed system in an embodiment of the invention.

FIG. 2A is a perspective illustration of a first partial view of the pick and place assembly and the wafer stage holding a wafer in an embodiment of the invention.

15 **FIG. 2B** is perspective illustration of a second partial view of the pick and place assembly in an embodiment of the invention.

20 **FIG. 3A** is a top view of the wafer stage in an embodiment of the invention without a wafer on the wafer stage, revealing the two ejectors.

FIG. 3B is a perspective view of the wafer stage in an embodiment of the invention without a wafer on the wafer stage, revealing the two ejectors.

25 **FIG. 3C** is a perspective view of an expanded area, showing the wafer stage in an embodiment of the invention without a wafer on the wafer stage, revealing the two ejectors.

30 **FIG. 3D** is a perspective view of an expanded area, showing the wafer stage in an embodiment of the invention with a wafer on the wafer stage.

FIG. 4A is a perspective view of the ejector assembly in an embodiment of the invention with the two ejectors.

FIG. 4B is a top view of the ejector assembly in an embodiment of the invention with the two ejectors.

- 5 **FIG. 4C** is a side cross-sectional view of the two ejectors on a common base in embodiment of the invention.

FIG. 4D is a side cross-sectional view of a pepper pot in an embodiment of the invention.

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FIG. 5A is a text flowchart of the initial wafer loading and imaging the wafer in an embodiment of the invention.

- 15 **FIG. 5B** is a text flowchart of the aligning of a first pepper pot below the first die in an embodiment of the invention.

FIG. 5C is a text flowchart of the ejecting and picking of the first die from the mounting tape using the first pepper pot in an embodiment of the invention.

- 20 **FIG. 5D** is an illustrated flowchart of the ejecting and picking of the first die from the mounting tape using the first pepper pot in an embodiment of the invention, following the same text flowchart steps of **FIG. 5C**.

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DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. The illustrative embodiments described in the detailed description, drawings and claims are not meant to be limiting. Other embodiments can be utilized, and other changes can be made, without departing from the spirit or scope of the subject matter presented herein. Unless specified otherwise, the terms “comprising,” “comprise,” “including” and “include” used herein, and grammatical variants thereof, are intended to represent “open” or “inclusive” language such that they include recited elements but also permit inclusion of additional, un-recited elements.

The terms “mount,” “mounted,” “mounting,” “connect,” “connected,” or “connecting” used herein, and grammatical variants thereof, are intended to represent a linking of two items either directly together or linking them indirectly together. The term “communication” is intended to represent a linking of two items either directly together or linking them indirectly together through dedicated wiring, a wireless network, and/or a wired network. The term network can be the internet, an intranet, and/or a combination of the two. The network can be accomplished using any combination of Wi-Fi, WAN, LAN, cellular, wired, optical cable to communicate data between two or more devices, such as between a user interface, a server, a database, and a storage unit.

Components in **FIGs. 1A-5D** are numbered as listed in Table 1 below.

Table 1 -- Description of Common Components

Component	Description
01	die feed system
02	pick and place assembly
02a	<ul style="list-style-type: none"> • first partial view
02b	<ul style="list-style-type: none"> • second partial view
03	wafer stage
04	ejector assembly
05	rigid frame
06	control unit
21	arms
22	suction cups
23	shuttle
23x	<ul style="list-style-type: none"> • x-axis shuttle actuator
23y	<ul style="list-style-type: none"> • y-axis shuttle actuator
31	expanded area
32	central opening
33	tensioning ring
34x	x-axis carriage
34y	y-axis carriage
35x	x-axis stage actuator
35y	y-axis stage actuator
41	ejectors
42a	rotation unit
42b	ejector actuators
42c	elevator
43	top (perforated) plate
44	stem
45	common base
47	pepper pot (housing)
48	ejector pin

50	wafer
51	mounting (blue) tape
52	dies
53	first die
70	camera unit
71	wafer camera
72a	first alignment camera
72b	second alignment camera
73	substrate camera

FIG. 1A is a simplified illustration of the prior art die feed system **01** and is described in the Background section of this invention description. For simplicity, item number **‘01’** is used to designate both the prior art and the improved die feed systems **01**, this should not be taken as an indication that the improved die feed system **01** illustrated in **FIGs. 1B-5D** is prior art.

FIG. 1B is a side view of the die feed system **01** in an embodiment of the invention.

FIG. 1C is a perspective view of the die feed system **01** in an embodiment of the invention. Though partially obscured in view through the rigid frame **05**, **FIGs. 1B** and **1C** illustrate the main blocks of the die feed system **01**: the pick and place assembly **02** on top, the wafer stage **03** in the middle, and the ejector assembly **04** on the bottom. These figures also illustrate a control unit **06**, displayed here as a dedicated terminal mounted on the rigid frame **05**. The x-y-z coordinate system shown in these figures is used consistently throughout the figures for convenience in understanding the invention, as the main blocks are mounted closely together and each figure illustrates a specific portion of the complete die feed system **01**.

FIG. 2A is a perspective illustration of a first partial view **02a** of the pick and place assembly **02** and the wafer stage **03** holding a wafer **50** in an embodiment of the invention. **FIG. 2B** is perspective illustration of a second partial view **02b** of the pick and place assembly **02** in an embodiment of the invention. The complete pick and

place assembly **02** is a combination of the first partial view **02a** and the second partial view **02b**. **FIG. 2A** illustrates the pick and place assembly **02** mounted above the wafer stage **03** holding a wafer **50**. The wafer stage **03** has an x-axis carriage **34x** and a y-axis carriage **34y**. The first partial view **02a** includes a wafer camera **71**, a first alignment camera **72a**, a second alignment camera **72b**, and a substrate camera **73**. The cameras comprise the full camera unit **70**, and in other embodiments all or some of these separate cameras can be combined. **FIG. 2B** illustrates in the second partial view **02b** of the pick and place assembly **02**, a shuttle **23** connected to an x-axis shuttle actuator and a y-axis shuttle actuator **23y**, the arms **21**, and the suction cups **22**.

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FIGs. 3A-3D illustrate views of the wafer stage **03**, with a view of the ejectors **41** below a central opening **32**. **FIG. 3A** is a top view of the wafer stage **03** in an embodiment of the invention without a wafer **50** on the wafer stage **03**, revealing the two ejectors **41**. **FIG. 3B** is a perspective view of the wafer stage **03** in an embodiment of the invention without a wafer **50** on the wafer stage **03**, revealing the two ejectors **41**. **FIG. 3C** is a perspective view of an expanded area **31** (see **FIG. 3B** for the context of the expanded area **31** in its larger view of the wafer stage **03**), showing the wafer stage **03** in an embodiment of the invention without a wafer **50** on the wafer stage **03**, revealing the two ejectors **41**. **FIG. 3D** is a perspective view of an expanded area **31**, showing the wafer stage **03** in an embodiment of the invention with a wafer **50** on the wafer stage **03**. These figures illustrate the location and shape of the central opening **32**, a wafer **50** (when placed on the wafer stage **03**, such as in **FIG. 3D**), the pepper pots **47** of the ejector assembly **04**, the rotation unit **42a**, the x-axis carriage **34x**, the y-axis carriage **34y**, the x-axis stage actuator **35x**, the y-axis stage actuator **35y**, and the tensioning ring **33**. Note that the pepper pots **47** rotate to match the orientation of the dies **52** (defined below as an angle theta) rather than the wafer stage **03** rotating.

FIGs. 4A-4D illustrate the dual pepper pots **47** in an embodiment of the invention. **FIG. 4A** is a perspective view of the ejector assembly **04** in an embodiment of the invention with the two ejectors **41**. **FIG. 4B** is a top view of the ejector assembly **04** in an embodiment of the invention with the two ejectors **41**. **FIG. 4C** is a side cross-sectional view of the two ejectors **41** on a common base **45** in embodiment of the

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invention. **FIG. 4D** is a side cross-sectional view of a pepper pot **47** in an embodiment of the invention. These figures illustrate in the ejector assembly **04** the two pepper pots **47** mounted on a common base **45**, the rotation unit **42a**, the stems **44** of the ejectors **41**, the ejector actuators **42b**, and the elevator **42c**. Each pepper pot **47** itself includes an ejector pin **48** and a top plate **43** (which is preferably perforated). There is a first and second ejector, as particularly illustrated in **FIG. 4C**, and there is a first and second pepper pot **47**. **FIG. 4D** shows one of the steps of the ejection of a first die **53** from the mounting tape **51** of the wafer **50**, this ejection process is shown in more detail in **FIG. 5D** as described below.

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FIGs. 5A-5D are flowcharts of the process of the pick and place using the first ejector **41**. **FIG. 5A** is a text flowchart of the initial wafer **50** loading and imaging of the wafer in an embodiment of the invention. **FIG. 5B** is a text flowchart of the aligning of a first pepper pot **47** below the first die **53** in an embodiment of the invention. **FIG. 5C** is a text flowchart of the ejecting and picking of the first die **53** from the mounting tape **51** using the first pepper pot **47** in an embodiment of the invention. **FIG. 5D** is an illustrated flowchart of the ejecting and picking of the first die **53** from the mounting tape **51** using the first pepper pot **47** in an embodiment of the invention, following the same text flowchart steps of **FIG. 5C**. These steps are described for the first die **53**, first alignment camera **72a**, first pepper pot **47**, first suction cup, and first arm. The below Tables 2A-2C describes the individual steps **5A-01** to **5C-06**.

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Table 2A -- Steps 5A-01 to 5A-06

load the wafer 50 onto the wafer stage 03 over the central opening 32	5A-01
engage tensioning ring 33 to hold the mounting tape 51 across the central opening 32 like the head of a drum, partially delaminating the die 52 from the mounting tape 51 and reducing adhesion of die 52 to the mounting tape 51	5A-02
set the first arm in a first holding position and the second arm in a second holding position	5A-03
image the wafer 50 with the wafer camera 71 to create wafer image and send wafer image to control unit 06	5A-04
employ processor of control unit 06 to: <ul style="list-style-type: none"> roughly match wafer image with associated wafer map in library identify rough x & y coordinates of first die 53, second die, and return die 52 (first die 53 of next pair of dies 52 in series) 	5A-05
index x-axis and y-axis stage actuators 35y to move first die 53 roughly above a first pepper pot 47 using the rough x & y coordinates of the first die 53	5A-06

Table 2B -- Steps 5B-01 to 5B-04

index x-axis and y-axis stage actuators 35y to move first die 53 roughly above the first pepper pot 47 using the rough x & y coordinates of the first die 53	5B-01
use image(s) from first alignment camera 72a to: <ul style="list-style-type: none"> precisely align first die 53 images with associated die 52 model in library identify precise x & y coordinates and angle theta of first die 53 	5B-02
index x-axis and y-axis stage actuators 35y to move first die 53 location precisely above first pepper pot 47 using the precise x & y coordinates of the first die 53	5B-03
index rotational actuator of ejector assembly 04 to rotate the first pepper pot 47 to align the rotational angle of the first pepper pot 47 with the rotational angle theta of the first die 53 ; this step may be performed simultaneously with step 5B-03	5B-04

Table 2C -- Steps 5C-01 to 5C-06

raise the first pepper pot 47 to its upward position with the first ejector actuator 42b such that the perforated plate of the first pepper pot 47 almost touches the bottom surface of the mounting tape 51 below the first die 53	5C-01
pull the mounting tape 51 down and hold the mounting tape 51 to the first pepper pot 47 by simultaneously: <ul style="list-style-type: none"> asserting low pressure in the first pepper pot 47 to allow low pressure to reach the top surface of first pepper pot 47 and pass through the perforated plate; and minutely raising the first pepper pot 47 with the first ejector actuator 42b 	5C-02
raise ejector pin 48 of first pepper pot 47 to its programmed upward position (up to 0.5mm) to lift the first die 53 and further delaminate the first die 53 from the mounting tape 51	5C-03
employ first suction cup of pick and place assembly 02 to grasp and lift the first die 53 off from the top surface of the mounting tape 51	5C-04
return the ejector pin 48 of the first pepper pot 47 to its downward position and index the first arm to move the first die 53 (held by the first suction cup) to the substrate stage for placement onto the first substrate	5C-05
de-assert low pressure in the first pepper pot 47 and lower the first pepper pot 47 to its lower position to release the mounting tape 51	5C-06

As discussed above, **FIG. 5D** is a graphical illustration of the pepper pot **47**, under the control of the control unit **06**, executing steps **5C-01** to **5C-06**.

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The steps for pick and place by the first pepper pot **47** are nearly identical to the steps for pick and place by the second pepper pot **47**. The difference is physical location of the pepper pots **47**. The ejectors **41** move up and down as indexed by the elevator **42c**, and the pepper pots **47** move up and down as indexed by the first and second ejector actuators **42b**. Likewise, the arms **21** and suction cups **22** move from the wafer stage **03** to the substrate stage. However, to simplify the die feed system **01** (and lower

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capital and maintenance costs) the ejectors **41** and the arms **21** operate in a simple, predictable manner. The die **52** alignment is primarily performed by the wafer stage **03**, though the ejectors **41** do rotate to match the angle theta of the dies **52** that are ejected by their pepper pots **47**. Thus the movement of the pepper pots **47** is minimal.

5 Because the two ejectors **41** are place at different locations, they can interact with the arms **21** (with their suction cups **22**) that are placed along different shuttle paths. For pick and place of dies **52** from eight inch wafers **50**, the pepper pots **47** are ideally placed about 31 mm apart (from their radial centers). For pick and place of dies **52** from twelve inch wafers **50**, the pepper pots **47** are ideally placed about 50 mm apart

10 (from their radial centers). These dimensions allow the pepper pots **7** to eject dies **52** at the edges of the wafer **50**. The die feed system **01** can be refitted with different size ejectors assemblies **04** for wafers **50** of different die **52** sizes.

While the first arm moves to the substrate stage, the pick and place process is

15 commenced for the second die using the second alignment camera **72b**, the second pepper pot **47**, the second suction cup, and the second arm. The process is identical to the steps set forth in **FIGs. 5B** and **5C**, but with the following textual replacements:

- second die <== first die **53**
- second alignment camera **72b** <== first alignment camera **72a**

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- second pepper pot **47** <== first pepper pot **47**
- second suction cup <== first suction cup
- second arm <== first arm

During pick and place of the second die, the first arm can be shuttled from the substrate stage to the first holding position above the wafer stage **03**. During pick and place of

25 the return die **52** of each cycle (the first die **53** of the next pair of dies **52** in the series), the second arm can be shuttled from the substrate stage to the second holding position above the wafer stage **03**.

A wafer **50** may have tens to thousands of dies **52**. The steps set forth in **FIGs. 5B** and

30 **5C** are repeated until all valid die **52** are picked and placed. When all the valid die **52** of a current wafer **50** have been removed from a wafer **50**, the remaining mounting tape

51 (possibly with defective die) is removed from the die feed system **01** and the full process is repeated from step **5A-01** with the load of the next wafer **50**.

The below Table 3 demonstrates cycles 01 to n for the pick and placement of a sequence of $2n$ die. The returning die **52** of cycle 01, for instance, becomes the first die **53** of cycle 02 and is picked and placed by the first pepper pot **47** and first arm. The controller may periodically update the sequence of die **52** based on new images taken by the wafer camera **71** and/or the placement cameras to ensure an efficient continuous sequence of pick and place activity alternating between the first pepper and the second pepper pot **47**. Refreshed images from the alignment cameras are needed frequently as the delamination of die **52** from the mounting tap slightly alters the x & y coordinates of the individual die **52** and their angle theta.

Table 3: Sequence of die 52 Pick and Place Using First and Second Pepper Pots 47

FIRST DIE OF PAIR	SECOND DIE OF PAIR	RETURN DIE (first die of next pair of dies in the series)	CYCLE
<ul style="list-style-type: none"> first alignment camera first die images precise x_1, y_1, θ_1 first pepper pot first ejector actuator first suction cup first arm first substrate 	<ul style="list-style-type: none"> second alignment camera second die images precise x_2, y_2, θ_2 second pepper pot second ejector actuator second suction cup second arm second substrate 		
01	02	03	01
03	04	05	02
05	06	07	03
07	08	09	04
...	...	...	...
$2(n-2) - 1$	$2(n-2)$	$2(n-1) - 1$	$n-2$
$2(n-1) - 1$	$2(n-1)$	$2n - 1$	$n-1$
$2n - 1$	$2n$		n

Having two ejectors **41** and two arms **21** enables the improved die feed system **01** to nearly double the pick and place speed of the die feed system **01** without doubling the expense of the die feed system **01**. The reduction in the number of die feed systems **01** required in assembly also translates to a reduced number of attendant staff, reduced power and maintenance fees, and a smaller footprint in the assembly floor. The smaller footprint can be significant as pick and place operations are often performed in clean rooms, which have higher square footage premiums.

Dies **52** are typically square or rectangular and arranged in rows on the wafer **50**. However due to tolerances in the loading of wafers **50** onto the wafer stage **03** and distortion of the tensioned mounting tape **51** upon which the dies **52** are held in place over the central opening **32**, the orientation angle of the dies **52** to the x/y plane of the wafer stage **03** (defined as angle theta in this application) will usually fall in the range of +/- 1 to 15 degrees.

In each pick and place of the dies **52**, the wafer stage **03** is indexed to place the pepper pot **47** below the die **52** according to the x- and y-coordinates of that die **52** and the pepper pot **47** is rotated to the angle theta of the die **52** with the rotation unit **42a**. The placement of a rotation unit **42a** on the ejector assembly **04** replaces the need for global alignment of the wafer **50** prior to pick and place, as the ejectors **41** are locally aligned to each individual die **52** for accurate ejection of that individual die **52** by the rotation unit **42a**. Note that if the rotation were to be made by the wafer stage **03**, as in the prior art, such rotation of the wafer stage **03** would be done typically only once to correct globally the average rotational orientation of the dies **52** on the wafer **50** based likely on a wafer notch position. Rotation of the pepper pot **47** therefore enables a finer adjustment of the ejector pins **48** angle theta to the individual dies **52** to be picked.

The placement of a rotation unit **42a** on the ejector assembly **04** also enables a simplification of the wafer stage **03**, as the rotational orientation correction of individual die **52** for the angle theta during ejection can be accommodated by a portion of the ejector assembly **04** rather than the wafer stage **03**. The wafer stage **03**, in a

preferred embodiment, already includes an x-axis carriage **34x** indexed by an x-axis stage actuator **35x** and a y-axis carriage **34y** indexed by a y-axis stage actuator **35y**. The inclusion of rotation capability on the wafer stage **03** would create additional complexity, cost, and instability. The ejectors **41** are lighter than the wafer stage **03** and have a smaller radius, thus rotation of the ejectors **41** can be accomplished with less power, less potential vibration, and greater speed. The rotation unit **42a** can be configured to rotate the entire stem **44** or merely the pepper pots **47**.

A first embodiment of the invention is an improved die feed system **01** for pick and place of a wafer **50** with a plurality of dies, comprising: (a) a wafer stage **03**; (b) an ejector assembly **04** mounted within the central opening **32**; (c) a pick and place assembly **02** with a first and second arm movably mounted on the rigid frame **05** configured for shuttling the dies **52** from the wafer **50** to a substrate stage for placement of the dies **52** on a plurality of substrates; (d) a camera unit **70** configured to create at least one wafer image; and (e) a control unit **06** including a library with at least one wafer map and at least one die **52** model, a processor, and a data bus that is in communication with the wafer stage **03**, the ejector assembly **04**, the pick and place assembly **02**, and the camera unit **70**. The wafer stage **03** includes a tensioning ring **33** configured to hold a mounting tape **51** of the wafer **50** in tension over a central opening **32** in the wafer stage **03**; and the wafer stage **03** is movably mounted to a rigid frame **05**. The ejector assembly **04** includes at least a first and a second ejector mounted on a common base **45**, and a rotation unit **42a**. Each ejector **41** includes a pepper pot **47**, an ejector pin **48**, a top plate **43**, an ejector actuator **42b**, and a stem **44**.

In the first embodiment, the processor is configured to: (i) instruct the camera unit **70** to image the wafer **50** and align at least one of the wafer images with at least one wafer map; (ii) align at least one of the wafer images with the die **52** model and identify a set of coordinates for each die, wherein the set of coordinates includes for each die **52** an x-coordinate, a y-coordinate, and an angle theta; (iii) organize the dies **52** into a series of pairs, each pair including a first die **53** and a second die; (iv) in a first cycle, index the wafer stage **03** to place the first pepper pot **47** below the first die **53** of each pair according to the x- and y-coordinates of the first die **53** and rotate the first pepper pot

47 to the angle theta of the first die 53 with the rotation unit 42a, then pick the first die 53 by action of the first ejector and the first arm; (v) in a second cycle, index the wafer stage 03 to place the second pepper pot 47 below the second die of each pair according to the x- and y-coordinates of the second die and rotate the second pepper pot 47 to the angle theta of the second die with the rotation unit 42a, then pick the second die by action of the second ejector and the second arm, wherein the first and second cycles are offset in phase; and (vi) repeat the first and second cycles of steps (iv) and (v) respectively for the series of pairs of die 52 until a completion status is indicated by the control unit 06.

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A second embodiment of the invention is a method for improved die feed for pick and place of a wafer 50 with a plurality of dies, comprising the steps of: (a) loading the wafer 50 on a wafer stage 03; (b) tensioning a mounting tape 51 of the wafer 50 over a central opening 32 in the wafer stage 03 using a tensioning ring 33, wherein the wafer stage 03 is movably mounted to a rigid frame 05; (c) providing an ejector assembly 04 mounted within the central opening 32, wherein: (i) the ejector assembly 04 includes at least a first and a second ejector mounted on a common base 45, and a rotation unit 42a; and (ii) each ejector 41 includes a pepper pot 47, an ejector pin 48, a top plate 43, an ejector actuator 42b, and a stem 44; (d) providing a pick and place assembly 02 with a first and second arm movably mounted on the rigid frame 05 configured for shuttling the dies 52 from the wafer 50 to a substrate stage for placement of the dies 52 on a plurality of substrates; (e) providing a camera unit 70 configured to create at least one wafer image; (f) providing a control unit 06 including a library with at least one wafer map and at least one die 52 model, a processor, and a data bus that is in communication with the wafer stage 03, the ejector assembly 04, the pick and place assembly 02, and the camera unit 70; (g) controlling via the processor the steps to: (i) instruct the camera unit 70 to image the wafer 50 and align at least one of the wafer images with at least one wafer map; (ii) align at least one of the wafer images with the die 52 model and identify a set of coordinates for each die, wherein the set of coordinates includes for each die 52 an x-coordinate, a y-coordinate, and an angle theta; (iii) organize the dies 52 into a series of pairs, each pair including a first die 53 and a second die; (iv) in a first cycle, index the wafer stage 03 to place the first pepper

pot **47** below the first die **53** of each pair according to the x- and y-coordinates of the first die **53** and rotate the first pepper pot **47** to the angle theta of the first die **53** with the rotation unit **42a**, then pick the first die **53** by action of the first ejector and the first arm; (v) in a second cycle, index the wafer stage **03** to place the second pepper pot **47**
5 below the second die of each pair according to the x- and y-coordinates of the second die and rotate the second pepper pot **47** to the angle theta of the second die with the rotation unit **42a**, then pick the second die by action of the second ejector and the second arm, wherein the first and second cycles are offset in phase; and (vi) repeat the first and second cycles of steps (iv) and (v) respectively for the series of pairs of dies **52**
10 until a completion status is indicated by the control unit **06**.

The first and second cycles can be in the range of 90 to 185 degrees out of phase. The first and second cycles can be substantially 180 degrees out of phase with substantially identical durations. Herein, “substantially 180 degrees” refers to the range of 175 to
15 185 degrees. The substrate stage can have a first area and second area where the first arm places die **52** onto the substrate located on the first area and the second arm places die **52** onto the substrate located on the second area.

The embodiment of the invention illustrated in the figures includes two ejectors **41**, but
20 the invention can be adapted to three, four, or more ejectors **41**. If three ejectors **41** are used, the first cycle and the second cycle would preferably be 120 degrees out of phase, such that the third ejector would run on a third cycle that is 240 degrees out of phase with the first ejector and 120 degrees out phase with the second ejector.

25 The camera unit **70** can be mounted to the pick and place assembly **02** and the camera unit **70** includes: (a) a wafer camera **71** configured to image an entire surface of the wafer **50** in a single image; (b) a first alignment camera **72a** dedicated to the first cycle and a second alignment camera **72b** dedicated to the second cycle; and (c) a substrate camera **73** dedicated to placement of the dies **52** onto the substrates. While **FIG. 2A**
30 illustrates a first and second alignment camera **72b**, the die feed system **01** can also employ a single alignment camera rather than two alignment cameras. The selection between use of a single camera for alignment, and perhaps a single camera for

alignment and full wafer **50** imaging, can be determined at the time of product design to maximize the effectiveness of the imaging at a reasonable cost point. The first and second alignment camera **72b** solution has the benefit of high resolution at the location of picking of the first and second die, which may be critical for application requiring
5 low tolerances in placing of the die **52** upon the substrates and/or wafers **50** with very small individual dies. The first and second alignment cameras **72b** can also assist the control unit **06** when updating the coordinates of each die, as the exact coordinates of a die **52** can change with distortion of the mounting tape **51** during pick and place due to temperature changes and removal of adjacent dies.

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The control unit **06** can be at least one of: (a) a stand-alone computer mounted on the rigid frame **05**; (b) a dedicated terminal mounted on the rigid frame **05**; (c) an embedded controller mounted to the rigid frame **05**; (d) a networked server; (e) a portable computing device in wireless communication with a network; (f) a cloud data
15 storage including the library; and (g) a portable data storage device including the library. The dedicated terminal, for instance, may include all or part of the library's information and be controllable and/or accessible both through its user interface and/or remotely by a server through a network.

20 The wafer stage **03** can include an x-axis carriage **34x** indexed by an x-axis stage actuator **35x** and a y-axis carriage **34y** indexed by a y-axis stage actuator **35y**, where the pick and place assembly **02** includes an x-axis shuttle actuator and a y-axis shuttle actuator **23y**. The first arm can include a first suction cup; and the second arm can include a second suction cup **22**.

25

To sort out the defective dies: (a) the wafer map can include meta data for each die **52** which includes a die tracking number and a status field indicate whether the die **52** is a valid die or a defective die; (b) the controller unit can then only pick and place the valid die; and (c) the completion status can then be indicated by the control unit **06** once all
30 valid dies from the wafer are placed onto substrates.

The rotation unit **42a** can be a single rotational actuator connected to the first ejector and the second ejector; and the ejector assembly **04** can include an elevator **42c** for raising and lowering the common stage.

- 5 While various aspects and embodiments have been disclosed herein, it will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims. The various aspects and
- 10 embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit of the invention being indicated by the appended claims.

CLAIMS

1. An improved die feed system for pick and place of a wafer with a plurality of dies, comprising:
 - 5 (a) a wafer stage, wherein:
 - (i) the wafer stage includes a tensioning ring configured to hold a mounting tape of the wafer in tension over a central opening in the wafer stage;
 - (ii) the wafer stage is movably mounted to a rigid frame;
 - (b) an ejector assembly mounted within the central opening, wherein:
 - 10 (i) the ejector assembly includes at least a first and a second ejector mounted on a common base, and a rotation unit; and
 - (ii) each ejector includes a pepper pot, an ejector pin, a top plate, an ejector actuator, and a stem;
 - (c) a pick and place assembly with a first and second arm movably mounted on the rigid frame configured for shuttling the dies from the wafer to a substrate stage for placement of the dies on a plurality of substrates;
 - 15 (d) a camera unit configured to create at least one wafer image; and
 - (e) a control unit including a library with at least one wafer map and at least one die model, a processor, and a data bus that is in communication with the wafer stage, the ejector assembly, the pick and place assembly, and the camera unit, wherein the processor is configured to:
 - 20 (i) instruct the camera unit to image the wafer and align at least one of the wafer images with at least one wafer map;
 - (ii) align at least one of the wafer images with the die model and identify a set of coordinates for each die, wherein the set of coordinates includes for each die an x-coordinate, a y-coordinate, and an angle theta;
 - 25 (iii) organize the dies into a series of pairs, each pair including a first die and a second die;
 - (iv) in a first cycle, index the wafer stage to place the first pepper pot below the first die of each pair according to the x- and y-coordinates of the first die and rotate the first pepper pot to the angle theta of the first die with
 - 30

- the rotation unit, then pick the first die by action of the first ejector and the first arm;
- 5 (v) in a second cycle, index the wafer stage to place the second pepper pot below the second die of each pair according to the x- and y-coordinates of the second die and rotate the second pepper pot to the angle theta of the second die with the rotation unit, then pick the second die by action of the second ejector and the second arm, wherein the first and second cycles are offset in phase; and
- 10 (vi) repeat the first and second cycles of steps (iv) and (v) respectively for the series of pairs of dies until a completion status is indicated by the control unit.
2. The system of claim 1, wherein the first and second cycles are in the range of 90 to 185 degrees out of phase.
- 15 3. The system of claim 1, wherein the first and second cycles:
- (a) are substantially 180 degrees out of phase; and
- (b) have substantially identical durations.
- 20 4. The system of claim 1, wherein:
- (a) the substrate stage has a first area and second area;
- (b) the first arm places die onto the substrate located on the first area; and
- (c) the second arm places die onto the substrate located on the second area.
- 25 5. The system of claim 1, wherein the camera unit is mounted to the pick and place assembly and the camera unit includes:
- (a) a wafer camera configured to image an entire surface of the wafer in a single image;
- (b) a first alignment camera dedicated to the first cycle and a second alignment
- 30 camera dedicated to the second cycle; and
- (c) a substrate camera dedicated to placement of the die onto the substrates.

6. The system of claim 1, wherein the control unit is at least one of:
- (a) a stand-alone computer mounted on the rigid frame;
 - (b) a dedicated terminal mounted on the rigid frame;
 - (c) an embedded controller mounted to the rigid frame.
- 5 (d) a networked server;
- (e) a portable computing device in wireless communication with a network;
 - (f) a cloud data storage including the library; and
 - (g) a portable data storage device including the library.
- 10 7. The system of claim 1, wherein the pick and place assembly includes an x-axis shuttle actuator **23x** and a y-axis shuttle actuator.
8. The system of claim 1, wherein:
- (a) the first arm includes a first suction cup; and
- 15 (b) the second arm includes a second suction cup.
9. The system of claim 1, wherein:
- (a) the wafer map includes meta data for each die including a die tracking number and a status field; and
- 20 (b) the controller unit does not pick and place any die with a status field indicating the die is defective.
10. The system of claim 1, wherein:
- (a) the rotation unit is a single rotational actuator connected to the first ejector and
- 25 the second ejector; and
- (b) the ejector assembly includes an elevator for raising and lowering the common stage.

11. A method for improved die feed for pick and place of a wafer with a plurality of dies, comprising the steps of:
- (a) loading the wafer on a wafer stage;
 - (b) tensioning a mounting tape of the wafer over a central opening in the wafer stage using a tensioning ring, wherein the wafer stage is movably mounted to a rigid frame;
 - (c) providing an ejector assembly mounted within the central opening, wherein:
 - (i) the ejector assembly includes at least a first and a second ejector mounted on a common base, and a rotation unit; and
 - (ii) each ejector includes a pepper pot, an ejector pin, a top plate, an ejector actuator, and a stem;
 - (d) providing a pick and place assembly with a first and second arm movably mounted on the rigid frame configured for shuttling the dies from the wafer to a substrate stage for placement of the dies on a plurality of substrates;
 - (e) providing a camera unit configured to create at least one wafer image;
 - (f) providing a control unit including a library with at least one wafer map and at least one die model, a processor, and a data bus that is in communication with the wafer stage, the ejector assembly, the pick and place assembly, and the camera unit;
 - (g) controlling via the processor the steps to:
 - (i) instruct the camera unit to image the wafer and align at least one of the wafer images with at least one wafer map;
 - (ii) align at least one of the wafer images with the die model and identify a set of coordinates for each die, wherein the set of coordinates includes for each die an x-coordinate, a y-coordinate, and an angle theta;
 - (iii) organize the die into a series of pairs, each pair including a first die and a second die;
 - (iv) in a first cycle, index the wafer stage to place the first pepper pot below the first die of each pair according to the x- and y-coordinates of the first die and rotate the first pepper pot to the angle theta of the first die with the rotation unit, then pick the first die by action of the first ejector and the first arm;

- 5 (v) in a second cycle, index the wafer stage to place the second pepper pot below the second die of each pair according to the x- and y-coordinates of the second die and rotate the second pepper pot to the angle theta of the second die with the rotation unit, then pick the second die by action of the second ejector and the second arm, wherein the first and second cycles are offset in phase; and
- (vi) repeat the first and second cycles of steps (iv) and (v) respectively for the series of pairs of dies until a completion status is indicated by the control unit.
- 10 12. The method of claim 11, wherein the first and second cycles are in the range of 90 to 185 degrees out of phase.
13. The method of claim 11, wherein the first and second cycles:
- 15 (a) are substantially 180 degrees out of phase; and
- (b) have substantially identical durations.
14. The method of claim 11, wherein:
- (a) the substrate stage has a first area and second area;
- 20 (b) the first arm places die onto the substrate located on the first area; and
- (c) the second arm places die onto the substrate located on the second area.
15. The method of claim 11, wherein the camera unit is mounted to the pick and place assembly and the camera unit includes:
- 25 (a) a wafer camera configured to image an entire surface of the wafer in a single image;
- (b) a first alignment camera dedicated to the first cycle and a second alignment camera dedicated to the second cycle; and
- (c) a substrate camera dedicated to placement of the die onto the substrates.
- 30 16. The method of claim 11, wherein the control unit is at least one of:
- (a) a stand-alone computer mounted on the rigid frame;

- (b) a dedicated terminal mounted on the rigid frame;
- (c) an embedded controller mounted to the rigid frame.
- (d) a networked server;
- (e) a portable computing device in wireless communication with a network;
- 5 (f) a cloud data storage including the library; and
- (g) a portable data storage device including the library.

17. The method of claim 11, wherein the pick and place assembly includes an x-axis shuttle actuator **23x** and a y-axis shuttle actuator.

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18. The method of claim 11, wherein:
- (a) the first arm includes a first suction cup; and
 - (b) the second arm includes a second suction cup.

15 19. The method of claim 11, wherein:

- (a) the wafer map includes meta data for each die including a die tracking number and a status field; and
- (b) the controller unit does not pick and place any die with a status field indicating the die is defective.

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20. The method of claim 11, wherein:

- (a) the rotation unit is a single rotational actuator connected to the first ejector and the second ejector; and
 - (b) the ejector assembly includes an elevator for raising and lowering the common
- 25 stage.