

Integrated circuit singulation method and system

Field of the invention

- 5 This invention relates to an integrated circuit singulation method and a system implementing the method.

Background of the Invention

- 10 Consumer electronic devices, such as smartphones, tablet computers, digital cameras and the like, contain large numbers of integrated circuit (IC) components. For ease of handling during manufacture, IC components and other semiconductor devices are typically fabricated in batches on a substrate, and then divided into individual units in a dicing machine, a process known as singulation.

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Due to high demand for semiconductor devices, manufacturers are constantly seeking to improve the efficiency of manufacturing processes, including singulation. A key figure of merit in a singulation system is the units per hour, or UPH, achievable by the system.

- 20 It would be desirable to provide a process which increases the UPH of known singulation machines, or which at least provides a useful alternative.

Summary of the Invention

- 25 Embodiments relate to a method for singulating IC units from a plurality of substrates, the substrates being divided into a sequence of two or more batches in one or more magazines, the method comprising, in a singulation apparatus having a singulation section and a sorting section:

- sequentially singulating substrates of a first batch in the singulation section and
30 transporting singulated IC units to the sorting section;

determining that singulated units of a last substrate of the first batch have reached the sorting section;

sequentially processing substrates of a next batch in the sequence until singulated units of the first substrate of the next batch are ready to be sorted in the sorting section; and

on receiving an indication that singulated units of the last substrate of the first batch have been cleared from the sorting section, continuing sequential processing of substrates of the next batch.

Said determining may comprise determining a boundary between the first batch and the next batch, for example by: receiving batch data representing at least a number of substrates in the first batch; maintaining a count of processed substrates which have reached the sorting section; and determining when the count of processed substrates equals the number of substrates in the first batch.

At least one batch may span across two or more magazines.

In certain embodiments, said determining comprises detecting a gap between substrates in the one or more magazines. The gap may be within a magazine. The magazine may be an empty magazine.

Embodiments also provide a method for singulating IC units from a plurality of substrates, the substrates being divided into a sequence of two or more batches in one or more magazines, the method comprising:

receiving batch data representing, for each batch, a batch identifier and a batch count indicating a number of substrates in the batch;

sequentially singulating substrates of a first batch of the sequence in a singulation section of a singulation apparatus, and transporting singulated IC units to a sorting section of the singulation apparatus;

incrementing a processed count indicating a number of substrates of the first batch which have been processed in the singulation section;

when the processed count equals the batch count for the first batch, sequentially processing substrates of a next batch of the sequence until singulated units of the first substrate of the next batch are ready to be sorted in the sorting section; and

on receiving an indication that singulated units of the last substrate of the first batch have been cleared from the sorting section, continuing sequential processing of substrates of the next batch.

- 5 Further embodiments provide a control system for a singulation apparatus having a magazine carrier, a singulation section and a sorting section, the singulation apparatus being configured to receive a plurality of substrates divided into a sequence of two or more batches in one or more magazines, the control system comprising:

at least one control module for communicating with and controlling the
10 singulation apparatus, the at least one control module being configured to:

instruct the magazine carrier to sequentially present substrates of a first batch and a next batch for processing in the singulation section;

determine that singulated units of a last substrate of the first batch have reached the sorting section;

15 receive a signal indicating that singulated units of the first substrate of the next batch are ready to be sorted in the sorting section; and

on receiving an indication that singulated units of the last substrate of the first batch have been cleared from the sorting section, instruct the singulation apparatus to continue sequential processing of substrates of the next batch.

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The at least one control module may comprise a first control module for communicating with and controlling the magazine carrier and components of the sorting section, and a second control module for communicating with and controlling the singulation section.

- 25 The at least one control module may be configured to determine a boundary between the first batch and the next batch. In certain embodiments, the at least one control module is configured to: receive batch data representing at least a number of substrates in the first batch; maintain a count of processed substrates which have reached the sorting section; and determine when the count of processed substrates equals the number of substrates in
30 the first batch.

In certain embodiments, said at least one control module is configured to detect a gap between substrates in the one or more magazines.

Yet further embodiments provide a non-transitory machine-readable storage medium
5 having stored thereon a program for controlling a singulation apparatus, the singulation apparatus having a magazine carrier, a singulation section and a sorting section, and being configured to receive a plurality of substrates divided into a sequence of two or more batches in one or more magazines, the program comprising instructions for:

causing the magazine carrier to sequentially present substrates of a first batch
10 and a next batch for processing in the singulation section;

determining that singulated units of a last substrate of the first batch have reached the sorting section;

receiving a signal indicating that singulated units of the first substrate of the next batch are ready to be sorted in the sorting section; and

15 on receiving an indication that singulated units of the last substrate of the first batch have been cleared from the sorting section, causing the singulation apparatus to continue sequential processing of substrates of the next batch.

The program may further comprise instructions for determining a boundary between the
20 first batch and the next batch.

In certain embodiments, the program further comprises instructions for: receiving batch data representing at least a number of substrates in the first batch; maintaining a count of processed substrates which have reached the sorting section; and determining when
25 the count of processed substrates equals the number of substrates in the first batch.

In other embodiments, the program further comprises instructions for detecting a gap between substrates in the one or more magazines.

Brief Description of the Drawings

Embodiments of the invention will now be described, by way of non-limiting example
5 only, with reference to the accompanying drawings in which:

Fig. 1 is a block diagram of a singulation system;

Fig. 2 is a block diagram of a singulation process;

Figs. 3 to 5 are flow diagrams of a method according to a first embodiment of the
10 invention;

Figs. 6 to 8 are flow diagrams of a method according to an alternative embodiment of
the invention; and

Figs. 9A, 9B, 10A and 10B show elements of a user interface of embodiments of the
invention.

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Detailed Description

Embodiments of the invention provide for batch processing of substrates in a
singulation apparatus. The substrates are loaded in magazines or cassettes which are
20 presented to the dicing section (also termed a singulation section herein) of the
singulation apparatus. The substrates are singulated in the dicing section and the
singulated units are subsequently sorted in a sorting section, and then offloaded.

A controller of the singulation apparatus detects boundaries between successive batches
25 of substrates. The batches are processed continuously and sequentially at stations of the
dicing section and the sorting section, so that the last few substrates of a first batch may
be undergoing processing in both the dicing section and the sorting section, while the
first few substrates of the next batch have been loaded and are undergoing processing in
the dicing section. When the controller detects that the last substrate of the first batch
30 has been processed and received at the sorting section, processing of the next batch can
resume by passing singulated units of the first substrate of the next batch to the sorting
section, while subsequent substrates of the next batch continue to be processed at

stations of the dicing section. Accordingly, it is possible to reduce the time between batches, since substrates of the next batch can be processed while the last few substrates of the previous batch are still passing through stations of the singulation apparatus.

- 5 Advantageously, a reduction in the time between batches is achieved while also ensuring that there is no mixing between units of successive batches, since the next batch does not reach the sorting section until it has been confirmed that the previous batch is cleared. This reduction in time can be achieved by applying the method to existing singulation machines without any change to the physical configuration of such
10 machines. Accordingly, embodiments of the invention allow existing machines to implement a substantially continuous batch process which does not mix units from different batches.

- Advantageously, the present inventors have found that the UPH achievable by
15 embodiments of the present invention can be increased by at least 20% over known methods, without any hardware modifications. This provides various advantages to a manufacturer employing the present method and system, including saving manpower, factory space, and power consumption.

- 20 By waiting until the last substrate reaches the sorting section, it is also possible to have sufficient time to reconfigure the singulation apparatus in the event that the next batch includes substrates of a different type (for example, having a different number of leads, or a different type of fiducial marking) than those being processed in the current batch, but still reducing the overall time between batches.

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- Referring to Fig. 1, a singulation system 100 comprises a singulation apparatus 105 which comprises a magazine carrier 120, a dicing section 130 and a sorting section 140. The dicing section 130 is coupled to a singulation control system 160 comprising a motion control and I/O board 170 and one or more software modules 165 for
30 communicating with motion control and I/O board 170. The singulation control system 160 has the general ability to control operation of components of the dicing section 130 and to receive data from those components relating to their status.

Similarly, magazine carrier 120 and sorting section 140 are coupled to and controlled by a control computer system 150. Computer system 150 causes magazines or cartridges loaded with substrates to be sequentially presented by the magazine carrier 120 to the dicing section 130 where they are singulated into individual IC units (under control of singulation control system 160). The singulated units may undergo further processing in the dicing section 130 before being conveyed to sorting section 140.

Dicing section 130 and sorting section 140 each comprise a plurality of stations at which various steps of the singulation and sorting process are carried out.

Computer system 150 comprises a motion control and I/O control board 110. The computer system 150 may be a standard computer system such as a 32-bit or 64-bit Intel Architecture-based computer system, and processes described below with reference to Figures 3 to 8 may be partly or wholly implemented in the form of programming instructions of one or more software modules 155 stored on non-volatile (e.g., hard disk) storage associated with the computer system. However, it will be apparent that at least parts of the process described below with reference to Figures 3 to 8 could alternatively be implemented as one or more dedicated hardware components, such as application-specific integrated circuits (ASICs) and/or field programmable gate arrays (FPGAs). One or more of the dedicated hardware components may form part of control board 110, for example. Singulation control system 160 may be similarly configured to computer system 150.

Computer system 150 and singulation control system 160 may each include at least one processor, memory (volatile and/or non-volatile), and one or more interfaces for connecting the computer system 150 or singulation control system 160 to other devices. For example, the interfaces may include a network interface controller (NIC) for connecting the computer system 150 to a communications network. The one or more interfaces may also include a display adapter for connecting computer system 150 to a display device such as an LCD panel display.

In some embodiments, each of computer system 150 and singulation control system 160 may be built into the housing of singulation apparatus 105. Display devices coupled to each system 150, 160 may be configured to display information relating to the operation of apparatus 105, in particular the status of the various components of the apparatus, such as dicing saws, pickers, sorting trays, cameras and the like, and/or the status of individual stations of the dicing section 130 and sorting section 140. The display devices are each preferably LCD touch screen displays which may also act as user input devices.

10 The software modules 155 of computer system 150 comprise a number of standard software modules, including an operating system such as Linux, OS/X of Apple, Inc., or Microsoft Windows, and also comprise modules for interacting with apparatus 105 via controller 110. For example, the modules 155 may comprise a first control module for issuing instructions to controller 110 to drive particular components of the apparatus 15 105 (including magazine carrier 120 and components or stations of sorting section 140) at certain times. Modules 155 may also comprise a user interface module for displaying information to an operator regarding the status of singulation apparatus 105 and execution of the singulation process, and for receiving operator input as will be described in more detail below.

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Similarly, software modules 165 of singulation control system 160 comprise: standard software modules including an operating system such as Linux, OS/X of Apple, Inc., or Microsoft Windows; a second control module for issuing instructions to controller 170 to drive components of the dicing section 130 at certain times; and a user interface 25 module for displaying information to an operator regarding the status of components of dicing section 130. The user interface module may also accept user input relating to parameters of dicing section components, for example relating to the type of substrate which is to be singulated.

30 The singulation apparatus 105 has the general ability to accept input of substrates (also termed strips or carriers herein) which carry a multiplicity of integrated circuit (IC) units, to singulate them by any suitable means (for example, using a dicing saw, die

punching, laser cutting, a water jet cutter, an air jet cutter, etc.), and to output the singulated IC units, typically following washing, drying and sorting operations. Examples of singulation apparatus suitable for use with embodiments of the present invention include those shown in US Patent No. 7,829,383 and PCT publication no. WO 2009/035419, the entire contents of each of which are incorporated herein by reference.

A typical sequence of steps involved in processing of a substrate, in one example of a singulation apparatus 105, is depicted in the block diagram of Fig. 2.

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Briefly, a substrate (also referred to as a strip herein) is pushed from a magazine by a loader 210 into the dicing section 130. A strip picker conveys the substrate/strip to one of two chuck tables 215a, 215b. The substrate is diced into individual IC units, which are gathered by a unit picker and conveyed to a brush unit (220) and then a cleaner unit (225), and the units are then dried on a drying table (at 230). A net picker gathers the dried units and conveys them to the sorting section 140 of the singulation apparatus 105. The units are placed on and attached (by a vacuum) to a flipper unit 235 which is inverted so as to invert the units, and the units are then placed on an idle block 240. Inspection of the units is performed by a camera (at 245) and by a processor which performs image analysis to determine the marking status and condition of the units. The net picker then conveys the units onto one of two net blocks 250a, 250b. A further inspection is carried out, and based on the results of the inspection, individual units are sorted into one of a good bin, a rework bin or a reject bin. The sorted units are placed by package pickers into trays, and the trays are removed from the apparatus 105 by the operator.

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Although particular embodiments are described with reference to the singulation apparatus and process outlined above, it will be appreciated that the invention has applicability to singulation apparatus more generally.

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In one embodiment, the control module (of software modules 155) receives batch data representing a batch identifier and a batch count (i.e., the number of substrates in a

batch) for each of a plurality of batches of substrates. The terms “batch” and “lot” will be used interchangeably in this specification. Each batch represents a plurality of substrates which are all of the same type.

5 The batch data may be input by a user into a user interface, e.g., implemented by the user interface module described above. For example, with reference to Fig. 10A, the user interface may present a lot input window 1000 having a user input area including a Lot Name column 1010 and a Strip Count column 1020. Each row in the user input area represents one of the batches. The user enters batch identifiers in the Lot Name column
10 1010 and batch counts in the Strip Count column 1020. In the illustrated example, the first batch has a batch identifier 123456, entered by the user into box 1012, and an associated batch count of 3, entered into box 1022. Similarly, a second batch has identifier 123457 (box 1014) and includes 2 strips (box 1024), and a third batch has identifier 123458 (box 1016) and includes 1 strip (box 1026). The user interface module
15 may include error checking functions to ensure integrity of the batch data. Fig. 10B illustrates that if a count of zero is entered into the Strip Count column, and a Lot Input button 1050 is pressed to finalise the batch data, an error window 1060 pops up to notify the user that they need to input a non-zero strip count. The user interface module then re-displays the Lot Input window 1000.

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In some embodiments, the user interface module permits the entry of additional batch data while a previous batch is still being processed. For example, the user interface module may receive user input indicating that additional batches are to be entered. If the last strip of a current batch has not yet reached the idle block of the sorting section 140,
25 the user interface module presents lot input window 1000 for entry of the additional batch data.

The batch data may be stored in memory of computer system 150. The batch counts of respective batches thus define the boundaries between successive batches. The control
30 module may then determine when a boundary between two successive batches has been reached, by monitoring counts of substrates in a manner which will be described in more detail below.

In another embodiment, the control module is not provided with predetermined batch data, but instead, a boundary between successive batches is defined by introducing a gap between the last substrate of one batch and the first substrate of the next, and the control module determines that the boundary has been reached when the gap is detected. For example, one batch may take up an entire magazine, and an empty magazine may be introduced between the magazine and the next batch, which may take up part or all of a magazine. Alternatively, a gap could be introduced within a magazine. For example, a magazine having a 20-substrate capacity could contain a first batch of 12 substrates, a one-substrate gap, and a second batch of 7 substrates.

A first exemplary batch singulation process 300 using the singulation apparatus 105 will now be described in more detail with reference to the flow charts of Figs. 3 to 5.

Starting at block 310, the control module causes the first magazine to be loaded by magazine carrier 120. The control module then determines (at 320), from the batch data, the lot count for the first lot. A strip pusher pushes strips from the first magazine. Each time a strip is pushed from the magazine, a push count is incremented (block 345) and the strip is then processed, for example in the manner described in US Patent No. 7,829,383 or as above. A sensor detects when a strip has been pushed from the magazine to the dicing section 120. Strips continue to be pushed and processed until the magazine is empty (block 325) or until the push count reaches the lot count (block 340). The magazine is regarded as empty if the sensor does not detect a pushed strip within a predetermined time period. If the magazine is empty, it is unloaded (block 330). Computer system 150 monitors the progress of each strip through the apparatus 105, via signals received by the controller 110 from the various components of apparatus 105.

The control module also maintains a net picker pickup count. The pickup count is incremented each time, during processing of a strip, that the net picker collects singulated units from a chuck table. On collection by the net picker, a feedback signal is sent to the controller 110, and in turn the controller 110 sends an indication to the control module of computer system 150 to cause the counter to be incremented.

The singulation apparatus 105 continues to process strips, until at block 335, the control module receives an indication that the last strip of the first lot has reached the sorting section 140, for example the idle block 240. Next, when the control module also
5 receives an indication that the idle picker is empty (block 410), it checks whether the pickup count has reached the lot count (block 415). This check is performed to determine whether there is a mismatch between the expected number of substrates in the lot, and the actual number of substrates which have been singulated at the time that the first magazine becomes empty. If the check fails, then the lot currently being processed
10 spans across two magazines, and the control module causes the user interface module to prompt the user (via mismatch error window 900, Fig. 9A) as to whether they wish to continue the current lot (block 440). The user can determine, for example from displayed status information, how many substrates have been processed, and how many remain in the lot. If the user interface module receives input indicating that the user
15 wishes to continue with the current lot (e.g. by detecting a click event for button 910), it then prompts the user to enter the number of remaining strips via a form 950 (Fig. 9B). The user can enter the number of strips into data entry box 960, and then click an OK button 970 to continue the process, or can click a close button 980 to return to the mismatch error window 900. The next magazine is then loaded (block 355, Fig. 3) and
20 processing continues at block 325 as before.

If the user interface module receives input indicating that the current lot is not to continue, then it alerts the user to perform a saw device data check (block 420). The alert prompts the user to check whether reconfiguration of the dicing section is required,
25 in the event that the next lot includes substrates of a different type than those being processed in the current lot. For example, the substrates of the next lot may have a different number of leads per unit, or different fiducial marks used for pattern recognition. Strips of the second lot will not be pushed into the dicing section 130 until input is received by the user interface module to confirm that the saw data check has
30 been performed. If it is necessary to adjust the parameters of processes performed in the dicing section 130, the user may adjust these parameters by entering any changed values via the touch screen display of singulation control system 160. Once this is done, the

user confirms (by clicking a button presented by the user interface module of computer system 150) that the saw data check is complete, and the process proceeds to block 425. When the saw data check is complete, the net picker pickup count and strip push count are both reset to zero.

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At block 425, the control module retrieves details (including the lot count) of the second lot, and begins processing the second lot (block 430) by instructing the controller 110 to push strips from the magazine, and sequentially process them in the dicing section, as before. Once the control module receives an indication that units of the first strip of the second lot have been retrieved by the idle picker from the dry block (at 435), it waits to receive confirmation that the net table and offload pickers are empty (block 510). This is to ensure that the first lot has been cleared from the apparatus 105, so that there is no mixing of units from the first and second lots. Once signals are received from the net table and offload pickers confirming that they are empty, the first lot has finished (block 15 515).

In order to be able to continue the process without mixing of units from the first and second lots, once the control module determines that the first lot has ended, it checks whether the reject bin has been cleared (block 520). At this point, all stations of the dicing section 130 are full, and units of the first substrate of the second lot are still yet to enter the sorting section 140 (typically, this would mean they are still sitting on the dry block). If the reject bin has been cleared, it is safe to proceed with sorting units of the second lot, and the control module causes a prompt to be issued by the user interface module for the user to restart the process (block 525), thus causing the first units of the second lot to be conveyed to the sorting section, and causing subsequent strips of the second lot to continue to be sequentially processed in the dicing section 130. If the reject bin has not yet been removed, the user is prompted to clear the reject bin (block 530). As previously mentioned, the control module will not allow the singulation apparatus 105 to be operated until the reject bin has been cleared (block 540).

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Figs. 6 to 8 depict another exemplary process according to an embodiment. At block 610, the magazine carrier conveys a first magazine to the dicing section 120 of the

singulation apparatus 105. A sensor is used at block 615, in similar fashion to the sensor used in process 300 described above, to detect whether the magazine is empty, and sends a signal (via controller 110) to the control module. If it is empty, it is unloaded (block 620). If it is not, the control module checks whether there is a gap in the magazine (block 630). If there is no gap then the next strip in the magazine is pushed to the dicing section (block 635) and processed (block 640).

At any time that a gap is detected, either an empty magazine or a gap within a magazine, the control module waits to receive an indication that the last strip of the first lot is at the idle block (at 625). When it subsequently receives an indication (at 710) that the idle picker is empty, it checks (at 715) whether a new magazine is needed (because the current one is empty), loads it if so (at 720), and in either case, starts processing the second lot (at 725) as before.

When the control module receives an indication that units of the first strip of the second lot have been retrieved by the idle picker from the dry block (at 730), and also subsequently receives an indication that the net table and offload pickers are empty (at 810), the first lot has finished (block 815). Then, the control module checks whether the reject bin has been removed (block 820), and prompts (by the user interface module) the user to restart the process (block 825) if it has. If the reject bin has not yet been removed, the user is prompted to clear the reject bin (block 830). The control module will not allow the singulation apparatus 105 to be operated until the reject bin has been cleared (block 835). Once it is cleared, strips of the second lot can continue to be processed as discussed above.

Claims

1. A method for singulating IC units from a plurality of substrates, the substrates being divided into a sequence of two or more batches in one or more magazines, the
5 method comprising, in a singulation apparatus having a singulation section and a sorting section:
 sequentially singulating substrates of a first batch in the singulation section and transporting singulated IC units to the sorting section;
 determining that singulated units of a last substrate of the first batch have
10 reached the sorting section;
 sequentially processing substrates of a next batch in the sequence until singulated units of the first substrate of the next batch are ready to be sorted in the sorting section; and
 on receiving an indication that singulated units of the last substrate of the
15 first batch have been cleared from the sorting section, continuing sequential processing of substrates of the next batch.
2. A method according to claim 1, wherein said determining comprises determining a
20 boundary between the first batch and the next batch.
3. A method according to claim 2, wherein said determining comprises receiving batch data representing at least a number of substrates in the first batch; maintaining a count of processed substrates which have reached the sorting section; and
25 determining when the count of processed substrates equals the number of substrates in the first batch.
4. A method according to any one of claims 1 to 3, wherein at least one batch spans across two or more magazines.
- 30 5. A method according to claim 2, wherein said determining comprises detecting a gap between substrates in the one or more magazines.

6. A method according to claim 5, wherein the gap is within a magazine.
7. A method according to claim 6, wherein the magazine is an empty magazine.
- 5 8. A method for singulating IC units from a plurality of substrates, the substrates being divided into a sequence of two or more batches in one or more magazines, the method comprising:
 - receiving batch data representing, for each batch, a batch identifier and a batch count indicating a number of substrates in the batch;
 - 10 sequentially singulating substrates of a first batch of the sequence in a singulation section of a singulation apparatus, and transporting singulated IC units to a sorting section of the singulation apparatus;
 - incrementing a processed count indicating a number of substrates of the first batch which have been processed in the singulation section;
 - 15 when the processed count equals the batch count for the first batch, sequentially processing substrates of a next batch of the sequence until singulated units of the first substrate of the next batch are ready to be sorted in the sorting section; and
 - on receiving an indication that singulated units of the last substrate of the first batch have been cleared from the sorting section, continuing sequential processing of substrates of the next batch.
9. A control system for a singulation apparatus having a magazine carrier, a singulation section and a sorting section, the singulation apparatus being configured to receive a plurality of substrates divided into a sequence of two or more batches in one or more magazines, the control system comprising:
 - at least one control module for communicating with and controlling the singulation apparatus, the at least one control module being configured to:
 - instruct the magazine carrier to sequentially present substrates of a first batch and a next batch for processing in the singulation section;
 - 30 determine that singulated units of a last substrate of the first batch have reached the sorting section;

receive a signal indicating that singulated units of the first substrate of the next batch are ready to be sorted in the sorting section; and

on receiving an indication that singulated units of the last substrate of the first batch have been cleared from the sorting section, instruct the singulation apparatus to continue sequential processing of substrates of the next batch.

10. A control system according to claim 9, wherein the at least one control module comprises a first control module for communicating with and controlling the magazine carrier and components of the sorting section, and a second control module for communicating with and controlling the singulation section.

11. A control system according to claim 9 or claim 10, wherein the at least one control module is configured to determine a boundary between the first batch and the next batch.

12. A control system according to claim 11, wherein the at least one control module is configured to: receive batch data representing at least a number of substrates in the first batch; maintain a count of processed substrates which have reached the sorting section; and determine when the count of processed substrates equals the number of substrates in the first batch.

13. A control system according to claim 11 or claim 12, wherein said control module is configured to detect a gap between substrates in the one or more magazines.

14. A non-transitory machine-readable storage medium having stored thereon a program for controlling a singulation apparatus, the singulation apparatus having a magazine carrier, a singulation section and a sorting section, and being configured to receive a plurality of substrates divided into a sequence of two or more batches in one or more magazines, the program comprising instructions for:

causing the magazine carrier to sequentially present substrates of a first batch and a next batch for processing in the singulation section;

determining that singulated units of a last substrate of the first batch have reached the sorting section;

receiving a signal indicating that singulated units of the first substrate of the next batch are ready to be sorted in the sorting section; and

5 on receiving an indication that singulated units of the last substrate of the first batch have been cleared from the sorting section, causing the singulation apparatus to continue sequential processing of substrates of the next batch.

15. A non-transitory machine-readable storage medium according to claim 14, further
10 comprising instructions for determining a boundary between the first batch and the next batch.

16. A non-transitory machine-readable storage medium according to claim 15, further
15 comprising instructions for: receiving batch data representing at least a number of substrates in the first batch; maintaining a count of processed substrates which have reached the sorting section; and determining when the count of processed substrates equals the number of substrates in the first batch.

17. A non-transitory machine-readable storage medium according to claim 15, further
20 comprising instructions for detecting a gap between substrates in the one or more magazines.