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(54) Method, computer programm, controller and binning apparatus for distributing wafers to bins

(57) A method for delivering wafers to a multitude of bins is provided. The method for delivering wafers to a multitude of bins includes configuring quality classes of the wafers dependent on at least one characteristic of the wafers; configuring priority groups including at least a high priority group and a low priority group; assigning each of the quality classes to one of the priority groups; assigning each of the multitude of bins to one of the priority groups; providing examination results for the wafers; classifying each of the wafers into one of the quality classes according to the examination result of the wafer; and delivering each of the wafers to one of the multitude of bins according to the priority group assigned to the quality class of the wafer. A computer program, a computer readable medium, a controller for a binning apparatus, and a binning apparatus (30) are also provided.

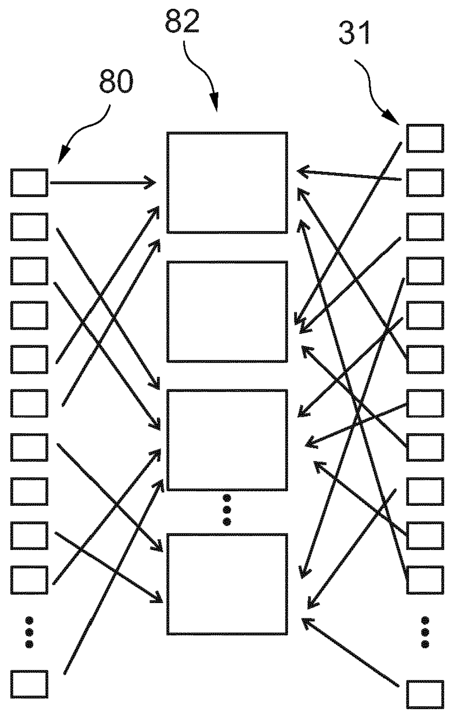

Fig. 9

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Description

FIELD OF THE INVENTION

[0001] Embodiments of the present disclosure relate a method for binning, a method for producing solar cells, a method for retrofitting a binning apparatus, a computer program, a computer readable medium including the computer program, and a binning apparatus for distributing wafers to bins. The present subject matter particularly relates to the production process and a production apparatus of solar cells. In particular, it relates to a method and apparatus for the binning of processed wafers, in particular, of solar cells.

DESCRIPTION OF THE RELATED ART

[0002] Solar cells are photovoltaic devices that convert sunlight into electrical power. A typical solar cell, which might also be called a "cell" herein, includes a substrate that may also be called "wafer" herein. The wafer is typically made of silicon. The wafer may be provided with one or more p-n junctions formed therein. Each p-n junction has a p-type region and an n-type region. When the p-n junction is exposed to sunlight, the sunlight is converted to electricity through the photovoltaic effect.

[0003] A multitude of solar cells is assembled in an array of solar cells that is typically known as solar panel or module. Solar panels are sold to end customers, such as private households, to be mounted on a house's roof so as to generate electricity for personal use and/or for feeding to the public electricity net.

[0004] The solar cell with the worst performance essentially defines the performance of the complete solar panel. Experience also shows that customers prefer panels with an homogenous color appearance of the individual wafers rather than panels with solar cells of different color. Furthermore, some cells might be more suitable to, for instance, direct light incidence whereas other cells are more suitable for indirect incidence. The same might be true for other circumstances.

[0005] Hence, it is a desire in the art to differentiate the solar cells depending on their characteristics, and to gather those wafers with identical or very similar properties separately from other wafers having different characteristics. It is furthermore desired that this way of collecting wafers does not reduce the overall performance of the solar cell production in terms of produced wafers per hour.

SUMMARY OF THE INVENTION

[0006] In view of the above, the present disclosure is directed at the following.

[0007] According to an aspect, a method for delivering wafers to a multitude of bins is provided. The method for delivering wafers to a multitude of bins includes configuring quality classes for the wafers dependent on at least one characteristic of the wafers; configuring priority groups including at least a high priority group and a low priority group; assigning each of the quality classes to one of the priority groups; assigning each of the multitude of bins to one of the priority groups; providing examination results of the wafers; classifying each of the wafers into one of the quality classes according to the examination result of the wafer; and delivering each of the wafers to one of the multitude of bins according to the priority group assigned to the quality class of the wafer.

[0008] According to an aspect, a method for producing solar cells is provided. The method includes: providing wafers; depositing conductive paths on the wafer; and binning the wafers as described herein.

[0009] According to an aspect, a controller for a binning apparatus is provided. The controller is configured to carry out the method as described herein.

[0010] According to an aspect, a binning apparatus for delivering wafers to a multitude of bins is provided. The binning apparatus includes one or more delivery systems for delivering wafers to the multitude of bins. The binning apparatus furthermore includes a controller as described herein for controlling the one or more delivery systems.

[0011] According to an aspect, a solar cell production apparatus is provided. The solar cell production apparatus includes one or more deposition apparatuses for depositing a conductive path on a wafer; one or more examination apparatuses for examining the wafer; and one or more binning apparatuses as described herein.

[0012] According to an aspect, a method for retrofitting a binning apparatus is provided. The binning apparatus includes a controller. The method includes uploading the computer program as described herein to the controller.

[0013] According to an aspect, a computer program is provided. The computer program includes computer code adapted to perform the method as described herein when the computer program is run on a computer.

[0014] According to an aspect, a computer readable medium is provided. The computer readable medium stores the computer program as described herein.

[0015] Further embodiments, aspects, details and advantages are furthermore evident from the dependent claims, the description, and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments. The accompanying drawings relate to embodiments of the disclosure and are described in the following:

Fig. 1 shows a schematic view of a solar cell production apparatus including a binning apparatus according to embodiments as described herein;

Fig. 2 shows a schematic view of a solar cell production apparatus including a binning apparatus according to embodiments as described herein;

Fig. 3 shows a schematic top view of an exemplary binning apparatus according to embodiments as described herein;

Fig. 4 shows a schematic top view of an exemplary binning apparatus according to embodiments as described herein with exemplary priority group numbers being depicted in each of the bins;

Fig. 5 shows an exemplary diagram illustrating the occurrence of wafers within various classes according to an exemplary test run of a solar cell production;

Fig. 6 shows an illustrative side perspective of a binning apparatus according to embodiments described herein;

Fig. 7 shows an illustrative three-dimensional view of a bin according to embodiments described herein;

Fig. 8 shows an illustration of the binning logics according to embodiments known in the art; and

Fig. 9 shows an illustration of the binning logics according to embodiments as described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0017] Reference will now be made in detail to the various embodiments of the invention, one or more examples of which are illustrated in the figures. Within the following description of the drawings, the same reference numbers refer to same components. In the present disclosure, only the differences with respect to individual embodiments are described. Each example is provided by way of explanation of the invention and is not meant as a limitation of the invention. Further, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. It is intended that the description includes such modifications and variations.

[0018] Wafers for the solar cell production industries are produced in a sequence of various processing steps. In particular an ingot (multicrystalline or monocrystalline) is typically sawed into individual wafers. Typically, the wafers are made of silicon. The wafers may have a thickness of below 150 μm or even below 100 μm. Typical sizes of the wafers are in the range of between 10 cm x 10 cm and 20 cm x 20 cm. Wafers as understood herein may be quadratic with optionally cut-off corners.

[0019] The wafers undergo several doping, drilling, printing, and heating steps so as to produce a solar cell that will be assembled together to form a solar panel. Although industries seek to be provided with a production process that is capable of producing solar wafers that are all perfectly identical, and have optimized characteristics, in practice, subsequent wafers stemming from the identical production process differ from each other in their characteristics, such as, the performance if exposed to sunlight, the color, their physical integrity, their adaption to incoming light, etc. This is due to differences in the raw materials and deviations and disturbances in the further processing steps.

[0020] Hence, the processed wafers may be analyzed for a set of relevant characteristics, and dependent on the outcome of the analysis, they may be collected separately from other wafers with different characteristics.

[0021] The collection of wafers is typically done in bins which shall be herein understood as units configured to store several wafers therein. Bins as understood herein may be boxes, such as made of polystyrene, with typically one or two walls missing. In other words, bins may be boxes with only two or three side walls. An example of such a bin is shown in Fig. 7. The binning apparatus as described herein may be configured such that the bins are aligned with the bin's bottom (see reference number 71 in Fig. 7) possibly having an angle to the horizontal, e.g., an angle of 10° or more.

[0022] The phrases "delivering wafers to bins", "distributing wafers to bins", "sorting wafers" and "binning" shall be understood synonymously herein, and shall be understood as moving the wafers to different bins. The characteristics of the processed wafers have to be within selectable intervals in order to classify as belonging to the respective bin. Thus, the wafers of each bin constitute a multitude of highly similar wafers. "Similar" in this context has to be understood as identical or with marginal deviations regarding the wafer characteristics that were analyzed for the binning process.

[0023] Each bin has a maximum capacity. Once the maximum capacity is reached, the respective bin has to be replaced by an empty bin. This may be done manually or automatically. The inventor found out, however, that known binning leads to a delay in the overall production. For instance, when binning is undertaken into a number of bins with each bin corresponding to a different quality class of processed wafers dependent on the wafer characteristics, if one bin is full and thus needs to be replaced by an empty bin, it may happen that the complete production has to be stopped. As will be evident from the present description, according to the embodiments of the present disclosure, even a manual change of bins, which may take several minutes, does typically not lead to a stop of the production process.

[0024] Fig. 1 schematically shows a solar cell production apparatus 1 for producing solar cells according to embodiments described herein. The wafers are processed in the one or more process apparatuses 10. For instance, the illustratively shown apparatus 10 may be a combination of one or more of the following apparatuses: sawing apparatus, cleaning apparatus, doping apparatus, deposition apparatus, printing apparatus, flipping apparatus, oven, inspection apparatus, drilling apparatus, etc. In particular, the apparatus 10 may include several printing apparatuses configured for printing one or more paths of conductive material onto the wafer. Notably, the process apparatus 10 may include one or more inspection apparatuses used for intermediate examination of the process steps and/or alignment of further processing steps.

[0025] As furthermore schematically illustrated in Fig. 1, after the processing of the wafers, in particular after completion of the solar cell, and before the binning, the wafer may be analyzed in the one or more inspection apparatuses 20. For instance, it is possible to provide one, two, three, or more inspection apparatuses each configured to inspect the wafer regarding a specific characteristics. The characteristics to be analyzed are typically selected by the operator in dependence on the technical and economic needs of the production process. In the following, though, some examples of characteristics to be analyzed shall be exemplarily discussed. It shall be highlighted that the term "processed wafer" particularly includes a completely finished solar cell.

[0026] For instance, one or more of the inspection apparatus may be configured to examine the processed wafers for their physical integrity, in particular, whether the wafer contains broken parts or edges, cracks, fractures, or the like. The wafers may also be examined as to whether there are printing residues, i.e., whether there is printing material deposited at positions of the wafer where it is not supposed to be.

[0027] One or more of the inspection apparatus may be configured for an inspection of the color of the solar cell. The color of the solar cell is relevant mainly for two reasons. One reason is that customers of solar panels assembled together using several solar cells prefer a homogenous appearance of the panel. In other words, solar panels where the solar cells have different coloring constitute drawbacks in the consumer market. Another reason is that the color, in particular the dark portion in the wafer, is relevant for the performance and the adaption to the typical sunlight environment. Bright solar wafers typically have a lower efficiency than dark solar cells due to the reason that bright solar cells reflect more light (and thus absorb less light) than dark solar cells.

[0028] One or more of the inspection apparatus may be configured for an inspection of the reflection properties dependent on the incoming light. This may be relevant for the decision in which region of the world the solar cell is best suited for being mounted. For instance, whereas solar cells in regions close to the equator are exposed to a high share of perpendicular and almost perpendicular sunlight throughout the year, solar cells in the northern or southern hemisphere of the world are exposed to largely varying incidence of light throughout the year. In particular, the incident angle is other than perpendicular for most of the time.

[0029] One or more of the inspection apparatus may be configured for an inspection of the performance of the solar cell. For instance, the inspection apparatus may include a solar simulator that is typically adapted to generate a flash of light according to a spectral distribution that is similar to natural sunlight. The produced energy may be measured. Performance of a solar cell is certainly one of the key factors of a solar cell.

[0030] Various other inspection apparatuses can be provided according to the present disclosure. It shall furthermore be highlighted that the binning described herein is also applicable to wafers of an intermediate solar cell production stage. For instance, the wafers may be inspected after sawing for characteristics such as homogeneity of the wafer surface, homogeneity of the wafer thickness, integrity of the wafer edges etc. The wafers can then be differentiated according to their characteristics for their further processing. Additionally or alternatively, the wafers may be binned as described herein during the processing, e.g., during printing of one or more electrically conducting paths on the wafer.

[0031] Solar cells have a front side and a back side with both sides typically being processed. In particular, it is typical that at least one printing, possibly two or even more printings are performed on each of the back side and front side. Hence, according to embodiments, a flipping apparatus may be provided in particular before, between, or after the one or more inspection apparatuses 20. A flipping apparatus shall be understood as an apparatus that flips the wafer from one side to the other side. For instance, the wafer may rest on the back side for some front side inspection in the one or more inspection apparatus. Thereupon, the wafer may be flipped by a flipping apparatus so as to rest on the front side. Hence, one or more further inspection apparatuses may examine the back side.

[0032] According to embodiments, the wafers are forwarded from the inspection apparatus 20 to the binning apparatus

30. Not limited to the embodiments of transferring the wafers from the inspection apparatus 20 to the binning apparatus, a wafer may be moved by a conveyor belt or a sequence of subsequent conveyor belts within, before, or after any apparatus described herein.

[0033] Based on the findings of the inspection, the wafers may be classified to different quality classes (or simply called "classes" herein) according to their characteristics. For instance, the wafers may be classified into n different classes with n denoting an integer that is typically larger than 24. For instance, n may be 48. Notably, the inventor found out that the number of processed wafers is not homogenously distributed over all quality classes, rather the production process typically leads to a high number of solar cells in some classes and a low number of solar cells in other classes. This will be further explained below.

[0034] Not limited to any embodiment, as explained, the quality classes of the wafers are configured dependent on at least one characteristic of the wafers. Furthermore, according to aspects of the present disclosure, the priority groups are configured. The priority groups include at least a high priority group and a low priority group. Herein, "configuring the quality classes" or "configuring the priority groups" can be understood as "making the definitions of the quality classes or priority groups available for the binning process". "Configuring" particularly includes defining by, for instance, an operator. Alternatively or additionally, "configuring" may include reading the respective definitions from a data base or other memory device such as a random-access device.

[0035] Furthermore, not limited to any embodiment, the quality classes are each assigned to one of the priority groups, and each of the multitude of bins is assigned to one of the priority groups according to aspects of the present disclosure. The assigning as understood herein shall be understood in that information about the assignment is made available for the binning process. "Assigning" may particularly include allowing an operator to input the assignment definition. Alternatively or additionally, "assigning" may include reading the assignment definition from a data base or other memory device such as a random-access device.

[0036] Configuring the quality classes and/or the priority groups is typically done in advance of a binning process but may be undertaken or repeated during the binning process. Additionally or alternatively, assigning the quality classes to one of the priority groups and/or assigning each of the multitude of bins is typically done in advance of a binning process but may be undertaken or repeated during the binning process.

[0037] Fig. 2 shows another example of a solar cell production apparatus. The exemplarily illustrated supply apparatus 90 provides unprocessed or pre-processed wafers to the processing apparatuses 110-119, such as one or more doping apparatus, one or more printing apparatus, one or more drilling apparatus, one or more drying ovens and the like. As mentioned before, the processing apparatus may particularly include a flipping apparatus. The number of processing apparatuses is not limited. The dots in Fig. 2 between the processing apparatus 111 and 119, as well as between the inspection apparatus 121 and 129 shall illustrate that further processing/inspection apparatuses may be provided, if desired.

[0038] After processing, the wafers are transferred to the inspection apparatuses 120-129. The number of inspection apparatuses may be three or more, or even five or more.

[0039] For instance, in the illustration of Fig. 2, the first inspection apparatus examines the physical integrity 120 of the wafer. If the the wafer is majorly damaged, the wafer may be transferred through the other inspection apparatuses without further inspection. The binning apparatus 30 will then put it into a waste bin.

[0040] As a further example, the second inspection apparatus 121 may examine the color of the wafer. The third inspection apparatus 122 may include a sunlight simulator and examine the performance under certain light conditions. A fourth inspection apparatus may be provided for inspecting further characteristics of the wafers. For illustrative purposes, in Fig. 2, a sequence of various inspection apparatuses 120-129 is depicted. Evidently, this shall not limit the number of inspection apparatuses to ten, rather any number suitable for the classification process may be chosen.

[0041] Generally, and not limited to the embodiment illustrated in Fig. 2, the measured information of each inspection apparatus 120-129 may be provided via input lines 125 to a controller 200. The input information may also be transmitted wirelessly. The controller thus collects the information about the examined characteristics of a wafer. This allows the controller to assign the wafer to the correct quality class. The quality class can typically be pre-defined by the operator of the solar cell production apparatus.

[0042] According to the shown embodiment, which is not limited to the illustration of Fig. 2, the controller 200 may control the binning apparatus 30. The controller 200 may control the binning apparatus 30 via the output line 210. The control may also be done wirelessly. Not shown in a figure, the controller 200 may be part of the binning apparatus. Alternatively, it is also possible that the binning apparatus is provided with an additional controller that receives information from the controller 200. The controller of the binning apparatus may then control the binning process.

[0043] Fig. 3 shows a detailed schematic top view of an embodiment of a binning apparatus. The binning apparatus as shown is provided with forty-eight bins 31 that are arranged in an 6x8 array, i.e., 6 rows and 8 columns. Generally, and not limited to the illustration of Fig. 3, the processed wafers may enter the binning apparatus, for instance, via a conveyor belt as indicated by arrow 29. The wafers may be moved within the binning apparatus by, for instance, a conveyor belt 50 until they may be gripped by a delivery system, such as a robot.

[0044] According to embodiments that shall be illustrated in view of Fig. 3, the delivery system includes one or more robots. In the exemplary drawing of Fig. 3, four robots 35, 36, 37, and 38 are arranged within or above the binning apparatus to grip the processed wafers and to distribute each wafer to one of the multitude of bins 31. The robots may be arranged above the conveyor belt 50. Each robot may be provided with one or more arms (see Fig. 6), and each robot is responsible for the delivery of the wafers to a specific set of bins. Typically, each robot is exclusively responsible for the delivery of the wafers to a specific set of bins. In particular, with r denoting the number of robots and b denoting the number of bins, each robot is configured to deliver incoming wafers to be divided by r different bins.

[0045] The travel time the delivery system requires to deliver a wafer to the various bins differs. For instance, to deliver a wafer to a bin closer to the conveyor belt may require less travel time than the delivery of a wafer to a bin far away from the conveyor belt. Hence, according to aspects of the present disclosure, each bin has a defined travel time that is taken into account for the binning process according to embodiments of the present subject-matter.

[0046] According to aspects of the disclosure, each quality class is assigned to a priority group. For instance, the number of priority groups may be three, four, five, or six. Without limitation of the scope, in the following, exemplary reference is made to five priority groups (priority group 1 to priority group 5). Furthermore, in the following, for illustrative purposes, that shall not be construed limiting, priority group 1 shall denote the highest priority ("highest priority"), priority group 2 shall denote a reduced priority as compared to priority group 1 ("high priority"), and so on. Priority group 5 shall denote the lowest priority ("lowest priority").

[0047] According to embodiments, only those quality classes which are assigned to a highest priority group, such as priority group 1, are very frequent (i.e., with a high number of wafers falling into this class). Only those classes that are assigned to a high priority group, such a priority group 2, are still frequent, but less frequent than the classes of priority group 1, and still more frequent than the classes of priority group 3. Hence, the lowest priority group, for instance priority group 5, will include only classes that are rather rare. The wording "a class is rare/frequent" shall refer to a situation where the production process leads to a low/high number of processed wafers with characteristics as defined by the respective quality class.

[0048] The assignment of the quality classes to priority groups is typically done in a test run of the solar cell production apparatus. A test run as understood herein is identical to the normal production of solar cells with the only difference being that the results of the wafer analysis are saved and evaluated.

[0049] A short example shall illustrate such a process. Notably, for sake of illustration, the example uses a small number of characteristics.

[0050] In the example, the operator of the solar cell production process defines three characteristics, namely, physical integrity with two possible outcomes (yes or no); performance with 5 possible outcomes (i.e., five intervals of possible performance outcomes upon a standardized flash illumination from a sunlight simulator); and color brightness of the solar cell with 5 possible outcomes dependent on the brightness of the solar cell (i.e., five brightness intervals). Hence, since in the case of a broken wafer a further differentiation is superfluous, this corresponds to 1 (wafer is broken) + 5x5 (wafer is not broken and has differing brightness and performance) = 26 classes. Alternatively to a definition by an operator, this information may be read from a memory device.

[0051] The solar cell production apparatus is operated to produce solar cells. Since at this stage it may not yet be clear what the distribution of the wafers over the classes will be, binning is performed in a classical way, i.e., each class may be assigned to one bin. In the case information about the occurrence of wafers per class are available already, e.g. from a former test run, binning may also be performed as it is disclosed herein. Either way, the robots of the binning apparatus are controlled to operate accordingly.

[0052] In embodiments, the results of the inspection are stored. In other embodiments, the detailed results of the analysis are discharged but the classification of the inspected wafers to the respective classes are stored and collected. This allows building up a statistic about the occurrence of processed wafers within the respective classes. According to aspects of the present subject-matter, this statistic is basis for the binning during normal operation.

[0053] The following shall illustrate such a statistic. Please note that the following statistic is for illustration purposes only. Thereby, statistics can also be understood as counting the number of wafers per quality class.

Class number	Number of wafer in the test run
1	12
2	5
3	1033
4	202
5	0

(continued)

Class number	Number of wafer in the test run
6	7
7	29
8	2329
9	523
10	1
11	0
12	4
13	89
14	1403
15	270
16	2
17	0
18	0
19	1802
20	1
21	389
22	1067
23	2190
24	901
25	13
26	451

[0054] In view of the results, the classes may be assigned to five priority groups as follows:

Priority group 1	Priority group 2	Priority group 3	Priority group 4	Priority group 5
Class 8	Class 3	Class 4	Class 1	Class 2
Class 14	Class 9	Class 13	Class 6	Class 5
Class 19	Class 22	Class 15	Class 7	Class 10
Class 23	Class 24	Class 21	Class 25	Class 11
		Class 26		Class 12
				Class 16
				Class 17
				Class 18
				Class 20

[0055] Each bin is assigned to a priority group. The assignment is typically such that the higher priority groups are assigned to the bins with a smaller travel time, and the lower priority groups are assigned to the bins with a higher travel time. As outlined, the assignment as described herein may be done by an operator or automatically. The assignment is typically performed based on a test run of the solar cell production process.

[0056] The number of bins may be larger than 20, or even larger than 40. In particular, 24 bins or 48 bins may be provided. According to the present disclosure, it is possible to define more quality classes than bins. For instance, the number of quality classes may be p times the number of bins with p being larger than 1.0, possibly even larger than 1.5 or even equal to or larger than 2.0. For example, it is possible that 36 quality classes are defined in a binning apparatus with 24 bins. Another example is the definition of 96 quality classes in a binning apparatus with 48 bins.

[0057] Fig. 4 illustrates an example with an array of 6 times 8 bins referenced to by reference number 31, and five priority groups. In the following example, the four robots 35, 36, 37 and 38, respectively, are configured to deliver wafers to the four bin groups 51, 52, 53, and 54 respectively. Alternatively to a robot, another delivery system could be employed. The term "bin group" shall refer to a multitude of bins each served by one robot. The numbers shown in each of the bins illustrated in Fig. 4 shall refer to the priority groups assigned to the respective bins in this example. For optimizing the travel time, priority group 1 is assigned to the bins close to the conveyor belt 50 and the responsible robots 35-38. In the example chosen, robot 53 is responsible for bin group 51, robot 36 is responsible for bin group 53, robot 37 is responsible for bin group 52, and robot 38 is responsible for bin group 54.

[0058] For instance, with reference to bin group 51 shown in the upper left quarter of the top view of the binning apparatus shown in Fig. 4, robot 35 has fast access to the three bins that were assigned with priority 1. Notably, the one bin of bin set 51 that has priority 4 is also positioned close to the belt, however, it is further away from robot 35, and collisions with robot 36 need to be safely avoided which leads to detours the robot 35 has to undertake to reach the bin with priority 4. Furthermore, the delivery time to those two bins assigned with priority number 5 in the shown bin set 51 is the largest. Hence, these bins are assigned to priority group 5.

[0059] According to aspects of the present disclosure, and not limited to the example of Fig. 4, the number of bins assigned to some priority groups, in particular high priority groups, such as priority group 1 or priority group 2, is larger than the number of classes within the respective priority group. In particular, it is possible that the number of bins assigned to the first priority group is twice the number of quality classes assigned to the priority group, or even more. According to embodiments, all but the lowest priority group have at least one bin more than the number of quality classes of the respective priority group.

[0060] For instance, in the example illustrated in the tables above, it is possible that eight bins are assigned to priority group 1 (wherein only four quality classes are assigned to this priority group). Furthermore, in this example it would be possible to assign six bins to the priority group 2 (wherein only four quality classes are assigned to this priority group).

[0061] According to further aspects of the present disclosure, the number of bins assigned to some priority groups, in particular low priority groups, is smaller than the number of quality classes assigned to the respective priority group. For instance, the low priority group, such as priority group 5, may include at least 1.5 times, 2 times, or even more times more classes than bins. This is because wafers of the respective quality classes in low priority groups are typically those that occur at a very rare rate, such as in the example illustrated above. For instance, in the example above, it would be possible to assign only 4 bins to priority group 5 (wherein in the example above 9 quality classes are assigned to this priority group). Without limitation to any embodiment, it is possible that the lowest priority group includes twice, three times, or even more classes than bins.

[0062] Fig. 5 illustrates the result of a test run in a chart. The y-axis, denoted with reference number 401, indicates the relative occurrence of wafers in this class; the x-axis, denoted with reference number 400, indicates the respective classes. Notably, the reference number of the class is typically freely selectable and does not allow information about the quality of the wafers in this class. As exemplarily shown in Fig. 5, quality class c3 represents the quality that the most wafers have, followed by classes c4, c15 etc. The occurrence of wafers in classes such as c20 and c99 in the present test run was marginal so that they are shown on the axis.

[0063] Generally, and not limited to any embodiment, assignment of the quality classes to the respective priority groups according to the present disclosure can be performed on the basis of the counting results in a test run. It is possible to base the assignment on the absolute counting results (i.e., wafers counted per quality class) or on the relative counting results (i.e., share of wafers per quality class wherein all shares add to 100%).

[0064] The assignment of the quality classes to priority groups may be amended during operation of the binning apparatus. For instance, according to embodiments, during normal operation of the solar cell production the wafer occurrence per quality class is counted and stored for a continuous evaluation. Should it turn out that there is a major shift in the occurrence, it is possible to re-assign the priority groups to the quality classes. In addition or alternatively, it is possible to re-assign the specific bins to the quality classes (where this is not done dynamically anyway).

[0065] The priority groups of the bins are typically defined in advance, e.g., before start of binning. This can be done by an operator. Alternatively, a computer program may use information about the travel time of each robot to each bin to assign different priority groups to the bins.

[0066] According to aspects of the present disclosure, at least within some of the priority groups, in particular low priority groups, before the binning is started it is undefined which bin receives which wafers. Instead, solar cell production may be started, and the first wafer of a quality class thus defines the quality class of the bin it is delivered to. In addition, once the bin is full and removed by an empty bin, it is possible that the former assignment may be overruled by a new assignment. The way of assigning quality classes to bins during operation shall be called "dynamic bin assignment" herein.

[0067] Dynamic bin assignment is performed within bins of the same priority group only. Dynamic bin assignment may particularly be applied to low priority groups. For the high priority group, the bins may be assigned to the quality classes in a predefined manner. In particular, an operator may be allowed to assign the quality classes to bins manually.

[0068] For instance, in the example given in the table above, the two bins with the shortest travel time within priority group 1 may be assigned to quality class 8. Two further bins with the subsequent shortest travel time within a priority group may be assigned to quality class 23.

[0069] According to embodiments of the present disclosure, the quality classes of the highest priority group are each handled by a different robot. For instance, in the example above, the wafers of the four classes 8, 14, 19, and 23, respectively, of priority group 1 are gripped and delivered to bins by the four robots 35, 36, 37, and 38, respectively (for instance, robot 35 is responsible for class 8; robot 36 is responsible for class 14; robot 37 is responsible for class 19; and robot 38 is responsible for class 23). This may additionally increase the operation speed of the binning.

[0070] In case of a priority group with more bins than classes (i.e., a high priority group), some bins will remain empty until another bin is completely filled with wafers. Once this happens, the controller may initiate two actions: First, further bins of this class may henceforth be delivered to a new bin that has been empty so far. Second, an exchange of the full bin is triggered, either automatically, or by sending a respective alarm to the operator in order to remove the full bin manually, and to replace it by an empty bin. The controller may memorize which bin is empty so that it may be filled again if another bin of the same priority group (but maybe of a different class) is full and needs replacement. Thus, operation of the binning apparatus can be continued during exchange of the full bin.

[0071] There may be priority groups according to the present disclosure, in particular priority groups of intermediate priority, such as priority group 3 or priority group 4, to which one or two more bins is/are assigned than the number of assigned quality classes. Let n denote the number of bins of this priority group, and m denote the number of quality classes of this priority group, then m of the n bins may be filled with wafers of the m different quality classes during operation of the binning apparatus. The remaining n-m bins remain empty until one of the other m bins is full. Once this happens, the controller may note to deliver the respective quality class to one of the empty bins henceforth. The controller may initiate an exchange of the full bin. As described, this may be done manually or automatically. In view of the rather low occurrence of wafers in the intermediate priority group, it is unlikely that a further bin is completely filled within the time needed to exchange the other bin. Hence, operation of the binning apparatus can be continued without having to stop.

[0072] Should this case happen nevertheless, in case n=m+1, the production has to be stopped until the change of the bin is completed. In case n=m+2, however, the second reserve bin may be used by the controller, and the operation of the binning apparatus does not need to be stopped.

[0073] In the case of a low priority group, wafers of this quality class are produced rather rarely. It is thus possible to assign more quality classes to a priority group than bins. In operation, the bins of this priority group are not assigned to classes in advance, i.e., before the operation of the binning apparatus. Rather, as described, the first wafer produced of a quality class of this priority group defines henceforth the class of this bin. It is possible to operate the binning apparatus this way until, for instance, all but one bin (or maybe two bins) of this priority group have received their first wafer. When this happens, according to embodiments, the controller initiates that one of the non-empty bins is already exchanged with an empty bin. Hence, even in the case that during the exchange another wafer of the same class arrives, it is already delivered to the one empty bin (or to one of the two bins). Hence, also this way of operation allows an operation without stop with, at the same time, a space and bin saving logics of low priority quality class handling.

[0074] Hence, once a bin of a quality class of a high priority group is full, it is replaced. Contrary to prior art, however, there is no need to halt the production but the robot will deliver further wafers of the same class to another empty bin of the same priority group. Still, due to the aspect that more classes are assigned to some priority groups than bins assigned to these priority groups (at least in the lowest priority group, i.e., priority group 5 in the described example), the classification into as many different classes as possible (for instance, 48 classes) is still viable.

[0075] Fig. 6 illustrates an example of a binning apparatus 30 in a schematic side view. The binning apparatus includes the robots 60 that may be, such as in the example of Fig. 6, be mounted to the upper part 70 of the binning apparatus 30. The robots are typically positioned above the conveyor belt (as discussed before). In the present view of Fig. 6, however, the bins 31 cover the view to the conveyor belt.

[0076] Without limitation to the example of Fig. 6, the binning apparatus may be configured to receive an array of k times l bins with k being, for instance, 8, 9, 10, or even more, and/or l being, for instance, 6, 7, 8, or even more. In the example of Fig. 6, k is 10 (that is why the side view as illustrated allows the perspective to 10 adjacent bins).

[0077] The binning apparatus as described herein includes one or more robot. The term "robot" shall be understood as any actuated unit configured to grip a wafer and to move the wafer. In particular, the binning apparatus may include two, three, four, or even more robots. The more robots used, the faster the binning is. All the robots may be controlled by the same controller.

[0078] A robot may include one or more robot arms, such as robot arms 65 in the illustration of Fig. 6. Furthermore, a robot may include an end effector, such as end effector 68 illustrated in Fig. 6, for gripping wafers. The end effector can particularly be a Bernoulli gripper.

[0079] Figs. 8 and 9 shall illustrate the underlying logics of the present disclosure (Fig. 9) as compared to the underlying logics of known binning (Fig. 8). In the art, it is known to assign each quality class 80 to a bin 31. It may also be known that this assignment is done dynamically, i.e., during the operation.

[0080] The present subject-matter, as illustrated in Fig. 9, essentially differs from this approach by introducing priority groups 82, and by assigning both quality classes 80 and bins 31 to the various priority groups 82. The assignment to the priority groups forms the basis for the binning, as explained previously herein in detail.

[0081] Thus, embodiments of the present invention subject-matter provide a method for binning, a method for producing solar cells, a method for retrofitting a binning apparatus, a computer program, a computer readable medium including the computer program, and a binning apparatus that allows faster binning and thus faster production of solar cells. Furthermore, the number of assignable quality classes to bins can be equal or even be higher than the number of bins, if desired.

[0082] While the foregoing is directed to embodiments of the invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

Claims

1. A method for delivering wafers to a multitude of bins, the method comprising:

    - configuring quality classes of the wafers dependent on at least one characteristic of the wafers;
    - configuring priority groups that include at least a high priority group and a low priority group;
    - assigning each of the quality classes to one of the priority groups;
    - assigning each of the multitude of bins to one of the priority groups;
    - providing examination results of the wafers;
    - classifying each of the wafers into one of the quality classes according to the examination result of the wafer; and
    - delivering each of the wafers to one of the multitude of bins according to the priority group assigned to the quality class of the wafer.

2. The method of claim 1, wherein the number of bins assigned to the high priority group is larger than the number of quality classes assigned to the high priority group, with the number of bins assigned to the high priority group preferably being at least twice the number of the quality classes assigned to the high priority group.

3. The method according to any of the preceding claims, wherein the number of bins assigned to the low priority group is smaller than the number of quality classes assigned to the low priority group with the number of quality classes assigned to the low priority group preferably being at least twice the number of the bins assigned to the low priority group.

4. The method according to any of the preceding claims, wherein the priority groups further include at least an intermediate priority group.

5. The method according to any of the preceding claims, further comprising:

    - providing examination results of at least 100 wafers, optionally at least 1000 wafers; and
    - counting the number of wafers per quality class;

    wherein assigning each of the quality classes to one of the priority groups is based on the counting results, wherein preferably a quality class with a higher number of wafers is assigned to a higher or equal priority group than a quality class with a smaller number of wafers.

6. The method according to any of the preceding claims, wherein at least part of the examination results of the wafers is stored and used for adapting the priority class assignment of the quality classes.

7. A computer program comprising computer program code adapted to perform the following method when the computer program is run on a computer:

    - configuring quality classes of the wafers dependent on at least one characteristic of the wafers;
    - configuring priority groups that include at least a high priority group and a low priority group;
    - assigning each of the quality classes to one of the priority groups;

- assigning each of the multitude of bins to one of the priority groups;
- receiving examination results for the wafers;
- classifying each of the wafers into one of the quality classes according to the examination result of the wafer; and
- controlling the delivery of each of the wafers to one of the multitude of bins according to the priority group assigned to the quality class of the wafer.

8. A computer readable medium storing the computer program according to claim 7.

9. A controller (200) for a binning apparatus (30) for delivering wafers to a multitude of bins (31), the controller being configured to carry out the following method:

- configuring quality classes for the wafers dependent on at least one characteristic of the wafers;
- configuring priority groups that include at least a high priority group and a low priority group;
- assigning each of the quality classes to one of the priority groups;
- assigning each of the multitude of bins to one of the priority groups;
- receiving examination results of the wafers;
- classifying each of the wafers into one of the quality classes according to the examination result of the wafer; and
- controlling the delivery of each of the wafers to one of the multitude of bins according to the priority group assigned to the quality class of the wafer.

10. A binning apparatus (30) for delivering wafers to a multitude of bins, comprising:

- at least one delivery system for delivering wafers to the multitude of bins; and
- a controller according to claim 9, wherein the controller is configured to control the at least one delivery system.

11. The binning apparatus according to claim 10, wherein the delivery system is a robot, wherein the binning apparatus preferably comprises at least four robots for delivering wafers to the multitude of bins.

12. The binning apparatus according to any of claims 10-11, comprising a conveyor belt for transporting the wafers, wherein the at least one delivery system is preferably arranged above the conveyor belt.

13. The binning apparatus according to any of claims 10-12, wherein exclusively bins directly adjacent to the conveyor belt are assigned to the high priority group.

14. The binning apparatus according to any of claims 10-13 being configured to house at least 24, particularly 48 bins.

15. A solar cell production apparatus (1), comprising:

- at least one deposition apparatus (10) for depositing a conductive path on a wafer;
- at least one inspection apparatus (20) for examining the wafer; and
- at least one binning apparatus (30) according to any of claims 10-14.

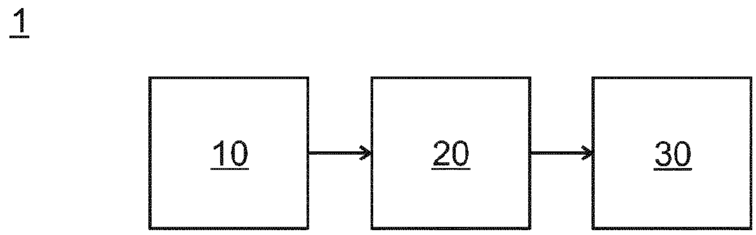

Fig. 1

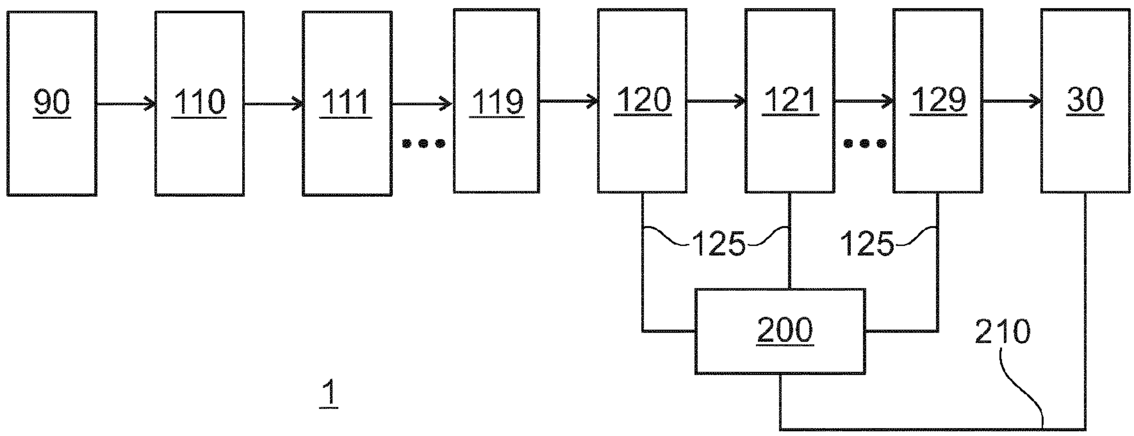

Fig. 2

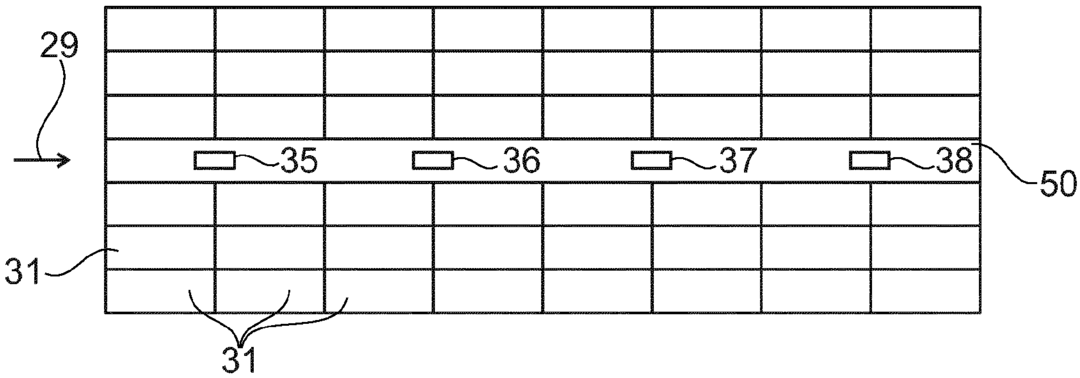
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Fig. 3

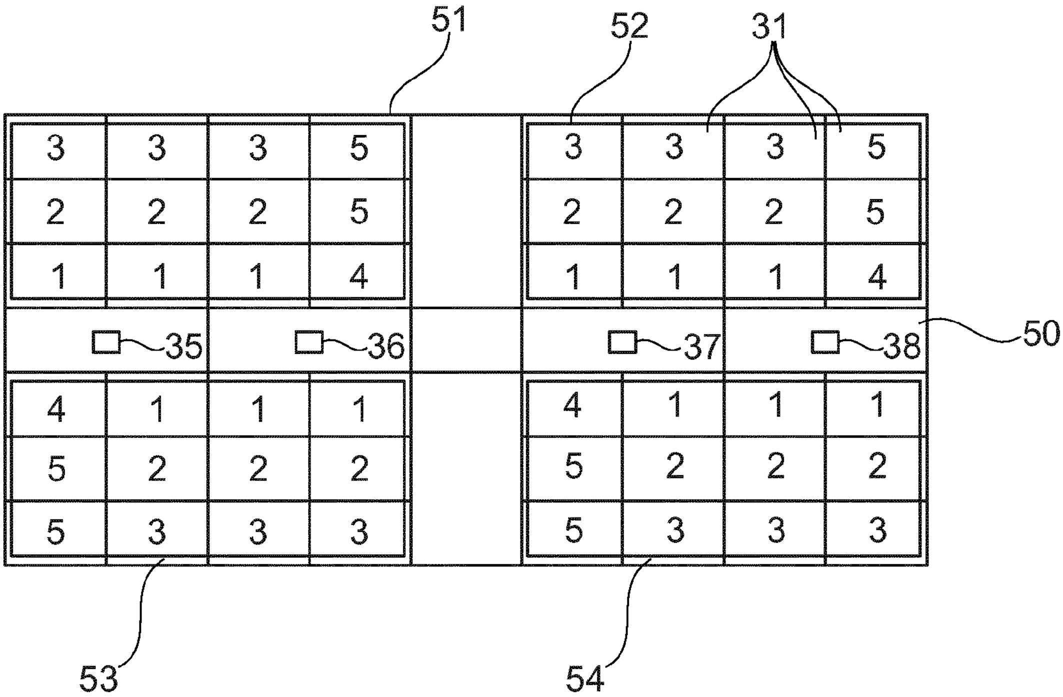
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Fig. 4

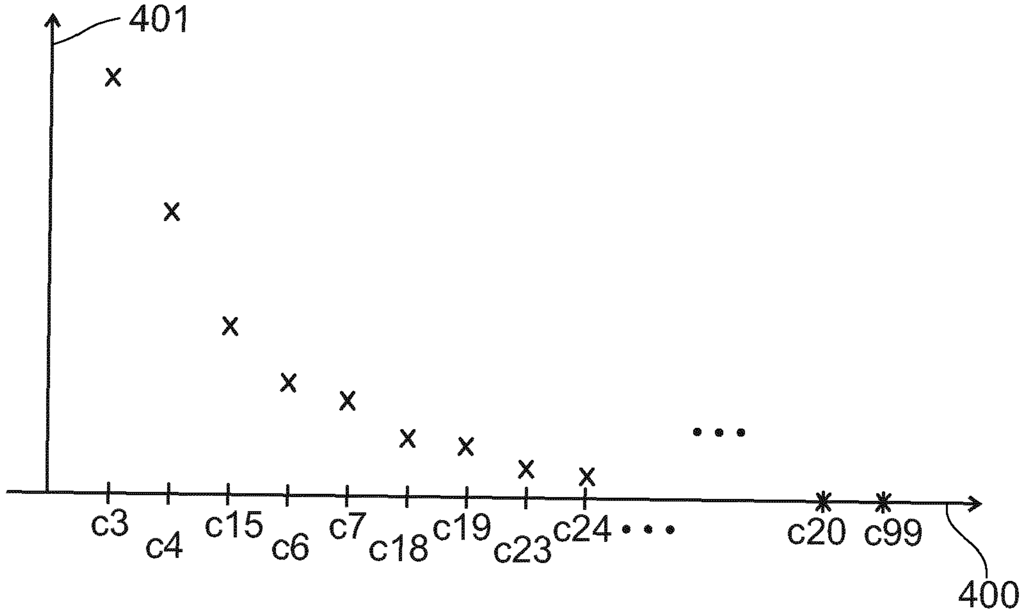
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Fig. 5

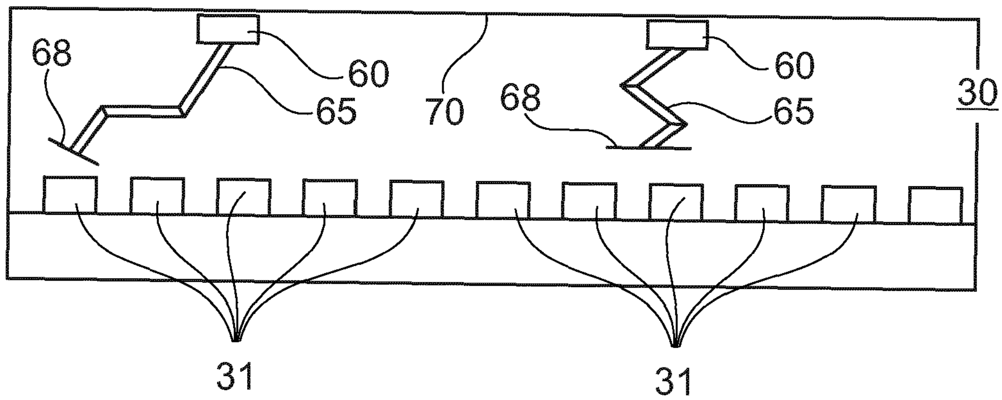
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Fig. 6

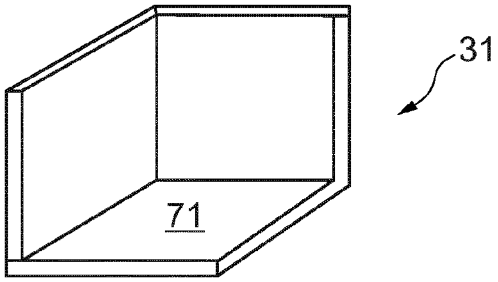

Fig. 7

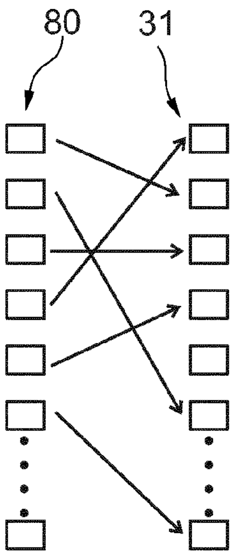

Fig. 8

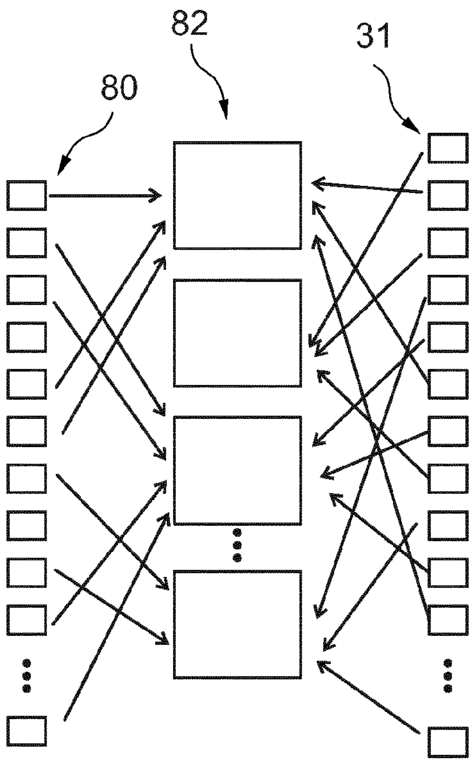

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 13 17 6132

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B07C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
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CATEGORY OF CITED DOCUMENTS

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