REAL-TIME AUTOMATIC CONTROL METHOD AND SYSTEM FOR SILICON WAFER PRODUCTION, MEDIUM AND DEVICE

TECHNICAL FIELD

[0001] The present invention relates to the technical field of photovoltaic slicing, and more specifically, to a real-time automatic control method and system for silicon wafer production, a medium and a device.

BACKGROUND

[0002] Monocrystalline silicon is a relatively active non-metallic element and an important component of crystal materials, which is at the forefront of the development of new materials. Monocrystalline silicon wafers are mainly used for producing solar batteries which generate power and supply heat using photovoltaics. Currently, monocrystalline silicon solar batteries are also the fastest developed type of solar batteries, of which the composition and production process have been finalized, and of which the products have been widely used in daily life, aerospace and some special ground facilities. Since solar energy has many advantages such as clean, environmental protective, and convenient, technologies utilizing the solar energy have made great progress in research and development, commercial production, and market development in the past thirty years, and have become one of the world's emerging industries with rapid and stable development.

[0003] Prior to the technology of the present invention, human power is mainly used in the existing technologies to produce monocrystalline silicon wafers, which has low efficiency and low accuracy with occurrence of frequent human errors.

SUMMARY

[0004] In view of the above problems, the present invention proposes a real-time

automatic control method and system for silicon wafer production, a medium and a device. Production efficiency and reliability of the monocrystalline silicon wafers can be improved by means of online automatic control of a production process of the monocrystalline silicon wafers, in combination with automatic identification and judgment by robot.

[0005] According to a first aspect, an embodiment of the present invention provides a real-time automatic control method for silicon wafer production.

[0006] In one or more embodiments, preferably, the real-time automatic control method for the silicon wafer production includes:

positioning a silicon rod through a robot to obtain a position of the silicon rod, setting a gluing speed target value to automatically glue and bond the silicon rod, and issuing a silicon rod bonding finished command;

automatically performing transportation and slicing through the robot after the robot receives the silicon rod bonding finished command, and issuing a slicing finished command after silicon wafer slicing is completed;

forming first target degummed silicon wafers through a degumming machine after the robot receives the slicing finished command, and issuing a degumming finished command;

arranging the first target degummed silicon wafers through a wafer arrangement machine after the robot receives the degumming finished command, to form second target degummed silicon wafers, and issuing an arranging finished command;

cleaning the second target degummed silicon wafers through a cleaning machine after the robot receives the arranging finished command, to form cleaning-finished silicon wafers, and issuing a silicon wafer cleaning finished command;

automatically completing classification and quality analysis of all silicon wafers through the robot after the robot fetches the silicon wafer cleaning finished command, and packaging and transporting them to a warehouse.

[0007] In one or more embodiments, preferably, positioning the silicon rod through the robot to obtain the position of the silicon rod, setting the gluing speed target value to automatically glue and bond the silicon rod, and issuing the silicon rod bonding finished command specifically include:

obtaining an initial position coordinate of the silicon rod, and automatically moving the silicon rod to a preset placement position coordinate through the robot;

calculating the position of the silicon rod according to a first calculation formula based on the initial position coordinate and the placement position coordinate;

automatically bonding the silicon rod to a dovetail base through the robot by using glue, and collecting a gluing thickness current value;

setting a gluing coefficient and a gluing constant, and calculating a glue-feeding speed given value according to a second calculation formula;

calculating a gluing uniformity according to a third calculation formula;

calculating a gluing overflow amount according to a fourth calculation formula;

calculating the gluing speed target value according to a fifth calculation formula;

automatically adjusting a glue-feeding process through the robot according to the position of the silicon rod, the gluing speed target value and the glue-feeding speed given value to fix the silicon rod, and issuing the silicon rod bonding finished command;

the first calculation formula being: $X=Fx-Cx$,

where X is the position of the silicon rod, Cx is the initial position coordinate, and Fx is the placement position coordinate;

the second calculation formula being: $V_{ref}=K_T(H_{ref}-H_d)+A_T$,

where V_{ref} is the glue-feeding speed given value, H_{ref} is a preset gluing thickness given value, H_d is the gluing thickness current value, K_T is the gluing coefficient, A_T is the gluing constant;

the third calculation formula being: $J=max(|V-V_0|)$,

where J is the gluing uniformity, V is a gluing speed collected in real time, max is a maximum function per unit time, and V_0 is an gluing speed initial value;

the fourth calculation formula being: $Y=P(V-V_{ref})-G$,

where Y is the gluing overflow amount, V is the gluing speed collected in real time, P is a preset glue-feeding correction coefficient, and G is a preset glue-feeding constant;

the fifth calculation formula being: $V_p=arg\ max(k_1J-k_2Y)$,

where Vp is the gluing speed target value, Y is the gluing overflow amount, $arg\ max(k_1J-k_2Y)$ is a calculated value of k_1J-k_2Y corresponding to all gluing speeds obtained, and

k_1 is a preset first gluing coefficient; k_2 is a preset second gluing coefficient.

[0008] In one or more embodiments, preferably, automatically performing the transportation and the slicing through the robot after the robot receives the silicon rod bonding finished command, and issuing the slicing finished command after the silicon wafer slicing is completed specifically include:

waiting according to a preset time interval and then automatically issuing a silicon rod moving command, after the robot receives the silicon rod bonding finished command;

delivering the silicon rod to a slicing workshop according to a preset route through the robot after the robot receives the silicon rod moving command;

automatically spraying and cleaning the silicon rod in the slicing workshop;

calculating a target slicing position of the cleaned silicon rod according to a sixth calculation formula;

slicing the silicon rod into several silicon wafers with a preset thickness according to the target slicing position by using back-and-forth grinding of diamond on a diamond wire;

issuing the slicing finished command after the silicon wafer slicing is completed;

the sixth calculation formula being: $W=M+X$,

where W is the target slicing position, and M is the preset thickness.

[0009] In one or more embodiments, preferably, forming the first target degummed silicon wafers through the degumming machine after the robot receives the slicing finished command, and issuing the degumming finished command specifically include:

sending the sliced silicon rod to the degumming machine through the robot after the robot receives the slicing finished command;

separating the silicon wafers from a glue layer by means of heating and an action of ultrasound combined with lactic acid in the degumming machine, to form degummed silicon wafers;

cleaning the degummed silicon wafers to form the first target degummed silicon wafers;

issuing the degumming finished command.

[0010] In one or more embodiments, preferably, arranging the first target degummed silicon wafers through the wafer arrangement machine after the robot receives the degumming

finished command, to form the second target degummed silicon wafers, and issuing the arranging finished command specifically include:

arranging the first target degummed silicon wafers in a slot through the wafer arrangement machine after the robot receives the degumming finished command;

placing the first target degummed silicon wafers at equal intervals through the wafer arrangement machine;

cleaning the first target degummed silicon wafers placed at the equal intervals to form the second target degummed silicon wafers;

issuing the arranging finished command.

[0011] In one or more embodiments, preferably, cleaning the second target degummed silicon wafers through the cleaning machine after the robot receives the arranging finished command, to form the cleaning-finished silicon wafers, and issuing the silicon wafer cleaning finished command specifically include:

placing the second target degummed silicon wafers and the slot in the cleaning machine after the robot receives the arranging finished command;

cleaning the second target degummed silicon wafers by using a cleaning agent and ultrasonic waves;

drying the cleaned second target degummed silicon wafers to obtain the cleaning-finished silicon wafers;

issuing the silicon wafer cleaning finished command.

[0012] In one or more embodiments, preferably, automatically completing the classification and the quality analysis of all the silicon wafers through the robot after the robot fetches the silicon wafer cleaning finished command, and packaging and transporting them to the warehouse specifically include:

obtaining a positioning accuracy of the silicon rod and an abnormality category of the silicon rod by automatically performing an abnormality analysis on the cleaning-finished silicon wafers, after the robot fetches the silicon wafer cleaning finished command;

calculating a quality level of the silicon wafers according to a seventh calculation formula;

setting a preset real-time correction coefficient and a preset real-time correction

index;

calculating a running speed adjustment coefficient according to an eighth calculation formula based on the quality level;

adjusting, according to the running speed adjustment coefficient, a tripping speed of the robot during a handling process;

performing automatic packaging according to the abnormality category of the silicon rod through the robot, and transferring to the warehouse;

the seventh calculation formula being: $Z_k = D+B$,

where Z_k is the quality level, D is the positioning accuracy of the silicon rod, and B is the abnormality category of the silicon rod;

the eighth calculation formula being: $T_K=k_0Z_k+c_0$,

where T_K is the running speed adjustment coefficient, Z_k is the quality level, k_0 is the preset real-time correction coefficient, and c_0 is the preset real-time correction index.

[0013] According to a second aspect, an embodiment of the present invention provides a real-time automatic control system for silicon wafer production.

[0014] In one or more embodiments, preferably, the real-time automatic control system for the silicon wafer production includes:

a rod-bonding module, configured to position a silicon rod through a robot to obtain a position of the silicon rod, set a gluing speed target value to automatically glue and bond the silicon rod, and issue a silicon rod bonding finished command;

a slicing module, configured to automatically perform transportation and slicing through the robot after the robot receives the silicon rod bonding finished command, and issue a slicing finished command after silicon wafer slicing is completed;

a degumming module, configured to form first target degummed silicon wafers through a degumming machine after the robot receives the slicing finished command, and issue a degumming finished command;

a wafer arrangement module, configured to arrange the first target degummed silicon wafers through a wafer arrangement machine after the robot receives the degumming finished command, to form second target degummed silicon wafers, and issue an arranging finished command;

a cleaning module, configured to clean the second target degummed silicon wafers through a cleaning machine after the robot receives the arranging finished command, to form cleaning-finished silicon wafers, and issue a silicon wafer cleaning finished command;

a checking and packaging module, configured to automatically complete classification and quality analysis of all silicon wafers through the robot after the robot fetches the silicon wafer cleaning finished command, and package and transport them to a warehouse.

[0015] According to a third aspect, an embodiment of the present invention provides a computer-readable storage medium on which a computer program instruction is stored, and when the computer program instruction is executed by a processor, the method according to any one of the embodiments of the present invention in the first aspect is implemented.

[0016] According to a fourth aspect, an embodiment of the present invention provides an electronic device including a memory and a processor, where the memory is configured to store one or more computer program instructions, where the one or more computer program instructions are executed by the processor to implement the method according to any one of the embodiments of the present invention in the first aspect.

[0017] The technical solutions provided in the embodiments of the present invention may include the following beneficial effects.

[0018] In the embodiments of the present invention, a method and a system for producing monocrystalline silicon based on a robot are provided, which improve production efficiency and reduce the probability of human errors by automatically completing the control of materials and devices in multiple production processes.

[0019] In the embodiments of the present invention, a robot-executed online quality control method for monocrystalline silicon is provided, which can automatically control a current production process online.

[0020] Additional features and advantages of the present invention will be elaborated in the description hereinafter, and part thereof will become obvious from the description or may be learned by implementing the present invention. The objectives and other advantages of the present invention may be realized and obtained by the structure particularly pointed out in the description and claims as well as the accompanying drawings.

[0021] The technical solutions of the present invention will be further described in detail hereinafter according to the accompanying drawings and embodiments.

BRIEF DESCRIPTION OF DRAWINGS

[0022] In order to more clearly illustrate the technical solutions in the embodiments of the present invention, the accompanying drawings required in the description of the embodiments will be briefly introduced below. Obviously, the accompanying drawings in the following description are only some embodiments of the present invention. For those skilled in the art, other accompanying drawings can also be obtained based on these accompanying drawings without any creative efforts.

[0023] FIG. 1 is a flow chart of a real-time automatic control method for silicon wafer production according to an embodiment of the present invention.

[0024] FIG. 2 is a flow chart of positioning a silicon rod through a robot to obtain a position of the silicon rod, setting a gluing speed target value to automatically glue and bond the silicon rod, and issuing the silicon rod bonding finished command in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0025] FIG. 3 is a flow chart of automatically performing transportation and slicing through the robot after the robot receives the silicon rod bonding finished command, and issuing a slicing finished command after silicon wafer slicing is completed in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0026] FIG. 4 is a flow chart of forming first target degummed silicon wafers through a degumming machine after the robot receives the slicing finished command, and issuing a degumming finished command in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0027] FIG. 5 is a flow chart of arranging the first target degummed silicon wafers through a wafer arrangement machine after the robot receives the degumming finished command, to form second target degummed silicon wafers, and issuing an arranging finished

command in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0028] FIG. 6 is a flow chart of cleaning the second target degummed silicon wafers through a cleaning machine after the robot receives the arranging finished command, to form cleaning-finished silicon wafers, and issuing a silicon wafer cleaning finished command in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0029] FIG. 7 is a flow chart of automatically completing classification and quality analysis of all silicon wafers through the robot after the robot fetches the silicon wafer cleaning finished command, and packaging and transporting them to a warehouse in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0030] FIG. 8 is a structural diagram of a real-time automatic control system for silicon wafer production according to an embodiment of the present invention.

[0031] FIG. 9 is a structural diagram of an electronic device according to an embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0032] Some of the processes as described in the specification and claims as well as the above-mentioned drawings of the present invention include multiple operations that appear in a specific order. However, it should be clearly understood that these operations may be performed in an order other than that appearing herein, or may be performed in parallel, and the sequence numbers for these operations, such as 101, 102, etc., are only used to distinguish different operations and the sequence numbers themselves do not represent any execution order. In addition, these processes may include more or fewer operations, and these operations may be performed sequentially or in parallel. It should be noted that the terms such as “first” and “second” herein are used to distinguish different messages, devices, modules, etc., and they do not represent the sequential order, nor do they limit the “first” and “second” being different types.

[0033] The technical solutions in the embodiments of the present invention will be clearly and comprehensively described below with reference to the accompanying drawings in the embodiments of the present invention. Obviously, the embodiments described are only some, not all, of the embodiments of the present invention. Based on the embodiments of the present invention, all other embodiments obtained by those skilled in the art without creative efforts shall fall within the protection scope of the present invention.

[0034] Monocrystalline silicon is a relatively active non-metallic element and an important component of crystal materials, which is at the forefront of the development of new materials. Monocrystalline silicon wafers are mainly used for producing solar batteries which generate power and supply heat using photovoltaics. Currently, monocrystalline silicon solar batteries are also the fastest developed type of solar batteries, of which the composition and production process have been finalized, and of which the products have been widely used in daily life, aerospace and some special ground facilities. Since solar energy has many advantages such as clean, environmental protective, and convenient, technologies utilizing the solar energy have made great progress in research and development, commercial production, and market development in the past thirty years, and have become one of the world's emerging industries with rapid and stable development.

[0035] Prior to the technology of the present invention, human power is mainly used in the existing technologies to produce monocrystalline silicon wafers, which has low efficiency and low accuracy with occurrence of frequent human errors.

[0036] In embodiments of the present invention, a real-time automatic control method and system for silicon wafer production, a medium and a device are provided. Production efficiency and reliability of the monocrystalline silicon wafers can be improved in this solution by means of online automatic control of a production process of the monocrystalline silicon wafers, in combination with automatic identification and judgment by robot.

[0037] According to a first aspect, an embodiment of the present invention provides a real-time automatic control method for silicon wafer production.

[0038] FIG. 1 is a flow chart of a real-time automatic control method for silicon wafer production according to an embodiment of the present invention.

[0039] In one or more embodiments, preferably, the real-time automatic control method

for the silicon wafer production includes:

S101: positioning a silicon rod through a robot to obtain a position of the silicon rod, setting a gluing speed target value to automatically glue and bond the silicon rod, and issuing a silicon rod bonding finished command;

S102: automatically performing transportation and slicing through the robot after the robot receives the silicon rod bonding finished command, and issuing a slicing finished command after silicon wafer slicing is completed;

S103: forming first target degummed silicon wafers through a degumming machine after the robot receives the slicing finished command, and issuing a degumming finished command;

S104: arranging the first target degummed silicon wafers through a wafer arrangement machine after the robot receives the degumming finished command, to form second target degummed silicon wafers, and issuing an arranging finished command;

S105: cleaning the second target degummed silicon wafers through a cleaning machine after the robot receives the arranging finished command, to form cleaning-finished silicon wafers, and issuing a silicon wafer cleaning finished command;

S106: automatically completing classification and quality analysis of all silicon wafers through the robot after the robot fetches the silicon wafer cleaning finished command, and packaging and transporting them to a warehouse.

[0040] In the embodiments of the present invention, the problems such as low accuracy and misoperation which may easily occur during manual production in the past are solved. Efficient and reliable production of the silicon wafers is achieved through automatic process control. During a specific execution process, all commands as well as transportation and operation of devices are executed by the robot. The robot runs according to a fixed running path, and after the robot receives a corresponding execution command, it proceeds with running to a next position in the running path. In the entire running path, the degumming machine for silicon wafer degumming, the wafer arrangement machine for silicon wafer arranging and the cleaning machine for silicon wafer cleaning are placed. After the robot reaches designated positions in the running path, corresponding steps or processes are started to complete the entire operation process.

[0041] FIG. 2 is a flow chart of positioning the silicon rod through the robot to obtain the position of the silicon rod, setting the gluing speed target value to automatically glue and bond the silicon rod, and issuing the silicon rod bonding finished command in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0042] As shown in FIG. 2, in one or more embodiments, preferably, positioning the silicon rod through the robot to obtain the position of the silicon rod, setting the gluing speed target value to automatically glue and bond the silicon rod, and issuing the silicon rod bonding finished command specifically include:

S201: obtaining an initial position coordinate of the silicon rod, and automatically moving the silicon rod to a preset placement position coordinate through the robot;

where the initial position coordinate of the silicon rod is an initially marked installation position of a gluing device, which is generally on a side of the gluing device closest to the robot; therefore, from the perspective of the robot, there will be an initial position coordinate and a placement position coordinate; the placement position coordinate is a preset placement position after an actual movement;

S202: calculating the position of the silicon rod according to a first calculation formula based on the initial position coordinate and the placement position coordinate;

S203: automatically bonding the silicon rod to a dovetail base through the robot by using glue, and collecting a gluing thickness current value;

where the dovetail base is a base of the gluing device and is configured for bonding with the silicon rod;

S204: setting a gluing coefficient and a gluing constant, and calculating a glue-feeding speed given value according to a second calculation formula;

where the gluing coefficient and the gluing constant are numbers set based on experience and are positive integers;

S205: calculating a gluing uniformity according to a third calculation formula;

S206: calculating a gluing overflow amount according to a fourth calculation formula;

S207: calculating the gluing speed target value according to a fifth calculation

formula;

S208: automatically adjusting a glue-feeding process through the robot according to the position of the silicon rod, the gluing speed target value and the glue-feeding speed given value to fix the silicon rod, and issuing the silicon rod bonding finished command;

the first calculation formula is: $X=Fx-Cx$,

where X is the position of the silicon rod, Cx is the initial position coordinate, and Fx is the placement position coordinate;

the second calculation formula is: $V_{ref}=K_T(H_{ref}-H_d)+A_T$,

where V_{ref} is the glue-feeding speed given value, H_{ref} is a preset gluing thickness given value, H_d is the gluing thickness current value, K_T is the gluing coefficient, A_T is the gluing constant;

the third calculation formula is: $J=max(|V-V0|)$,

where J is the gluing uniformity, V is a gluing speed collected in real time, max is a maximum function per unit time, and V_0 is an gluing speed initial value;

the fourth calculation formula is: $Y=P(V-V_{ref})-G$,

where Y is the gluing overflow amount, V is the gluing speed collected in real time, P is a preset glue-feeding correction coefficient, and G is a preset glue-feeding constant;

the fifth calculation formula is: $V_p=arg\ max(k_1J-k_2Y)$,

where V_p is the gluing speed target value, Y is the gluing overflow amount, $arg\ max\ (k_1J-k_2Y)$ is a calculated value of k_1J-k_2Y corresponding to all gluing speeds obtained, and k_1 is a preset first gluing coefficient; k_2 is a preset second gluing coefficient.

[0043] In the embodiments of the present invention, in order to ensure the thickness, uniformity and overflow amount of the gluing process and improve the safety of slicing the silicon rod, the method of automatically controlling the real-time gluing speed and glue-feeding amount is adopted, where the gluing speed initial value is a preset speed, but the gluing speed will be fine-adjusted during the process since the entire gluing process is dynamic. The preset glue-feeding correction coefficient is a coefficient set for controlling the gluing process, which is generally 1. When the gluing speed is required to be adjusted quickly, the preset glue-feeding correction coefficient will be greater than 1. A smallest value of the preset glue-feeding correction coefficient can be set to 0. The preset glue-feeding constant is

generally set according to the parameters recommended by the manufacturer of the gluing device. Combined specifically with the second calculation formula, the third calculation formula, the fourth calculation formula and the fifth calculation formula, the adaptive control of the entire glue-feeding process is completed, and the bonding of the silicon rod is achieved efficiently and accurately by the robot. In addition, in order to enable a subsequent process to be started accurately, a specific bonding position of the rod is recorded.

[0044] Among others, k_1 is the preset first gluing coefficient; k_2 is the preset second gluing coefficient, of which the initial values are set to 0.5. During the gluing process, they can be adjusted to further control a relative degree between the gluing overflow amount and the gluing uniformity.

[0045] FIG. 3 is a flow chart of automatically performing the transportation and the slicing through the robot after the robot receives the silicon rod bonding finished command, and issuing the slicing finished command after the silicon wafer slicing is completed in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0046] As shown in FIG. 3, in one or more embodiments, preferably, automatically performing the transportation and the slicing through the robot after the robot receives the silicon rod bonding finished command, and issuing the slicing finished command after the silicon wafer slicing is completed specifically include:

S301: waiting according to a preset time interval and then automatically issuing a silicon rod moving command, after the robot receives the silicon rod bonding finished command;

S302: delivering the silicon rod to a slicing workshop according to a preset route through the robot after the robot receives the silicon rod moving command;

S303: automatically spraying and cleaning the silicon rod in the slicing workshop;

S304: calculating a target slicing position of the cleaned silicon rod according to a sixth calculation formula;

S305: slicing the silicon rod into several silicon wafers with a preset thickness according to the target slicing position by using back-and-forth grinding of diamond on a diamond wire;

S306: issuing the slicing finished command after the silicon wafer slicing is completed;

the sixth calculation formula is: $W=M+X$,

where W is the target slicing position, and M is the preset thickness.

[0047] In the embodiments of the present invention, automatic transportation and automatic spraying are performed by the automatic robot, and automatic slicing is performed in conjunction with the preset slicing position to form multiple standard thin silicon wafers with a uniform thickness. The preset thickness is a required thickness when slicing, which is preset before slicing. There is no dynamic adjustment during each slicing process. The entire process is not realized manually, with high efficiency and high accuracy.

[0048] FIG. 4 is a flow chart of forming the first target degummed silicon wafers through the degumming machine after the robot receives the slicing finished command, and issuing the degumming finished command in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0049] As shown in FIG. 4, in one or more embodiments, preferably, forming the first target degummed silicon wafers through the degumming machine after the robot receives the slicing finished command, and issuing the degumming finished command specifically include:

S401: sending the sliced silicon rod to the degumming machine through the robot after the robot receives the slicing finished command;

S402: separating the silicon wafers from a glue layer by means of heating and an action of ultrasound combined with lactic acid in the degumming machine to form degummed silicon wafers;

S403: cleaning the degummed silicon wafers to form the first target degummed silicon wafers;

S404: issuing the degumming finished command.

[0050] In the embodiments of the present invention, after the slicing is completed, the silicon rod sliced is sent to the degumming machine, and the silicon wafers are separated from the glue layer by means of the heating and the action of ultrasound combined with lactic acid in the degumming machine; the silicon wafers are pre-cleaned; where the process is entirely

performed by the robot.

[0051] FIG. 5 is a flow chart of arranging the first target degummed silicon wafers through the wafer arrangement machine after the robot receives the degumming finished command, to form the second target degummed silicon wafers, and issuing the arranging finished command in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0052] As shown in FIG. 5, in one or more embodiments, preferably, arranging the first target degummed silicon wafers through the wafer arrangement machine after the robot receives the degumming finished command, to form the second target degummed silicon wafers, and issuing the arranging finished command specifically include:

S501: arranging the first target degummed silicon wafers in a slot through the wafer arrangement machine after the robot receives the degumming finished command;

S502: placing the first target degummed silicon wafers at equal intervals through the wafer arrangement machine;

S503: cleaning the first target degummed silicon wafers placed at the equal intervals to form the second target degummed silicon wafers;

S504: issuing the arranging finished command.

[0053] In the embodiments of the present invention, the silicon wafers degummed are arranged into the slot by the wafer arrangement machine, so that the silicon wafers are placed equidistantly from each other.

[0054] FIG. 6 is a flow chart of cleaning the second target degummed silicon wafers through the cleaning machine after the robot receives the arranging finished command, to form the cleaning-finished silicon wafers, and issuing the silicon wafer cleaning finished command in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0055] As shown in FIG. 6, in one or more embodiments, preferably, cleaning the second target degummed silicon wafers through the cleaning machine after the robot receives the arranging finished command, to form the cleaning-finished silicon wafers, and issuing the silicon wafer cleaning finished command specifically include:

S601: placing the second target degummed silicon wafers and the slot in the

cleaning machine after the robot receives the arranging finished command;

S602: cleaning the second target degummed silicon wafers by using a cleaning agent and ultrasonic waves;

S603: drying the cleaned second target degummed silicon wafers to obtain the cleaning-finished silicon wafers;

S604: issuing the silicon wafer cleaning finished command.

[0056] In the embodiments of the present invention, the silicon wafers and the slot are passed through the cleaning machine to remove and clean the oxide layers and impurities on the surfaces of the silicon wafers, where the cleaning is required in this process by means of the cleaning agent combined with the ultrasonic.

[0057] FIG. 7 is a flow chart of automatically completing the classification and the quality analysis of all the silicon wafers through the robot after the robot fetches the silicon wafer cleaning finished command, and packaging and transporting them to the warehouse in the real-time automatic control method for the silicon wafer production according to an embodiment of the present invention.

[0058] As shown in FIG. 7, in one or more embodiments, preferably, automatically completing the classification and the quality analysis of all the silicon wafers through the robot after the robot fetches the silicon wafer cleaning finished command, and packaging and transporting them to the warehouse specifically include:

S701: obtaining a positioning accuracy of the silicon rod and an abnormality category of the silicon rod by automatically performing an abnormality analysis on the cleaning-finished silicon wafers, after the robot fetches the silicon wafer cleaning finished command;

S702: calculating a quality level of the silicon wafers according to a seventh calculation formula;

S703: setting a preset real-time correction coefficient and a preset real-time correction index;

S704: calculating a running speed adjustment coefficient according to an eighth calculation formula based on the quality level;

S705: adjusting, according to the running speed adjustment coefficient, a tripping

speed of the robot during a handling process;

S706: performing automatic packaging according to the abnormality category of the silicon rod through the robot, and transferring to the warehouse;

the seventh calculation formula is: $Z_k = D+B$,

where Z_k is the quality level, D is the positioning accuracy of the silicon rod, and B is the abnormality category of the silicon rod;

the eighth calculation formula is: $T_K=k_0Z_k+c_0$,

where T_K is the running speed adjustment coefficient, Z_k is the quality level, k_0 is the preset real-time correction coefficient, and c_0 is the preset real-time correction index.

[0059] In the embodiments of the present invention, by automatically analyzing the current quality level and the abnormality category of the silicon rod, automatically classifying and packaging, and adjusting the entire running process of the robot, the entire production process of the silicon wafers can be automatically corrected during operation; and then the running speed of the automatic production of the silicon wafers by the robot is adjusted while ensuring quality. Specifically, k_0 is the preset real-time correction coefficient, of which an initial value is 1; when it is necessary to increase the quality control by the robot, the preset real-time correction coefficient will be increased up to a maximum value of 2, and a minimum value of the preset real-time correction coefficient is 0; c_0 is the preset real-time correction index, of which an initial value is 0 and which is set directly on the robot when modifications are required.

[0060] According to a second aspect, an embodiment of the present invention provides a real-time automatic control system for silicon wafer production.

[0061] FIG. 8 is a structural diagram of a real-time automatic control system for silicon wafer production according to an embodiment of the present invention.

[0062] In one or more embodiments, preferably, the real-time automatic control system for the silicon wafer production includes:

a rod-bonding module 801, configured to position a silicon rod through a robot to obtain a position of the silicon rod, set a gluing speed target value to automatically glue and bond the silicon rod, and issue a silicon rod bonding finished command;

a slicing module 802, configured to automatically perform transportation and

slicing through the robot after the robot receives the silicon rod bonding finished command, and issue a slicing finished command after silicon wafer slicing is completed;

a degumming module 803, configured to form first target degummed silicon wafers through a degumming machine after the robot receives the slicing finished command, and issue a degumming finished command;

a wafer arrangement module 804, configured to arrange the first target degummed silicon wafers through a wafer arrangement machine after the robot receives the degumming finished command, to form second target degummed silicon wafers, and issue an arranging finished command;

a cleaning module 805, configured to clean the second target degummed silicon wafers through a cleaning machine after the robot receives the arranging finished command, to form cleaning-finished silicon wafers, and issue a silicon wafer cleaning finished command;

a checking and packaging module 806, configured to automatically complete classification and quality analysis of all silicon wafers through the robot after the robot fetches the silicon wafer cleaning finished command, and package and transport them to a warehouse.

[0063] In the embodiment of the present invention, the real-time automatic control system for producing the silicon wafers from the silicon rod is provided, which automatically controls the entire production process of the silicon wafers in real time via the robot to improve production efficiency.

[0064] Further, the rod-bonding module 801 includes:

a silicon rod placement unit, configured to obtain an initial position coordinate of the silicon rod, and automatically move the silicon rod to a preset placement position coordinate through the robot;

a silicon rod position unit, configured to calculate the position of the silicon rod according to a first calculation formula based on the initial position coordinate and the placement position coordinate;

a gluing and collecting unit, configured to automatically bond the silicon rod to a dovetail base through the robot by using glue, and collect a gluing thickness current value;

a glue-feeding speed calculation unit, configured to set a gluing coefficient and a gluing constant, and calculate a glue-feeding speed given value according to a second calculation formula;

a gluing uniformity calculation unit, configured to calculate a gluing uniformity according to a third calculation formula;

a gluing overflow calculation unit, configured to calculate a gluing overflow amount according to a fourth calculation formula;

a gluing speed target value calculation unit, configured to calculate the gluing speed target value according to a fifth calculation formula;

a unit for sending the silicon rod bonding finished command, configured to automatically adjust a glue-feeding process through the robot according to the position of the silicon rod, the gluing speed target value and the glue-feeding speed given value to fix the silicon rod, and issue the silicon rod bonding finished command;

the first calculation formula is: $X=Fx-Cx$,

where X is the position of the silicon rod, Cx is the initial position coordinate, and Fx is the placement position coordinate;

the second calculation formula is: $V_{ref}=K_T(H_{ref}-H_d)+A_T$,

where V_{ref} is the glue-feeding speed given value, H_{ref} is a preset gluing thickness given value, H_d is the gluing thickness current value, K_T is the gluing coefficient, A_T is the gluing constant;

the third calculation formula is: $J=max(|V-V_0|)$,

where J is the gluing uniformity, V is a gluing speed collected in real time, max is a maximum function per unit time, and V_0 is an gluing speed initial value;

the fourth calculation formula is: $Y=P(V-V_{ref})-G$,

where Y is the gluing overflow amount, V is the gluing speed collected in real time, P is a preset glue-feeding correction coefficient, and G is a preset glue-feeding constant;

the fifth calculation formula is: $V_p=arg\ max(k_1J-k_2Y)$,

where V_p is the gluing speed target value, Y is the gluing overflow amount, $arg\ max\ (k_1J-k_2Y)$ is a calculated value of k_1J-k_2Y corresponding to all gluing speeds obtained, and k_1 is a preset first gluing coefficient; k_2 is a preset second gluing coefficient.

[0065] Further, the slicing module 802 includes:

a unit for issuing a silicon rod moving command, configured to wait according to a preset time interval and then automatically issue the silicon rod moving command, after the robot receives the silicon rod bonding finished command;

a silicon rod delivering unit, configured to deliver the silicon rod to a slicing workshop according to a preset route through the robot after the robot receives the silicon rod moving command;

an automatic spraying and cleaning unit, configured to automatically spray and clean the silicon rod in the slicing workshop;

a target slicing position calculation unit, configured to calculate a target slicing position of the cleaned silicon rod according to a sixth calculation formula;

a unit for generating silicon wafers with a preset thickness, configured to slice the silicon rod into several silicon wafers with a preset thickness according to the target slicing position by using back-and-forth grinding of diamond on a diamond wire;

a slicing finished command issuing unit, configured to issue the slicing finished command after the silicon wafer slicing is completed;

the sixth calculation formula is: $W=M+X$,

where W is the target slicing position, and M is the preset thickness.

[0066] Further, the degumming module 803 includes:

a silicon rod sending-for-degumming unit, configured to send the sliced silicon rod to the degumming machine through the robot after the robot receives the slicing finished command;

a unit for generating degummed silicon wafers, configured to separate the silicon wafers from a glue layer by means of heating and an action of ultrasound combined with lactic acid in the degumming machine, to form degummed silicon wafers;

a unit for generating the first target degummed silicon wafers, configured to clean the degummed silicon wafers to form the first target degummed silicon wafers;

a degumming finished command issuing unit, configured to issue the degumming finished command.

[0067] Further, the wafer arrangement module 804 includes:

a silicon wafer arranging-into-slot unit, configured to arrange the first target degummed silicon wafers in a slot through the wafer arrangement machine after the robot receives the degumming finished command;

an equidistant placement unit, configured to place the first target degummed silicon wafers at equal intervals through the wafer arrangement machine;

a unit for generating the second target degummed silicon wafers, configured to clean the first target degummed silicon wafers placed at the equal intervals to form the second target degummed silicon wafers;

an arranging finished command issuing unit, configured to issue the arranging finished command.

[0068] Further, the cleaning module 805 includes:

a cleaning preparation unit, configured to place the second target degummed silicon wafers and a slot in the cleaning machine after the robot receives the arranging finished command;

a unit for cleaning degummed silicon wafers, configured to clean the second target degummed silicon wafers by using a cleaning agent and ultrasonic waves;

a drying unit, configured to dry the cleaned second target degummed silicon wafers to obtain the cleaning-finished silicon wafers;

a unit for issuing the silicon wafer cleaning finished command, configured to issue the silicon wafer cleaning finished command.

[0069] Further, the checking and packaging module 806 includes:

a silicon rod abnormality distinguishing unit, configured to obtain a positioning accuracy of the silicon rod and an abnormality category of the silicon rod by automatically performing an abnormality analysis on the cleaning-finished silicon wafers, after the robot fetches the silicon wafer cleaning finished command;

a quality level calculation unit, configured to calculate a quality level of the silicon wafers according to a seventh calculation formula;

a real-time correction index setting unit, configured to set a preset real-time correction coefficient and a preset real-time correction index;

a unit for calculating the running speed adjustment coefficient, configured to

calculate a running speed adjustment coefficient according to an eighth calculation formula based on the quality level;

a running speed adjustment unit, configured to adjust, according to the running speed adjustment coefficient, a tripping speed of the robot during a handling process;

a transfer-to-warehouse unit, configured to perform automatic packaging according to the abnormality category of the silicon rod through the robot, and transfer to the warehouse;

the seventh calculation formula is: $Z_k=D+B$,

where Z_k is the quality level, D is the positioning accuracy of the silicon rod, and B is the abnormality category of the silicon rod;

the eighth calculation formula is: $T_K=k_0Z_k+c_0$,

where T_K is the running speed adjustment coefficient, Z_k is the quality level, k_0 is the preset real-time correction coefficient, and c_0 is the preset real-time correction index.

[0070] According to a third aspect, an embodiment of the present invention provides a computer-readable storage medium on which a computer program instruction is stored, and when the computer program instruction is executed by a processor, the method according to any one of the embodiments of the present invention in the first aspect is implemented.

[0071] According to a fourth aspect, an embodiment of the present invention provides an electronic device. FIG. 9 is a structural diagram of an electronic device according to an embodiment of the present invention. The electronic device shown in FIG. 9 is a general real-time automatic control device for silicon wafer production, including a general computer hardware structure, which at least includes a processor 901 and a memory 902. The processor 901 and the memory 902 are connected by a bus 903. The memory 902 is adapted to store instructions or programs executable by the processor 901. The processor 901 can be an independent microprocessor or a collection of one or more microprocessors. Thus, the processor 901 executes the instructions stored in the memory 902 to execute the method flow in the embodiments of the present invention as described above to process data and control other devices. The bus 903 is configured to connect the above-mentioned plurality of components together, and meanwhile connect the above-mentioned components to a display controller 904, a display device and an input/output (I/O) device 905. The input/output (I/O)

device 905 may be a mouse, a keyboard, a modem, a network interface, a touch input device, a motion sensing input device, a printer, and other devices known in the art. Typically, the input/output device 905 is connected to the system through an input/output (I/O) controller 906.

[0072] The technical solutions provided in the embodiments of the present invention may include the following beneficial effects.

[0073] In the embodiments of the present invention, a method and a system for producing monocrystalline silicon based on a robot are provided, which improve production efficiency and reduce the probability of human errors by automatically completing the control of materials and devices in multiple production processes.

[0074] In the embodiments of the present invention, a robot-executed online quality control method for monocrystalline silicon is provided, which can automatically control a current production process online.

[0075] It should be understood by those skilled in the art that the embodiments of the present invention may provide the method, system, or computer program product. Thus, the present invention may take the form of entirely hardware embodiments, entirely software embodiments, or a combination of hardware embodiments and software embodiments. Furthermore, the present invention may take the form of a computer program product embodied on one or more computer-usable storage media (including, but not limited to, magnetic disk storage, optical storage, etc.) including computer-usable program codes therein.

[0076] The present invention is described with reference to flowchart diagrams and/or block diagrams of the method, device (system), and computer program product according to the embodiments of the present invention. It will be understood that each process and/or block in the flowchart diagrams and/or block diagrams, and combinations of processes and/or blocks in the flowchart diagrams and/or block diagrams, can be implemented by the computer program instructions. These computer program instructions may be provided to a processor of a general-purpose computer, special-purpose computer, embedded processor, or other programmable data processing device to produce a machine, such that the instructions executed by the processor of the computer or other programmable data processing device produce a device for implementing the functions specified in one or more processes of the

flowchart diagram and/or one or more blocks of the block diagram.

[0077] These computer program instructions may also be stored in a computer-readable memory that causes a computer or other programmable data processing device to operate in a particular manner, such that the instructions stored in the computer-readable memory produce an article including an instruction device. The instruction device implements the functions specified in one or more processes of the flowchart diagram and/or one or more blocks of the block diagram.

[0078] These computer program instructions may also be loaded onto a computer or other programmable data processing device, causing a series of operating steps to be performed on the computer or other programmable device to produce computer-implemented processing, thereby the instructions executed on the computer or other programmable device provide the steps for implementing the functions specified in one or more processes of the flowchart diagram and/or one or more blocks of the block diagram.

[0079] Obviously, various amendments and variations can be made by those skilled in the art to the present invention, without departing from the spirit and scope of the present invention. By this way, if these amendments and variations of the present invention fall within the scope of the claims of the present invention and equivalent technologies, the present invention is also intended to include these amendments and variations.