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Kim et al.

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(54) **TEST DEVICE AND IMAGING DEVICE INCLUDING THE SAME**

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(51) **Int. Cl.**

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G10K 11/34	(2006.01)
G01N 29/06	(2006.01)
G01N 29/26	(2006.01)
G01S 17/89	(2006.01)
G01S 13/89	(2006.01)

(52) **U.S. Cl.**

CPC ***G01S 7/5205*** (2013.01); ***G01N 29/0654*** (2013.01); ***G01N 29/262*** (2013.01); ***G01S 7/52025*** (2013.01); ***G01S 7/52047*** (2013.01); ***G01S 7/52077*** (2013.01); ***G01S 15/8915*** (2013.01); ***G01S 15/8925*** (2013.01); ***G01S 15/8929*** (2013.01); ***G10K 11/346*** (2013.01); *G01N 2291/044* (2013.01); *G01S 13/89* (2013.01); *G01S 17/89* (2013.01)

(58) **Field of Classification Search**

CPC . G01S 7/5205; G01S 7/52047; G01S 7/52077

See application file for complete search history.

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(57) **ABSTRACT**

A test device includes a plurality of transceivers that respectively transmit a wave to a test target point of a test object, respectively receive a wave reflected, scattered, or refracted from the test object, and respectively output a signal generated in response to the received wave; a combiner that combines the plurality of received signals generated by the plurality of transceivers; and a plurality of switches that are opened or closed to transfer the plurality of received signals to the combiner or block the plurality of received signals from being transferred to the combiner.

13 Claims, 9 Drawing Sheets

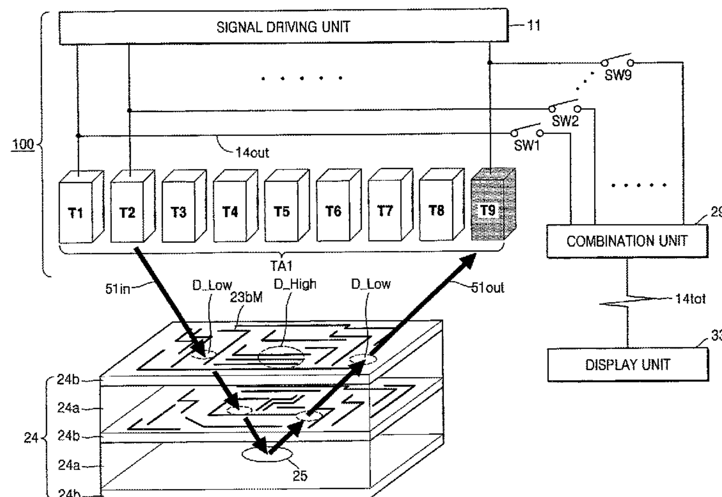

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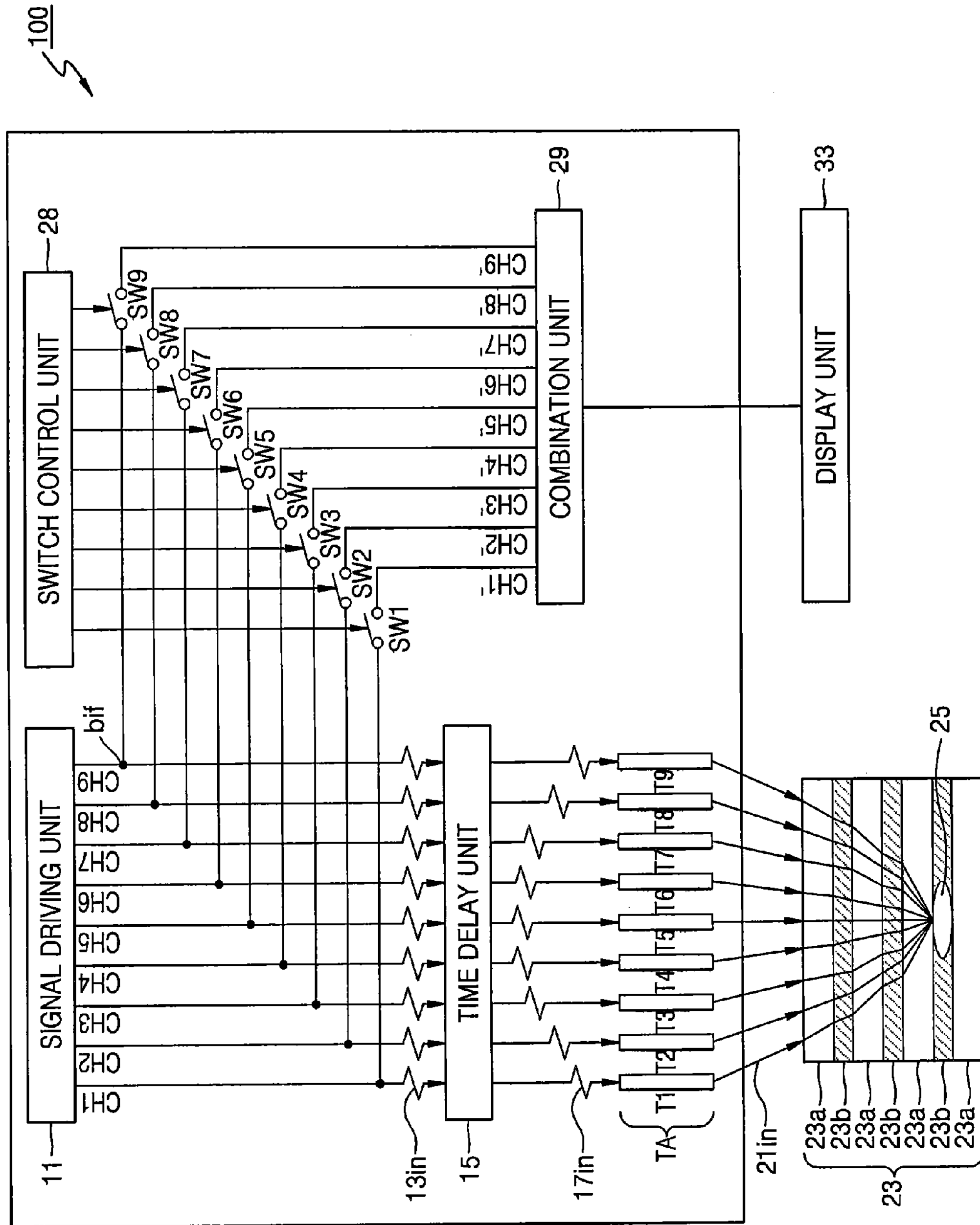
FIG. 1



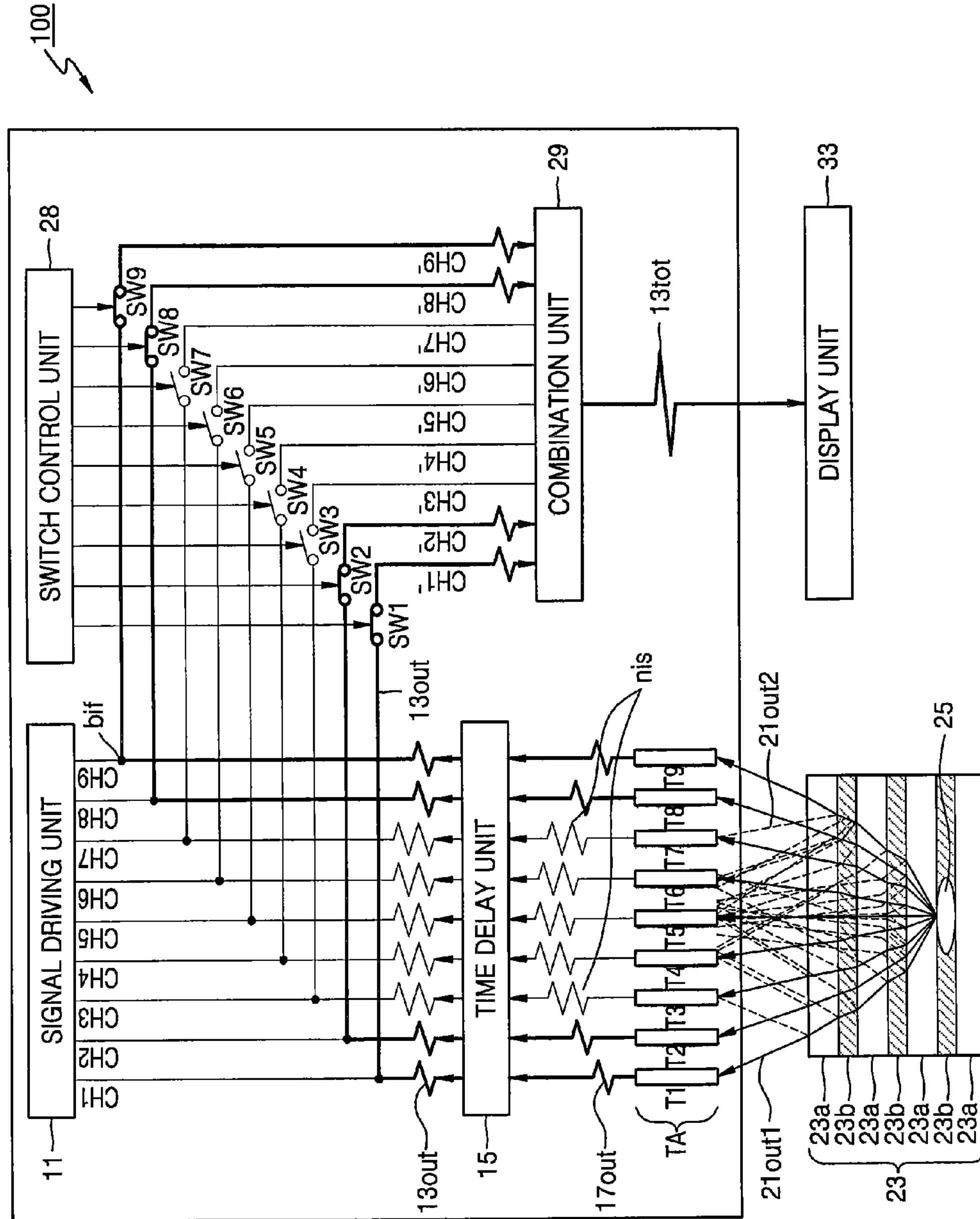


FIG. 2

FIG. 3

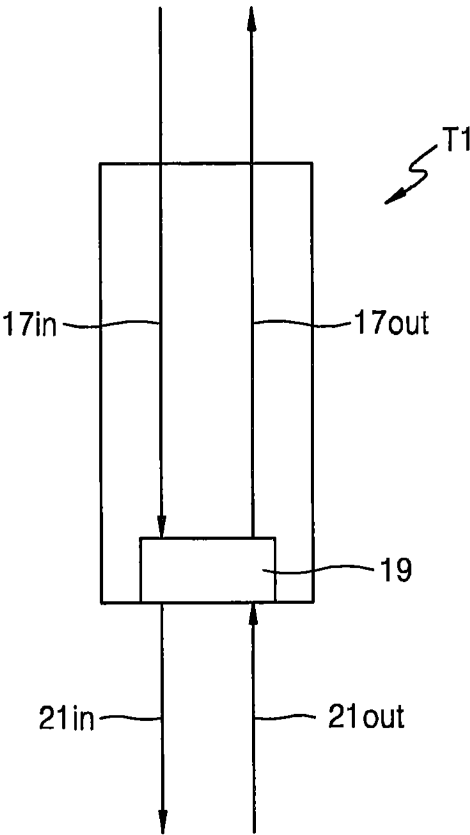


FIG. 4

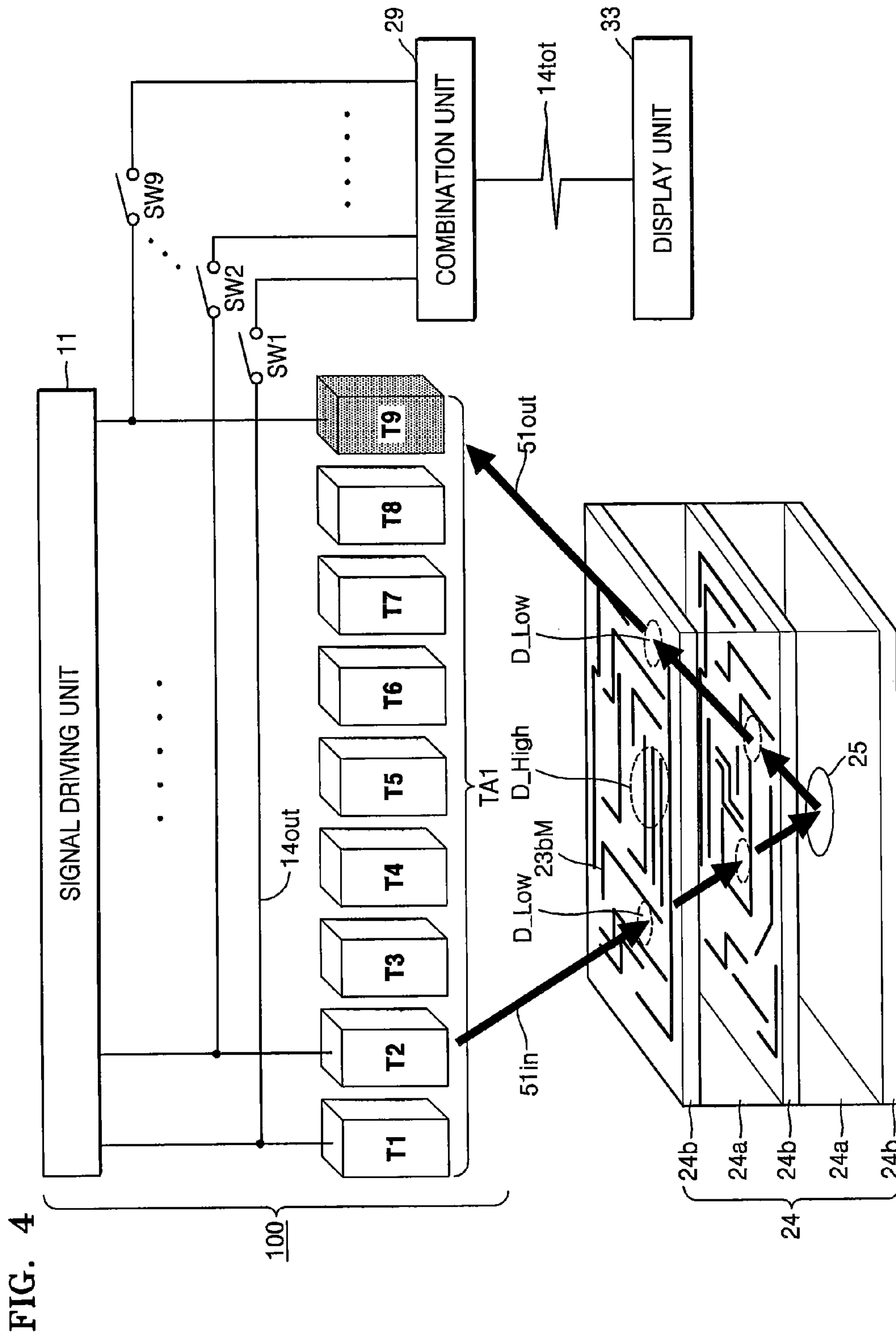
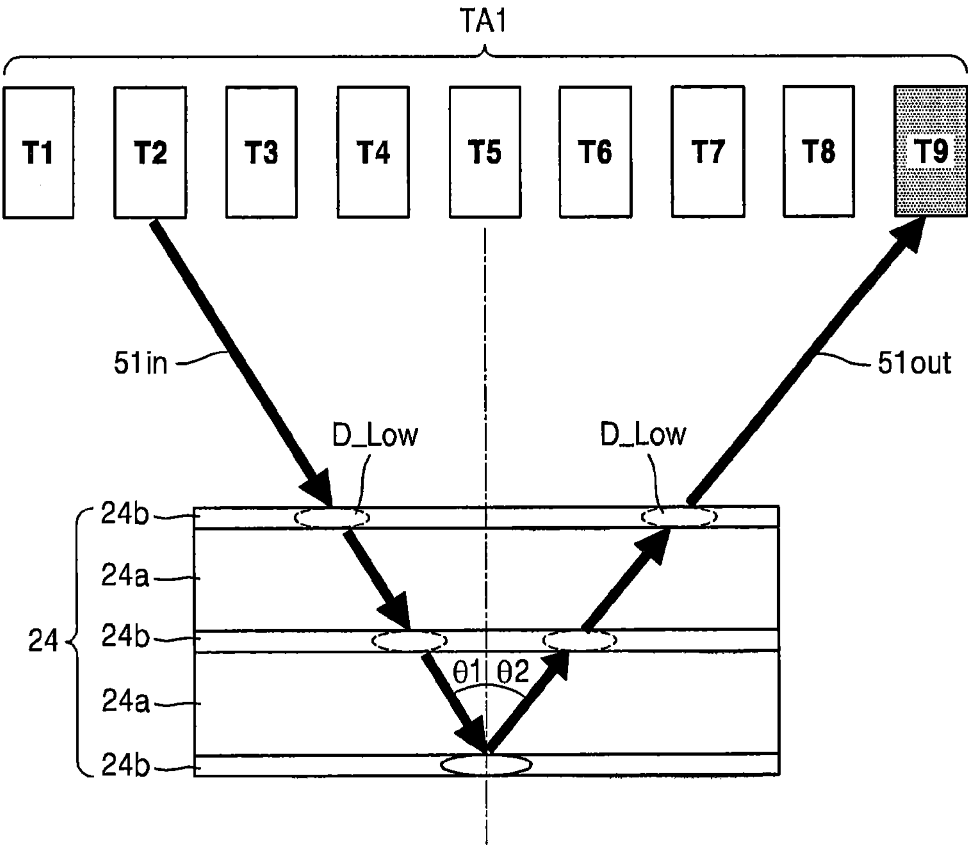


FIG. 5



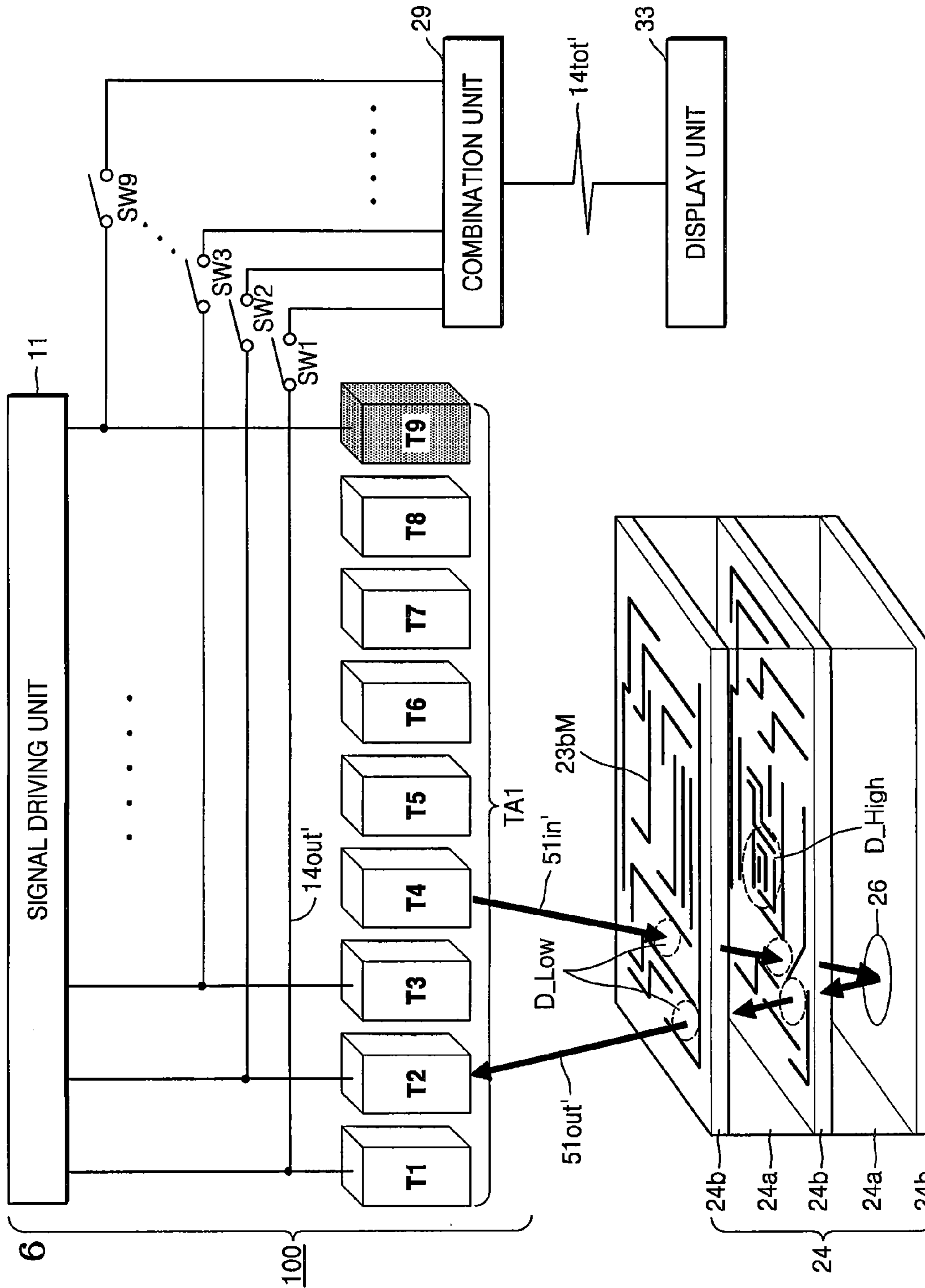


FIG. 6

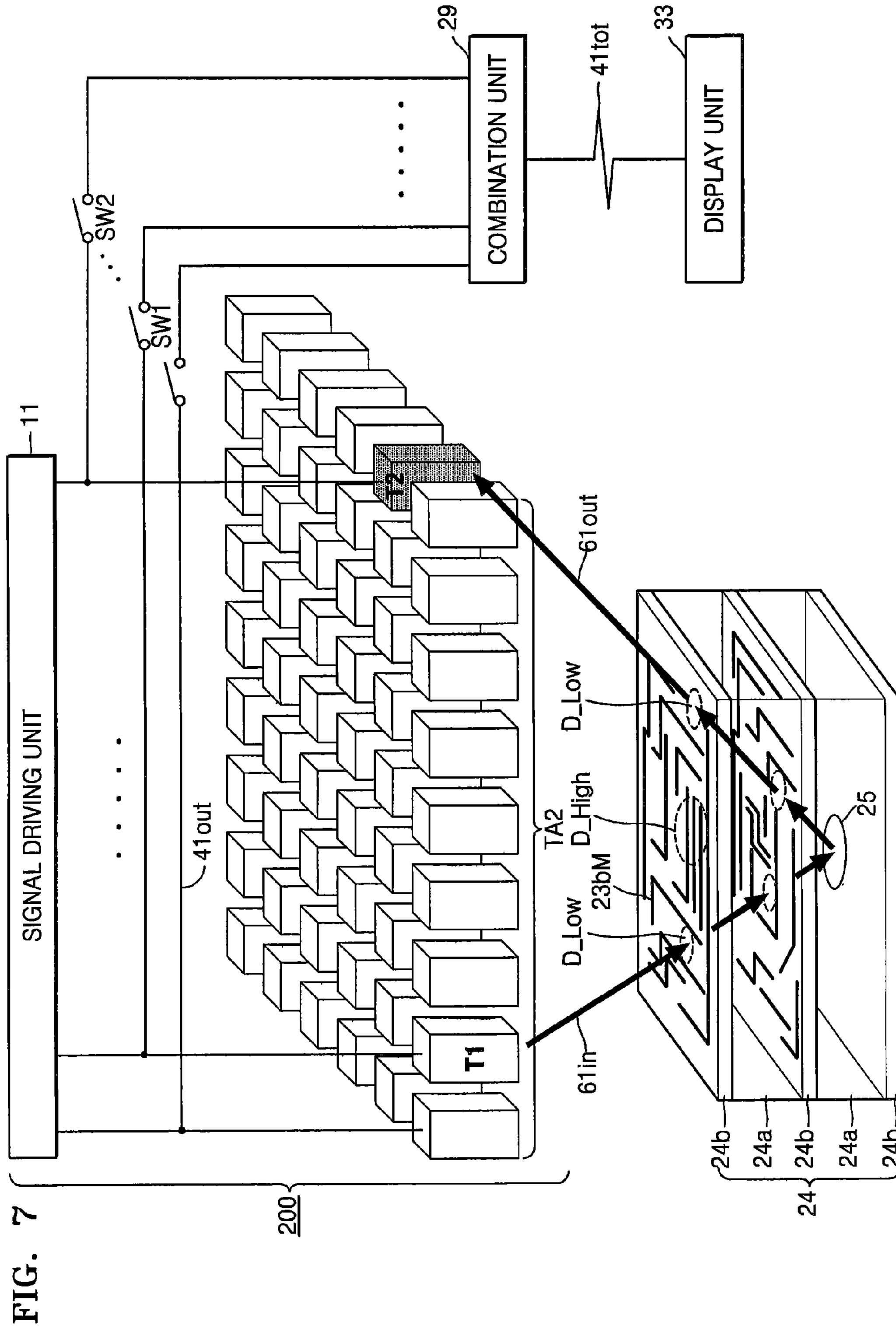


FIG. 7
200
11
SIGNAL DRIVING UNIT
41out
SW1
SW2
29
COMBINATION UNIT
41tot
33
DISPLAY UNIT
T1
T2
TA2
61in
61out
D_Low
D_High
23bM
25
24
24a
24b

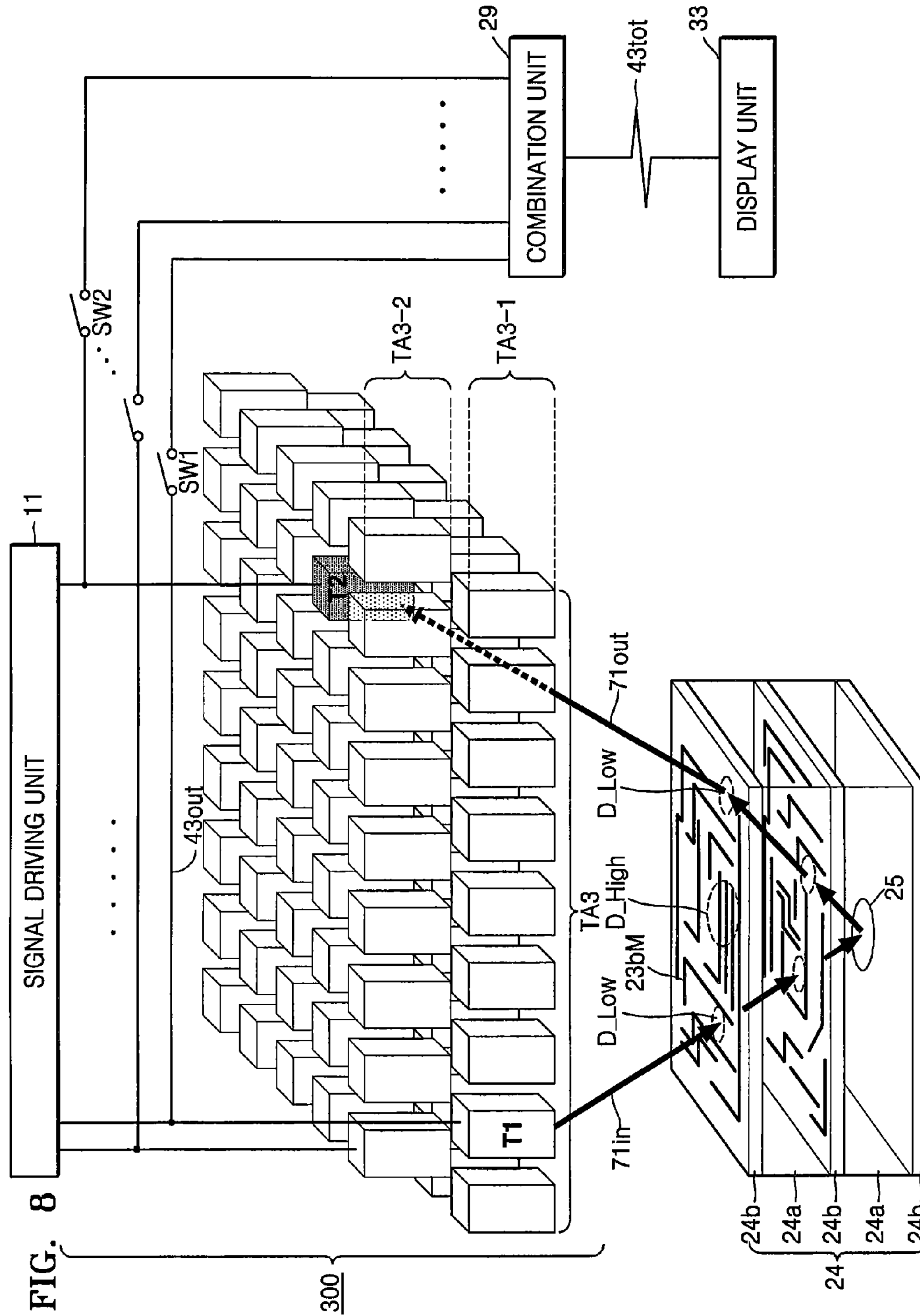


FIG. 8

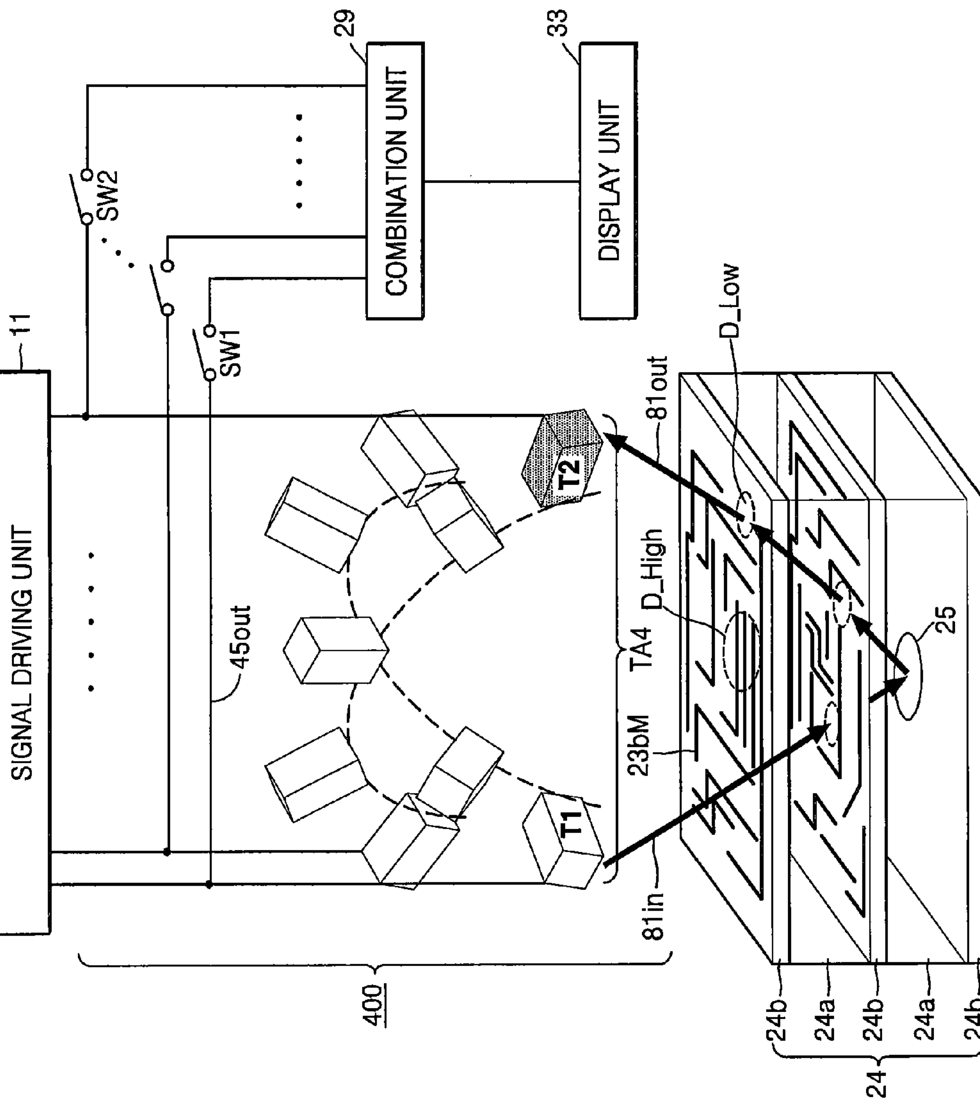


FIG. 9

TEST DEVICE AND IMAGING DEVICE INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to Korean Patent Application No. 10-2014-0146433, filed on Oct. 27, 2014, the disclosure of which is incorporated herein in its entirety by reference.

FIELD OF THE INVENTION

The inventive concept relates to a test device including a plurality of transceivers and an imaging device including the test device.

BACKGROUND

A test device may include a transceiver that transmits a wave to a test object and receives a wave reflected, scattered, or refracted from the test object. The transmitted wave and the received wave may be used for acquiring information on the test object.

Generally, the test device may detect information on a test target point while the test target point and a transceiver are in 1:1 correspondence. However, the test target point is inside the test object, noise may be generated by other components of the test object, and thus, the reception sensitivity may be low.

SUMMARY

The inventive concept provides a test device that exhibits high reception sensitivity with respect to test target points of a test object and an imaging device including the same.

According to an aspect of the inventive concept, there is provided a test device including: a plurality of transceivers configured to respectively transmit a wave to a test target point of a test object, to respectively receive a wave reflected, scattered, and/or refracted from the test object, and to respectively generate and output a signal in response to the received wave; a combiner configured to combine the signals generated by the plurality of transceivers; and a plurality of switches configured to selectively transfer the signals to the combiner and to selectively block the received signals from being transferred to the combiner.

In some embodiments, the waves transmitted by the plurality of transceivers may be focused on the test target point.

In some embodiments, the wave received by any one of the plurality of transceivers may include waves reflected, scattered, and/or reflected in response to the waves transmitted by the other transceivers.

In some embodiments, the test device may further include a switch control unit configured to control opening and closing of the plurality of switches to selectively transfer the signals to the combiner and to selectively block the received signals from being transferred to the combiner.

In some embodiments, the switch control unit may close the switch corresponding to at least one of the generated signals having a reduced level of noise from among the generated signals and open the switches corresponding to the other generated signals.

In some embodiments, the test object may include a semiconductor structure having an irregular wiring density, and the switch control unit may control the plurality of switches such that at least one of the generated signals corresponding to the reflected, scattered, or refracted wave passing through a region with a lowest wiring density is transferred to the combiner and the other generated signals are blocked.

In some embodiments, the plurality of switches may be further configured so that opening and closing thereof are reset according to a change of the test target point.

In some embodiments, an input angle of the wave transmitted from any one of the plurality of transceivers to the test target point may be different from a reflection angle of the wave received by the transceiver, which corresponds to the received signal transferred to the combiner.

In some embodiments, the plurality of transceivers may be arranged in a matrix form.

In some embodiments, the plurality of transceivers may be arranged in a multilayer structure.

In some embodiments, the plurality of transceivers may be arranged in a spherical shape.

In some embodiments, the wave may be a sound wave, and each of the transceivers may include a piezoelectric element that receives the reflected, scattered, or refracted wave from the test object and converts the received wave into an electric signal.

In some embodiments, the wave may be an electromagnetic wave, and each of the transceivers may include a photoelectric element that receives the reflected, scattered, or refracted wave from the test object and converts the received wave into an electric signal.

In some embodiments, the electromagnetic wave may be a terahertz wave, an X-ray, an infrared ray, or a micro wave.

In some embodiments, the test device may further include a display unit configured to display an image of the test object in response to the generated signals transferred to the combiner.

According to an aspect of the inventive concept, there is provided an ultrasonic imaging device including: a plurality of ultrasonic transceivers, each of the plurality of ultrasonic transceivers including a piezoelectric element that is configured to transmit an ultrasonic wave to a test object and is configured to receive an echo ultrasonic wave generated from the test object and generate and output a signal in response to the received echo ultrasonic wave; a combiner that combines the signals generated by the plurality of ultrasonic transceivers; and a plurality of switches between the plurality of ultrasonic transceivers and the combiner, the plurality of switches being configured to open or close to selectively transfer the generated signals to the combiner or to selectively block the generated signals from being transferred to the combiner, wherein the plurality of switches are further configured to close and selectively block at least one of the generated signals that contains a relatively high level of noise from among the generated signals and the opening and closing of the plurality of switches are reset according to a change in a position of the test object.

According to an aspect of the inventive concept, there is provided a test device including: a plurality of transceivers configured to respectively transmit a wave to a test target point of a test object, to respectively receive a wave reflected, scattered, and/or refracted from the test object, and to respectively generate and output a signal in response to the received wave; a controller configured to select ones of the signals generated by the plurality of transceivers having relatively low levels of noise; and a combination unit configured to receive the selected ones of the signals generated by the plurality of transceivers having relatively low levels of noise and to output a combined signal.

In some embodiments, the test device further comprises a plurality of switches configured to selectively transfer the signals to the combiner and to selectively block the received signals from being transferred to the combiner, and the controller comprises a switch control unit configured to control the plurality of switches to selectively transfer the selected ones of the signals generated by the plurality of transceivers having relatively low levels of noise.

In some embodiments, the waves transmitted by the plurality of transceivers are focused on the test target point.

In some embodiments, the plurality of switches are further configured so that opening and closing thereof are reset according to a change of the test target point.

In some embodiments, an input angle of the wave transmitted from any one of the plurality of transceivers to the test target point is different from a reflection angle of the wave received by the transceiver, which corresponds to the received signal transferred to the combiner.

According to an aspect of the inventive concept, there is provided a test device including: a first transceiver and a second transceiver configured to respectively transmit an input wave to a test object and respectively receive a reflected wave; a combiner that receives a first signal and a second signal respectively output by the first transceiver and the second transceiver in response to the received reflected waves; and a first switch between the first transceiver and the combiner, and a second switch between the second transceiver and the combiner.

In some embodiments, the reflected wave may include a first input wave transmitted from a transmitter of the first transceiver and a second input wave transmitted from a transmitter of the second transceiver.

In some embodiments, the first switch and the second switch may be configured such that either of the first switch and the second switch is opened so that one from the first signal and the second signal that contains more noise is blocked from being transmitted to the combiner.

In some embodiments, the input wave may be a sound wave or an electromagnetic wave.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the inventive concept will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. **1** is a diagram illustrating a signal transmission of a test device, according to an exemplary embodiment of the inventive concept;

FIG. **2** is a diagram illustrating a signal reception of the test device of FIG. **1**, according to an exemplary embodiment of the inventive concept;

FIG. **3** is a schematic diagram of a transceiver included in the test device of FIGS. **1** and **2**, according to an exemplary embodiment;

FIG. **4** is a diagram of an operation of a case where the test device of FIGS. **1** and **2** is used for testing another test target point;

FIG. **5** is a diagram illustrating an input angle and a reflection angle of a wave input to the test device of FIG. **4**;

FIG. **6** is a diagram of an operation when the test device of FIG. **4** is used for testing a changed test target point; and

FIGS. **7** to **9** are diagrams illustrating test devices, according to exemplary embodiments of the inventive concept.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Hereinafter, embodiments of the inventive concept will be described with reference to the accompanying drawings. The inventive concept may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the inventive concept to those of ordinary skill in the art. It should be understood, however, that there is no intent to limit the inventive concept to the particular forms disclosed, but on the contrary, the inventive concept is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the inventive concept. Like reference numerals denote like elements throughout the specification and drawings. In the drawings, the dimensions of structures are exaggerated or reduced for clarity of the inventive concept.

Also, though terms "first" and "second" are used to describe various members, components, regions, layers, and/or portions in various embodiments of the inventive concept, the members, components, regions, layers, and/or portions are not limited to these terms. These terms are used only to differentiate one member, component, region, layer, or portion from another one. Therefore, a member, a component, a region, a layer, or a portion referred to as a first member, a first component, a first region, a first layer, or a first portion in an embodiment may be referred to as a second member, a second component, a second region, a second layer, or a second portion in another embodiment.

Unless otherwise defined, all terms used herein, including technical and scientific terms, have the same meaning as commonly understood by one of ordinary skill in the art to which the inventive concept belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

When a certain embodiment may be implemented differently, a specific process order may be performed differently from the described order. For example, two consecutively described processes may be performed substantially at the same time or performed in an order opposite to the described order.

In the accompanying drawings, the modifications of the illustrated shapes may be expected according to manufacturing technologies and/or tolerance. Therefore, the exemplary embodiments should not be construed as being limited to specific shapes of the illustrated regions. The shapes may be changed during the manufacturing processes.

FIG. **1** is a diagram illustrating a signal transmission of a test device **100**, according to an exemplary embodiment of the inventive concept, and FIG. **2** is a diagram illustrating a signal reception of the test device **100** of FIG. **1**, according to an exemplary embodiment of the inventive concept.

Referring to FIGS. **1** and **2**, the test device **100** may include a signal driving unit **11** that generates pulse signals **13**in, a time delay unit **15** that adjusts timings of the pulse signals **13**in, a plurality of transceivers T**1** to T**9** that receive a timing-adjusted pulse signal **17**in, transceive waves **21**in, **21**out**1**, and **21**out**2** to/from a test object **23**, and output a plurality of received signals **17**out, a combination unit **29** that combines a plurality of timing-adjusted received signals **13**out, and a plurality of switches SW**1** to SW**9** that select some of the timing-adjusted received signals **13**out transferred from the combination unit **29**. The combination unit **29** may include at least one combiner.

The test device **100** may output a combined received signal **13**tot by combining the received signals selected by the switches SW**1** to SW**9**. The switches SW**1** to SW**9** may

be closed such that the received signals **13**out containing small noise signals nis among the received signals **13**out are transferred to the combination unit **29**, and the switches SW**1** to SW**9** may be opened such that the received signals **13**out containing many noise signals nis are not transferred to the combination unit **29**. Accordingly, since the received signals **13**out transferred to the combination unit **29** contain small noise signals nis, the test device **100** may acquire the high-quality combined received signal **13**tot.

The test device **100** may further include a switch control unit **28** that controls the opening and closing of the switches SW**1** to SW**9**. The switch control unit **28** may be set to open and close the switches SW**1** to SW**9** according to the magnitudes of the noise signals nis contained in the received signals **13**out.

The test device **100** is illustrated as including nine transceivers T**1** to T**9**, but the exemplary embodiment is not limited thereto. According to the exemplary embodiment, any suitable number of the transceivers T**1** to T**9** may be used, as long as the test device **100** includes a plurality of transceivers. Accordingly, the test device **100** may include two to eight transceivers or may include ten or more transceivers.

In addition, the nine transceivers T**1** to T**9** included in the test device **100** are illustrated as being arranged in a row, but the exemplary embodiment is not limited thereto. According to the exemplary embodiment, the plurality of transceivers included in the test device **100** may be arbitrarily arranged. The arrangement of the plurality of transceivers will be described below with reference to FIGS. **7** to **9**.

In some exemplary embodiments, the test device **100** may be included in an imaging device. That is, an image of the test object **23** may be implemented by transferring the combined received signal **13**tot from the combination unit **29** to a display unit **33**. As described above, since it is possible to acquire the high-quality combined received signal **13**tot by the selection of the switches SW**1** to SW**9**, the imaging device including the test device **100** may provide an accurate image of the test object **23**.

The signal transmission of the test device **100** will be described below in detail with reference to FIG. **1**. Since the test device **100** as illustrated includes the nine transceivers T**1** to T**9**, the signal driving unit **11**, the time delay unit **15**, the switch control unit **28**, and the combination unit **29** are connected to one another through nine channels CH**1** to CH**9**.

The signal driving unit **11** may generate the pulse signals **13**in and transfer the generated pulse signals **13**in to the time delay unit **15**. At this time, the nine pulse signals **13**in in generated through the nine channels CH**1** to CH**9** may be transferred to the time delay unit **15** through the nine channels CH**1** to CH**9**, respectively.

The nine pulse signals **13**in may be transferred to the time delay unit **15** at the same timing. The time delay unit **15** may adjust the timings of the nine pulse signals **13**in transferred at the same timing. According to the exemplary embodiment, the plurality of transceivers T**1** to T**9** may be used for testing one test target point **25** of the test object **23**. That is, the plurality of transceivers T**1** to T**9** may generate a plurality of input waves **21**in focused on one test target point **25**, and the plurality of transceivers T**1** to T**9** may be driven for detecting reflected waves **21**out**1** and **21**out**2**. Therefore, the timings of the nine pulse signals **13**in may be adjusted such that the nine waves **21**in generated by the nine pulse signals **17**in are focused on the test object **23**. That is, the nine waves **21**in may be focused on the test target point **25** by adjusting the transmission timings of the nine pulse signals **13**in.

Specifically, the timings of the nine pulse signals **17**in having undergone a time delay in the time delay unit **15** may be adjusted like waveforms appearing on the nine channels CH**1** to CH**9**. That is, the timings of the nine pulse signals **17**in may be adjusted such that the pulse signal **17**in passing through the fifth transceiver T**5** closest to the test target point **25** has a large time delay, and the pulse signals **17**in passing through the first and ninth transceivers T**1** and T**9** farthest from the test target point **25** have a small time delay. Similarly, the timings of the nine pulse signals **17**in may be adjusted such that the second to eighth transceivers T**2** to T**8** have time delays according to the distance from the test target point **25**.

The nine timing-adjusted pulse signals **17**in may be transferred to the nine transceivers T**1** to T**9**, respectively. Accordingly, the nine transceivers T**1** to T**9** may generate nine input waves **21**in, respectively.

The nine input waves **21**in may form a wave field in the test object **23** and be transmitted such that the waves are focused on the test target point **25**.

In FIG. **1**, the test object **23** may be a semiconductor device in which insulating layers **23***a* and metal wiring layers **23***b* are alternately stacked. Since the insulating layers **23***a* and the metal wiring layers **23***b* are stacked, the respective layers are provided with different materials. Thus, each of the nine input waves **21**in may be refracted in the respective layers.

Next, the signal reception of the test device **100** will be described below in detail with reference to FIG. **2**. Since the same reference numerals denote the same elements, a redundant description thereof will be omitted. The nine input waves **21**in of FIG. **1** are incident with focusing on the test target point **25** of the test object **23**, and the plurality of reflected waves **21**out**1** are generated. At this time, the reflected waves **21**out**1** may be scattered or refracted by other adjacent materials. Thus, as compared with the input waves **21**in of FIG. **1**, the amplitudes of the reflected waves **21**out**1** may be reduced or the phases thereof may be changed, resulting in an occurrence of noise. In particular, the test object **23** has the stack structure of the insulating layers **23***a* and the metal wiring layers **23***b*, which may disturb the reflected waves **21**out**2** from the surfaces of the insulating layers **23***a* and the metal wiring layers **23***b*. The disturbed reflected waves **21**out**2** may serve as main noise that may rapidly reduce the reception sensitivities of the reflected waves **21**out**1** generated from the test target point **25**.

The nine transceivers T**1** to T**9** receive the reflected waves **21**out**1**. At this time, the reflected wave **21**out**1** received by the first transceiver T**1** does not contain only the reflected wave generated by the input wave **21**in that is generated by the first transceiver T**1**. That is, the reflected wave **21**out**1** received by the first transceiver T**1** may contain the reflected waves **21**out**1** generated by the input waves **21**in that are generated by the second to ninth transceivers T**2** to T**9**. Similarly, the reflected wave **21**out**1** received by any one of the second to ninth transceivers T**2** to T**9** may contain the reflected waves generated by the input waves that are generated by the other transceivers.

The disturbed reflected waves **21**out**2** may be transmitted to some of the nine transceivers T**1** to T**9** more than others. In FIG. **2**, the disturbed reflected waves **21**out**2** are transmitted more to the third to seventh transceivers T**3** to T**7**.

The nine transceivers T1 to T9, which receive the reflected waves 21out1 and the disturbed reflected waves 21out2, may generate nine received signals 17out, respectively. The nine received signals 17out appear as waves on the nine channels CH1 to CH9. The received signals 17out, which pass through the third to seventh channels CH3 to CH7 connected to the third to seventh transceivers T3 to T7 receive relatively more disturbed reflected waves 21out2, which may contain relatively more noise signals nis.

The nine received signals 17out may be transferred to the time delay unit 15. As described above, since the distances between the test target point 25 and the nine transceivers T1 to T9 are different, the timings of the nine received signals 17out are different. The time delay unit 15 may adjust the timings of the nine received signals 17out. In this case, the time delay provided to the channels CH1 to CH9 by the time delay unit 15 may be reversely applied. The time delay unit 15 may perform adjustment such that the timings of the received signals 13out passing through the nine channels CH1 to CH9 become substantially equal to one another. However, even in these cases, the noise signals nis generated by the disturbed reflected waves 21out2 are not derived from the test target point 25, and the timing cannot be adjusted by the time delay unit 15. Therefore, the timings of the received signals 13out passing through the third to seventh channels CH3 to CH7 containing relatively more noise signals nis derived from the disturbed reflected waves 21out2 may be different from the timings of the received signals 13out passing through the first, second, eighth, and ninth channels CH1, CH2, CH8, and CH9, which contain relatively fewer noise signals nis.

The nine received signals 13out having undergone the time delay unit 15 may be transferred to the combination unit 29 through first to ninth channels CH1' to CH9' that transfer the nine received signals 13out. The first to ninth channels CH1' to CH9' may be branched from nodes bif of the nine channels CH1 to CH9 that connect the signal driving unit 11 and the time delay unit 15.

In order to select the received signals 13out to be transferred to the combination unit 29, first to ninth switches SW1 to SW9 may be provided at the first to ninth channels CH1' to CH9'. Since the received signals 13out passing through the third to seventh channels CH3' to CH7' contain relatively greater noise signals nis, the third to seventh switches SW3 to SW7 may be opened to block the received signals 13out containing the noise signals nis from being transferred to the combination unit 29. The first, second, eighth, and ninth switches SW1, SW2, SW8, and SW9 maintain the closed state, and the received signals 13out passing through the first, second, eighth, and ninth channels CH1', CH2', CH8', and CH9' are transferred to the combination unit 29. In this manner, the combined received signal 13tot may be generated. The combined received signal 13tot, to which a reduced amount or no noise signals are transferred, may more accurately reflect information on the test target point 25.

In order to control the opening and closing of the first to ninth switches SW1 to SW9, the test device 100 may further include a switch control unit 28 connected to the first to ninth switches SW1 to SW9. The switch control unit 28 may open the switches SW1 to SW9 when the magnitudes of the noise signals nis contained in the received signals 13out are out of a predetermined range. However, in order to control the opening and closing of the first to ninth switches SW1 to SW9, a tester may select the opening and closing of the first to ninth switches SW1 to SW9, without including the switch control unit 28.

As described above, in the test device 100, the plurality of transceivers T1 to T9 may be disposed near the test object 23, generate the plurality of input waves 21in focused on one test target point 25, and detect the reflected waves 21out1 and 21out2. Since the plurality of received signals 17out are obtained with respect to one test target point 25 through the plurality of transceivers T1 to T9, it is possible to select the received signals 17out that reflect a relatively more accurate test result.

In addition, among the received signals 13out obtained from the plurality of transceivers T1 to T9, the received signals 13out containing relatively higher levels of noise signals nis may be removed through the plurality of switches SW1 to SW9, and thus, only the received signals 13out reflecting a more accurate test result are extracted. Accordingly, it is possible to realize the test device 100 having high reception sensitivity.

Furthermore, since the test device 100 includes the plurality of transceivers T1 to T9, all points of the test object 23 may be within a predetermined distance suitable to transceive the input waves 21in and the reflected waves 21out1. Therefore, even when the test target point 25 is changed within the test object 23, all points of the test object 23 may be tested without moving the test device 100 on the test object 23. The test device 100 according to the exemplary embodiment may transceive signals having high reception sensitivity in a short time.

The test device 100 according to the exemplary embodiment may solve the limitation occurring when one transceiver is installed. That is, in a case where one transceiver is included in the test device, one test target point is tested by one transceiver. Thus, as described above, the noise signals generated by the multilayer structure are inevitably contained in the received signals, resulting in the reduction in the reception sensitivity. In addition, a long time may be taken to test all points of the test object because one transceiver needs to pass through all points of the test object.

Furthermore, the test device 100, in which the plurality of transceivers T1 to T9 are used for testing one test target point 25, may solve the limitation occurring in the test device that simply includes a plurality of transceivers. That is, the test device that simply includes the plurality of transceivers needs to be mechanically moved so as to test all points of the test object. However, in a case where only the plurality of transceivers are simply included, the plurality of transceivers are not used for testing one test target point, but are respectively used for testing all points therebelow. Since one transceiver is driven for one test target point, it is possible to reduce or avoid the problem that the noise signals are contained in the received signals.

In some exemplary embodiments, the test device 100 may be a test device that detects a defect of the test object 23. The defect of the test object 23 may be detected from different aspects of response to the waves as compared to adjacent materials. The defect may be a void or a crack.

In some embodiments, the test device 100 may be included in an imaging device. The combined received signal 13tot, which is obtained with respect to the test target point 25 by using the test device 100, may be transferred to the display unit 33 to implement a two-dimensional or three-dimensional image of the test target point 25. Since the imaging device using the test device 100 reduces the influence of the noise signals, it is possible to implement a high-quality test image.

FIG. 3 is a schematic diagram of the transceiver T1 according to an exemplary embodiment.

Referring to FIG. **3**, the transceiver T**1** included in the test device **100** of FIGS. **1** and **2** may include a conversion element **19** that converts the electrical pulse signal **17**in transferred from the time delay unit **15** into the input wave **21**in. The conversion element **19** may electrically convert the reflected wave **21**out into the received signal **17**out.

In some embodiments, a transmitter included in the transceiver T**1** may generate a sound wave. That is, the input wave **21**in and the reflected wave **21**out may be sound waves. For example, the sound wave may be an ultrasonic wave, a high-frequency wave, or a low-frequency wave. Accordingly, the conversion element **19** may be a piezoelectric element that converts an electric signal into a mechanical pressure, and vice versa.

In some embodiments, a transmitter included in the transceiver T1 may generate an electromagnetic wave. That is, the input wave **21**in and the reflected wave **21**out may be electromagnetic waves. For example, the input wave **21**in and the reflected wave **21**out may be a terahertz wave, an X-ray, an infrared ray, or a micro wave. Accordingly, the conversion element **19** may be a photoelectric element that converts an electromagnetic wave into an electric signal.

In some embodiments, the plurality of transceivers T**1** to T**9** included in the test device **100** may test the test object **23** by transceiving an ultrasonic wave. In this case, conversion elements **19** included in the plurality of transceivers T**1** to T**9** may be piezoelectric elements. Accordingly, the test device **100** may be included in an inspection apparatus using an ultrasonic wave. The inspection apparatus using the ultrasonic wave may be used for detecting a defect of a semiconductor device or a semiconductor package. With the increase in the integration degree of semiconductor devices, a design rule for elements of the semiconductor devices has been reduced or made smaller. Thus, a semiconductor device manufacturing process is becoming more difficult. Even when a fine void or crack occurs in the semiconductor device, the operation of the semiconductor device may be greatly degraded. Hence, it is necessary to test such a defect.

FIG. **4** is a diagram of an operation of a case where the test device **100** of FIGS. **1** and **2** is applied for another test object.

Referring to FIG. **4**, as described above with reference to FIGS. **1** to **2**, the test device **100** may include a signal driving unit **11** that generates pulse signals (not illustrated), a time delay unit (not illustrated) that adjusts timings of the pulse signals, a plurality of transceivers T**1** to T**9** that receive timing-adjusted pulse signals **17**in, transceive waves **51**in and **51**out to/from a test object **23**, and output a plurality of received signals **17**out, a combination unit **29** that combines a plurality of received signals **14**out, and a plurality of switches SW**1** to SW**9** that select some of the received signals **14**out transferred from the combination unit **29**. The plurality of transceivers T**1** to T**9** may be arranged in a row to form a transceiver array TA**1**.

The test object **24** may be a semiconductor structure in which insulating layers **24***a* and metal wiring layers **24***b* are alternately stacked. As compared to the metal wiring layers **24***b*, the insulating layers **24***a* do not greatly influence the transmission of the waves **51**in and **51**out. However, since a plurality of metal wirings **24***b*M included in the metal wiring layers **24***b* hardly transmit the waves **51**in and **51**out, the reception sensitivities of the transceivers T**1** to T**9** may be rapidly reduced. The plurality of metal wirings **24***b*M may be irregularly arranged within the metal wiring layers **24***b*, with insulating materials being disposed therebetween. Therefore, even the same metal wiring layer **23***b* may have a region D_High with a high wiring density and a region D_Low with a low wiring density.

The plurality of transceivers T**1** to T**9** may generate a plurality of input waves (not illustrated) focused on the test target point **25** of the test object **24**. However, the input wave **51**in, which is generated by the second transceiver T**2** and passes through the region D_Low with the low wiring density, may be the most valid input wave **51**in that forms a plurality of reflected waves (not illustrated) received by the plurality of transceivers T**1** to T**9**.

The plurality of reflected waves may be the same as the plurality of input waves. The plurality of transceivers T**1** to T**9** may receive reflected waves (not illustrated), respectively. However, the reflected wave **51**out, which passes through the region D_Low with the low wiring density and is received by the ninth transceiver T**9**, may be the most valid reflected wave **51**out having high reception sensitivity.

Except for the ninth switch SW**9** receiving the received signal **14**out transferred from the ninth transceiver T**9**, the first to eighth switches SW**1** to SW**8** connected to the first to eighth transceivers T**1** to T**8** may be opened. Therefore, it is possible to obtain the combined received signal **14**tot having an increased reception sensitivity or the highest reception sensitivity with respect to the test target point **25**.

For clarity and ease of representation, only the path of the input wave **51**in transmitted from the second transceiver T**2** and the path of the reflected wave **51** out received by the ninth transceiver T**9** are illustrated in FIG. **4**. However, in practice, there may exist any number of input waves and reflected waves that are transceived between the plurality of transceivers T**1** to T**9** and the test object **24**. In addition, only one reflected wave **51**out passing through the region D_Low with the low wiring density is illustrated, but there may exist two or more reflected waves.

In some exemplary embodiments, the plurality of switches SW**1** to SW**9** connected to the plurality of transceivers T**1** to T**9** may be selectively opened or closed in consideration of the wiring density of the metal wiring layer **24***b* existing on the reflected wave **51**out and the disturbed reflected wave formed at the interface between the insulating layer **24***a* and the metal wiring layer **24***b*.

FIG. **5** is a diagram illustrating an input angle and a reflection angle of a wave input on the test device **100** of FIG. **4**.

Specifically, FIG. **5** illustrates the path of the most valid input wave **51**in between the second transceiver T**2** and the test target point **25** and the path of the most valid reflected wave **51** out between the test target point **25** and the ninth transceiver T**9**. An input angle θ**1** formed between the input wave **51**in and the normal line of the test target point **25** may not be equal to a reflection angle θ**2** formed between the reflected wave **51**out and the normal line of the test target point **25**. As described above with reference to FIG. **4**, since the wiring densities within the metal wiring layers are asymmetrical, the input angle θ**1** of the most valid input wave **51**in may not be matched with the reflected angle θ**2** of the reflected wave **51**out having the highest reception sensitivity.

FIG. **6** is a diagram of an operation of a case where the test device **100** of FIG. **4** is used for testing a changed test target point. For convenience of description, in FIG. **6**, the test target point **25** of FIG. **4** is referred to as a first test target point **25**.

Specifically, FIG. **6** illustrates the path of the most valid input wave **51**in' when testing a second test target point **26** that is different from the first test target point **25** of FIG. **4** with respect to the same test object **24** and the path of the

reflected wave **51**out' having the highest reception sensitivity. Among a plurality of input waves (not illustrated), which are generated by the plurality of transceivers T**1** to T**9** and are input to the second test target point **26**, the path of the input wave **51**in' generated by the fourth transceiver T**4** may pass through the region with the low wiring density and thus the corresponding wave may become the most valid input wave **51**in'. Among a plurality of reflected waves (not illustrated), which are reflected from the second test target point **26** and are received by the plurality of transceivers T**1** to T**9**, the path of the reflected wave **51**out' received by the second transceiver T**2** may pass through the region with the low wiring density and thus the corresponding wave may become the reflected wave **51**out' having the highest reception sensitivity.

Except for the second switch SW**2** receiving the received signal **14**out' transferred from the second transceiver T**2**, the first switch SW**1** and the third to eighth switches SW**3** to SW**8** connected to the first transceiver T**1** and the third to eighth transceivers T**3** to T**8** may be opened. Therefore, it is possible to obtain the combined received signal **14**tot' having the highest reception sensitivity with respect to the second test target point **26**.

For clarity and ease of representation, only the path of the input wave **51**in' transmitted from the fourth transceiver T**4** and the path of the reflected wave **51**out' received by the second transceiver T**2** are illustrated in FIG. **6**. However, in practice, there may exist input waves and reflected waves that are transceived between the plurality of transceivers T**1** to T**9** and the test object **24**.

As described above, according to the exemplary embodiment, the test device **100** including the plurality of transceivers T**1** to T**9** may efficiently test all points of the test object **24**, without being moved.

FIGS. **7** to **9** are diagrams illustrating test devices **200**, **300**, and **400**, respectively, according to exemplary embodiments of the inventive concept. The test devices **200**, **300**, and **400** differ from the test device **100** described above with reference to FIGS. **1** to **6** in terms of the number of transceivers included therein. Reference symbols T**1** to T**9** used in FIGS. **7** to **10** are only used to distinguish a plurality of transceivers from one another, and do not refer to the same members.

Referring to FIG. **7**, a plurality of transceivers included in the test device **200** may be arranged in a matrix form. For example, the test device **200** may have a transceiver array TA**2** of a 9×6 matrix form. Since the plurality of transceivers are densely arranged, a plurality of input waves (not illustrated) and a plurality of reflected waves (not illustrated) passing through a region D_Low with a low wiring density may be increased. As a result, the reception sensitivities of the received signals may be increased.

In FIG. **7**, an input wave **61**in, which is generated by the first transceiver T**1** of the first row in the transceiver array TA**2**, may be most valid, and a reflected wave **61**out, which is received by the second transceiver T**2** of the second row in the transceiver array TA**2**, may have the highest reception sensitivity. In the transceiver array TA**1** of FIG. **4** in which the nine transceivers T**1** to T**9** are arranged in a row, it is analyzed that the reflected wave, which is received by the ninth transceiver T**9** disposed at the end of the same row with respect to the same test target point **25** as that of FIG. **7**, has the highest reception sensitivity. However, in the transceiver array TA**2** included in the test device **200** of FIG. **7**, the plurality of transceivers are arranged two-dimensionally more densely, and the combined received signal **41**tot having higher reception sensitivity may be obtained at the second transceiver T**2** disposed at the end of the second row.

Switches, which are connected to the transceivers other than the second transceiver T**2** in the transceiver array TA**2**, may be opened. Therefore, it is possible to obtain the combined received signal **41**tot having the highest reception sensitivity with respect to the test target point **25**.

Referring to FIG. **8**, a plurality of transceivers included in the test device **300** may be arranged to have a stack structure of matrix forms. For example, the test device **300** may include a double-layer transceiver array TA**3** in which a first transceiver array TA**3-1** of a 9×6 matrix form is disposed on the ground floor and a second transceiver array TA**3-2** of an 8×5 matrix form is disposed on the second floor. At this time, in order to secure the path of the reflected wave transferred from the test target point **25**, the first transceiver array TA**3-1** and the second transceiver array TA**3-2** may be offset from one another. Since the plurality of transceivers are densely arranged, a plurality of input waves (not illustrated) and a plurality of reflected waves (not illustrated) passing through a region D_Low with a low wiring density may be increased. As a result, the reception sensitivities of the received signals may be increased.

In FIG. **8**, the most valid input wave **71**in may be generated from the first transceiver T**1** disposed at the second position of the first row of the first transceiver array TA**3-1** disposed on the ground floor in the double-layer transceiver array TA**3**. A reflected wave **71** out, which is received by the second transceiver T**2** disposed at the seventh position of the second row of the second transceiver array TA**3-2** disposed on the second floor in the double-layer transceiver array TA**3**, may have the highest reception sensitivity.

Switches, which are connected to the transceivers other than the second transceiver T**2** in the transceiver array TA**2**, may be opened. Therefore, it is possible to obtain the combined received signal **43**tot having the highest reception sensitivity with respect to the test target point **25**.

Referring to FIG. **9**, a plurality of transceivers included in a test device **400** may be arranged in a spherical shape. For example, the test device **400** may have a transceiver array TA**4** including a transceiver disposed at a first level highest from a test object **24**, four transceivers disposed around at a second level lower than the first level, and four transceivers disposed at a third level lower than the second level. Since the plurality of transceivers are arranged at various positions and various angles, a plurality of input waves (not illustrated) and a plurality of reflected waves (not illustrated) passing through a region D_Low with a low wiring density may be increased. As a result, the reception sensitivities of the received signals may be increased.

In FIG. **9**, the most valid input wave **81**in may be generated from the first transceiver T**1** disposed at the third level in the transceiver array TA**4**. A reflected wave **81**out, which is received by the second transceiver T**2** disposed at the third level in the transceiver array TA**4**, may have the highest reception sensitivity. Switches, which are connected to the transceivers other than the second transceiver T**2** in the transceiver array TA**4**, may be opened. Therefore, it is possible to obtain the combined received signal **45**tot having the highest reception sensitivity with respect to the test target point **25**.

While the inventive concept has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood that various changes in form and details may be made therein without departing from the spirit and scope of the following claims.

What is claimed is:

1. A test device comprising:

a plurality of transceivers configured to respectively transmit a wave to a test target point of a test object, to respectively receive a wave reflected, scattered, and/or refracted from the test object, and to respectively generate and output a signal in response to the received wave;

a combiner configured to combine the signals generated by the plurality of transceivers;

a plurality of switches configured to selectively transfer some of the signals to the combiner and to selectively block the others of the signals from being transferred to the combiner;

a switch control unit configured to control closing and opening of the plurality of switches to selectively transfer some of the signals to the combiner and to selectively block the others of the signals from being transferred to the combiner; and

wherein the test object comprises a semiconductor structure having an irregular wiring density comprising a first region having a first wiring density and a second region having a second wiring density, wherein the first wiring density is lower than the second wiring density,

wherein the switch control unit controls the plurality of switches such that at least one of the signals corresponding to the reflected, scattered, and/or refracted wave passing through the first wiring density is transferred to the combiner and others of the signals are blocked.

2. The test device of claim **1**, wherein the waves transmitted by the plurality of transceivers are focused on the test target point.

3. The test device of claim **1**, wherein the wave received by any one of the plurality of transceivers includes waves reflected, scattered, and/or reflected in response to the waves transmitted by the other transceivers.

4. The test device of claim **1**, wherein the switch control unit closes the switch corresponding to at least one of the signals having a reduced level of noise from among the generated signals and opens the switches corresponding to the other generated signals.

5. The test device of claim **1**, wherein the plurality of switches are further configured so that opening and closing thereof are reset according to a change of the test target point.

6. The test device of claim **1**, wherein an input angle of the wave transmitted from any one of the plurality of transceivers to the test target point is different from a reflection angle of the wave received by the transceiver in a predefined plane, which corresponds to the received signal transferred to the combiner.

7. The test device of claim **1**, wherein the plurality of transceivers are arranged in a matrix form.

8. The test device of claim **1**, wherein the plurality of transceivers are arranged in a multilayer structure.

9. The test device of claim **1**, wherein the plurality of transceivers are arranged in a spherical shape.

10. The test device of claim **1**, wherein the wave is a sound wave, and each of the transceivers comprises a piezoelectric element that receives the reflected, scattered, or refracted wave from the test object and converts the received wave into an electric signal.

11. The test device of claim **1**, wherein the wave is an electromagnetic wave, and each of the transceivers comprises a photoelectric element that receives the reflected, scattered, or refracted wave from the test object and converts the received wave into an electric signal.

12. The test device of claim **1**, further comprising a display unit configured to display an image of the test object in response to the generated signals transferred to the combiner.

13. An ultrasonic imaging device comprising:

a plurality of ultrasonic transceivers, each of the plurality of ultrasonic transceivers including a piezoelectric element that is configured to transmit an ultrasonic wave to a test object and is configured to receive an echo ultrasonic wave generated from the test object and generate and output a signal in response to the received echo ultrasonic wave;

a combiner that combines the signals generated by the plurality of ultrasonic transceivers; and

a plurality of switches between the plurality of ultrasonic transceivers and the combiner, the plurality of switches being configured to open or close to selectively transfer the generated signals to the combiner or to selectively block the generated signals from being transferred to the combiner,

wherein the plurality of switches are further configured to close and selectively block at least one of the signals that contains a relatively high level of noise from among the generated signals and the opening and closing of the plurality of switches are reset according to a change in a position of the test object; and

a switch control unit configured to control closing and opening of the plurality of switches to selectively transfer some of the signals to the combiner and to selectively block others of the signals from being transferred to the combiner;

wherein the test object comprises a semiconductor structure having an irregular wiring density comprising a first region having a first wiring density and a second region having a second wiring density, wherein the first wiring density is lower than the second wiring density, and

wherein the switch control unit controls the plurality of switches such that at least one of the signals corresponding to reflected, scattered, or refracted wave passing through the first wiring density is transferred to the combiner and others of the generated signals are blocked.

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