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## ULTRASONIC TRANSDUCER, FINGERPRINT RECOGNITION MODULE, AND ELECTRONIC DEVICE

### Abstract

An ultrasonic transducer, a fingerprint recognition module, and an electronic device are provided, and belong to the field of ultrasonic detection technologies. The ultrasonic transducer includes a first electrode layer (**01**), a piezoelectric material layer (**02**), and a second electrode layer (**03**) that are sequentially stacked. The first electrode layer (**01**) includes a plurality of spaced first electrode blocks (**011**), the second electrode layer (**03**) includes a plurality of spaced second electrode blocks (**031**), and orthographic projection of each first electrode block (**011**) on the second electrode layer (**03**) overlaps at least one second electrode block (**031**). The first electrode layer (**01**) is disposed in a discretized manner, and a thickness of each first electrode block (**011**) is greater than a thickness threshold, so that a plurality of waveguide structures that can limit propagation paths of ultrasonic waves can be formed at the first electrode layer (**01**).

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## Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of International Application No. PCT/CN2023/104548, filed on Jun. 30, 2023, which claims priority to Chinese Patent Application No. 202211348458.7, filed on Oct. 31, 2022. The disclosures of the aforementioned applications are hereby incorporated by reference in their entireties.

TECHNICAL FIELD
[0002] This application relates to the field of ultrasonic detection technologies, and in particular, to an ultrasonic transducer, a fingerprint recognition module, and an electronic device.
BACKGROUND
[0003] An ultrasonic transducer is a device that can implement mutual conversion between acoustic energy and electric energy based on piezoelectric effect. The ultrasonic transducer is usually used in fields such as fingerprint recognition, ultrasonic imaging, and flaw detection of an industrial device.
[0004] An operating principle of the ultrasonic transducer is as follows: The ultrasonic transducer emits an ultrasonic wave. After the ultrasonic wave is transmitted to a detected object, the detected object reflects the ultrasonic wave to the ultrasonic transducer. Because acoustic impedance in different positions of the detected object is different, signal strength of ultrasonic waves reflected from different positions is different, and the ultrasonic transducer can convert the ultrasonic waves of different strength into electrical signals of different strength. A signal processing circuit (for example, a fingerprint recognition circuit) may further detect the detected object based on the electrical signals of different strength.
[0005] However, there is crosstalk between the ultrasonic waves reflected from different positions of the detected object, affecting detection accuracy of the ultrasonic transducer.
SUMMARY
[0006] This application provides an ultrasonic transducer, a fingerprint recognition module, and an electronic device to resolve a technical problem where crosstalk between reflected ultrasonic waves affects detection accuracy of the ultrasonic transducer.
[0007] According to a first aspect, an ultrasonic transducer is provided. The ultrasonic transducer includes a first electrode layer, a piezoelectric material layer, and a second electrode layer that are sequentially stacked. The first electrode layer includes a plurality of spaced first electrode blocks, and the second electrode layer includes a plurality of spaced second electrode blocks. Orthographic projection of each first electrode block on the second electrode layer overlaps at least one second electrode block, a thickness of each first electrode block is greater than a thickness threshold, and the thickness threshold is positively correlated with a wavelength of an ultrasonic wave emitted by the piezoelectric material layer. For example, the thickness threshold may be equal to ⅛ of the wavelength of the ultrasonic wave emitted by the piezoelectric material layer.
[0008] It may be understood that the plurality of electrode blocks at the same electrode layer being spaced indicates there is a gap between any two electrode blocks at the same electrode layer.

[0009] It may be further understood that the plurality of first electrode blocks at the first electrode layer may be configured to drive the piezoelectric material layer to emit the ultrasonic wave, and the plurality of second electrode blocks at the second electrode layer may be configured to detect an electrical signal generated by the piezoelectric material layer based on a reflected ultrasonic wave. In addition, when the plurality of first electrode blocks drive the piezoelectric material layer to emit the ultrasonic wave, the plurality of second electrode blocks are all grounded; and when the plurality of second electrode blocks receive the electrical signal, the plurality of first electrode blocks are all grounded. Alternatively, one electrode layer (for example, the second electrode layer) of the first electrode layer and the second electrode layer is configured to: drive the piezoelectric material layer to emit the ultrasonic wave, and detect the electrical signals. The other electrode layer (for example, the first electrode layer) is configured to be grounded.
[0010] According to the solution provided in this application, the first electrode layer is disposed in a discretized manner and the thickness of each first electrode block is greater than the thickness threshold, so that a plurality of waveguide structures that can limit propagation paths of ultrasonic waves can be formed at the first electrode layer. Therefore, crosstalk between ultrasonic waves reflected from different positions of a detected object can be effectively reduced, thereby ensuring high detection accuracy of the ultrasonic transducer.
[0011] Optionally, the orthographic projection of each first electrode block on the second electrode layer may overlap one second electrode block. Therefore, it can be ensured that an electrical signal detected by each second electrode block is generated based on a reflected ultrasonic wave transmitted by one first electrode block, thereby effectively reducing the crosstalk between the reflected ultrasonic waves transmitted at the first electrode layer and ensuring a high signal-to-noise ratio of the electrical signal detected by the second electrode block.
[0012] Optionally, the first electrode layer further includes a plurality of first connection structures, and each first connection structure is configured to connect at least two first electrode blocks arranged in a first direction.
[0013] The at least two first electrode blocks arranged in the first direction are connected by using the plurality of first connection structures so that a quantity of leading wires that need to be disposed between the first electrode layer and a drive circuit can be effectively reduced, and wiring complexity can be reduced.
[0014] Optionally, the first electrode layer may further include a plurality of second connection structures, and each second connection structure is configured to connect at least two first electrode blocks arranged in a second direction, where the second direction intersects the first direction.
[0015] The plurality of second connection structures are disposed so that the plurality of first electrode blocks can all be interconnected in a staggered manner in both the first direction and the second direction. Therefore, the quantity of leading wires that need to be disposed can be further reduced, and the wiring complexity can be further reduced.
[0016] Optionally, each first connection structure is located between two adjacent first electrode blocks; or each first connection structure is located on a side that is of at least two first electrode blocks and that is close to or away from the piezoelectric material layer. In addition, to effectively reduce crosstalk signals propagated in the connection structure, a width of each first connection structure may be less than a width of the first electrode block, and may be as small as possible within a range allowed by a process and may be, for example, a minimum width limit of the process.
[0017] Optionally, each first electrode block may be a bar-shaped electrode, and orthographic projection of the bar-shaped electrode on the second electrode layer overlaps at least two second electrode blocks.
[0018] The bar-shaped first electrode block can effectively isolate some crosstalk signals. In addition, because a manufacturing process of the bar-shaped electrode is simple, complexity and manufacturing costs of the manufacturing process of the ultrasonic transducer can be effectively

reduced.

[0019] Optionally, the thickness of each first electrode block may be n/4 times the wavelength of the ultrasonic wave emitted by the piezoelectric material layer, and n is a positive integer. For example, the thickness of the first electrode block may be about 50 micrometers (m). In the solution provided in this application, permitted by a process condition and an overall thickness, the thickness of the first electrode block may be increased. Therefore, convergence effect of the first electrode block on the ultrasonic wave can be effectively increased and the crosstalk between the ultrasonic waves can be effectively reduced.

[0020] Optionally, the ultrasonic transducer may further include a lens layer located on a side of the first electrode layer that is away from the piezoelectric material layer. The lens layer includes a plurality of spaced lenses, and orthographic projection of each lens on the second electrode layer overlaps at least one second electrode block.

[0021] Each lens may be configured to focus on the ultrasonic wave emitted by the piezoelectric material layer and the ultrasonic wave reflected by the detected object, thereby effectively reducing the crosstalk between the ultrasonic waves.

[0022] Optionally, the orthographic projection of each lens on the second electrode layer overlaps one second electrode block, and orthographic projection of each lens on the first electrode layer overlaps one first electrode block. Therefore, a plurality of waveguide structures that are in one-to-one correspondence with the plurality of second electrodes can be formed at the first electrode layer and the lens layer, so that the crosstalk between the ultrasonic waves can be effectively reduced.

[0023] Optionally, if a refractive index of the lens is less than a refractive index of an adjacent layer of the lens, all the plurality of lenses are convex lenses; or if a refractive index of the lens is greater than a refractive index of an adjacent layer of the lens, all the plurality of lenses are concave lenses. In addition, a surface that is of each lens and that is close to the first electrode layer may be a plane, or may be a curved surface.

[0024] Optionally, the piezoelectric material layer may include a plurality of spaced piezoelectric blocks; and orthographic projection of each piezoelectric block on the second electrode layer overlaps at least one second electrode block.

[0025] The piezoelectric material layer is disposed in a discretized manner, so that the crosstalk of the reflected ultrasonic waves at the piezoelectric material layer can be effectively reduced, thereby effectively improving the signal-to-noise ratio of the electrical signal detected by the second electrode layer.

[0026] Optionally, the orthographic projection of each piezoelectric block on the second electrode layer overlaps one second electrode block, and orthographic projection of each piezoelectric block on the first electrode layer overlaps one first electrode block. Based on this, the plurality of waveguide structures that are in one-to-one correspondence with the plurality of second electrodes can be formed at the first electrode layer and the piezoelectric material layer, so that the crosstalk between the ultrasonic waves can be effectively reduced.

[0027] Optionally, the ultrasonic transducer may further include a waveguide layer, and the waveguide layer is located on a side of the first electrode layer or the second electrode layer that is away from the piezoelectric material layer; and the waveguide layer includes a plurality of spaced waveguide blocks, and an orthographic projection of each waveguide block on the first electrode layer overlaps at least one first electrode block.

[0028] A material of the waveguide layer is different from a material of an electrode layer (for example, the first electrode layer or the second electrode layer) adjacent to the waveguide layer. In addition, acoustic impedance of the material of the waveguide layer may be approximate to acoustic impedance of the material of the adjacent electrode layer (for example, an acoustic impedance difference between the two is less than a first threshold), and the material of the waveguide layer has low costs and is easy to process. Therefore, the manufacturing costs and the

complexity of the manufacturing process of the ultrasonic transducer can be effectively reduced while a thickness of the waveguide structure is ensured.
[0029] Optionally, if the ultrasonic transducer further includes the lens layer, the waveguide layer may be located between the first electrode layer and the lens layer, and a material of the waveguide layer is the same as a material of the lens layer. The material of the lens layer may include a polymer material like resin.
[0030] Optionally, a gap between the plurality of first electrode blocks and a gap between the plurality of second electrode blocks may be vacuum or air. Alternatively, the ultrasonic transducer may further include a filling material filled between the plurality of first electrode blocks and filled between the plurality of second electrode blocks. To ensure a large sound wave reflectivity, a difference between acoustic impedance of the filling material and the acoustic impedance of the material of the waveguide structure (mainly the first electrode block) needs to be as large as possible. For example, a difference between the two is greater than a second threshold.
[0031] Optionally, the plurality of second electrode blocks include a plurality of electrode groups arranged in the first direction, and each electrode group includes at least two second electrode blocks arranged in the second direction, where every two adjacent electrode groups are arranged in a staggered manner.
[0032] The second electrode blocks are arranged in the staggered manner, so that a density of the second electrode blocks in the ultrasonic transducer can be effectively increased, thereby effectively improving detection precision of the ultrasonic transducer.
[0033] According to a second aspect, an ultrasonic transducer is provided. The ultrasonic transducer includes a first electrode layer, a piezoelectric material layer, a second electrode layer, a waveguide layer, and a lens layer. The first electrode layer is of an entire-layer structure, and the second electrode layer includes a plurality of spaced second electrode blocks; the waveguide layer includes a plurality of spaced waveguide blocks, and orthographic projection of each waveguide block on the second electrode layer overlaps at least one second electrode block; and the lens layer includes a plurality of spaced lenses, and orthographic projection of each lens on the second electrode layer overlaps at least one second electrode block.
[0034] The first electrode layer, the piezoelectric material layer, and the second electrode layer are sequentially stacked, and the waveguide layer and the lens layer are sequentially stacked on a side that is of the first electrode layer or the second electrode layer and that is away from the piezoelectric material layer. The lens layer and the waveguide layer that are disposed in a discretized manner are used, so that ultrasonic waves reflected from different positions of a detected object can be transmitted to the piezoelectric material layer via different lenses and waveguide blocks. Therefore, crosstalk between the ultrasonic waves reflected from different positions of the detected object can be effectively reduced, thereby ensuring high detection accuracy of the ultrasonic transducer.
[0035] It may be understood that the first electrode layer may be configured to drive the piezoelectric material layer to emit an ultrasonic wave, and the plurality of second electrode blocks at the second electrode layer are configured to detect an electrical signal generated by the piezoelectric material layer based on a reflected ultrasonic wave. Alternatively, the second electrode layer is configured to: drive the piezoelectric material layer to emit the ultrasonic wave, and detect the electrical signal. The first electrode layer is configured to be grounded.
[0036] Optionally, a thickness of each waveguide block at the waveguide layer may be greater than a thickness threshold, and the thickness threshold is positively correlated with a wavelength of the ultrasonic wave. For example, the thickness threshold may be equal to ⅛ of the wavelength of the ultrasonic wave. For example, the thickness of each waveguide block may be n/4 times the wavelength of the ultrasonic wave, and n is a positive integer. Therefore, convergence effect of the waveguide layer on the ultrasonic wave can be effectively improved, and the crosstalk between the ultrasonic waves can be further reduced.

[0037] Optionally, the orthographic projection of each waveguide block on the second electrode layer overlaps one second electrode block, and overlaps orthographic projection of one lens on the second electrode layer.
[0038] Optionally, the waveguide layer is located between the first electrode layer and the lens layer, and a material of the waveguide layer is the same as a material of the lens layer.
[0039] According to a third aspect, a fingerprint recognition module is provided. The fingerprint recognition module includes a fingerprint recognition circuit and the ultrasonic transducer according to any one of the foregoing aspects. The fingerprint recognition circuit is configured to provide a drive signal for the ultrasonic transducer to drive the ultrasonic transducer to emit an ultrasonic wave; and receive an electrical signal generated by the ultrasonic transducer based on a received reflected ultrasonic wave and perform fingerprint recognition based on the electrical signal.
[0040] According to a fourth aspect, an electronic device is provided. The electronic device includes a display and the fingerprint recognition module, located on a side of the display, according to the foregoing aspects.
[0041] This application provides an ultrasonic transducer, a fingerprint recognition module, and an electronic device. The ultrasonic transducer includes a first electrode layer, a piezoelectric material layer, and a second electrode layer that are sequentially stacked. The first electrode layer includes a plurality of spaced first electrode blocks, the second electrode layer includes a plurality of spaced second electrode blocks, and orthographic projection of each first electrode block on the second electrode layer overlaps at least one second electrode block. The first electrode layer is disposed in a discretized manner, so that ultrasonic waves reflected from different positions of a detected object can be transmitted to the piezoelectric material layer via different first electrode blocks. Therefore, crosstalk between the ultrasonic waves reflected from different positions of the detected object can be effectively reduced, thereby ensuring high detection accuracy of the ultrasonic transducer.

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## Description

BRIEF DESCRIPTION OF DRAWINGS
[0042] FIG. **1** is a diagram of a structure of an ultrasonic transducer according to an embodiment of this application;
[0043] FIG. **2** is a sectional view of an ultrasonic transducer according to an embodiment of this application;
[0044] FIG. **3** is a diagram of a structure of a first electrode layer according to an embodiment of this application;
[0045] FIG. **4** is a diagram of a structure of another first electrode layer according to an embodiment of this application;
[0046] FIG. **5** is a diagram of a structure of still another first electrode layer according to an embodiment of this application;
[0047] FIG. **6** is a diagram of a structure of yet another first electrode layer according to an embodiment of this application;
[0048] FIG. **7** is a diagram of a structure of still yet another first electrode layer according to an embodiment of this application;
[0049] FIG. **8** is a diagram of a structure of another ultrasonic transducer according to an embodiment of this application;
[0050] FIG. **9** is a diagram of a structure of a lens layer according to an embodiment of this application;
[0051] FIG. **10** is a diagram of a structure of still another ultrasonic transducer according to an embodiment of this application;

[0052] FIG. **11** is a diagram of a structure of yet another ultrasonic transducer according to an embodiment of this application;
[0053] FIG. **12** is a diagram of a structure of still yet another ultrasonic transducer according to an embodiment of this application;
[0054] FIG. **13** is a diagram of a structure of a further ultrasonic transducer according to an embodiment of this application;
[0055] FIG. **14** is a diagram of a structure of a still further ultrasonic transducer according to an embodiment of this application;
[0056] FIG. **15** is a diagram of a structure of a yet further ultrasonic transducer according to an embodiment of this application;
[0057] FIG. **16** is a diagram of a structure of a second electrode layer according to an embodiment of this application;
[0058] FIG. **17** is a diagram of a structure of a still yet further ultrasonic transducer according to an embodiment of this application;
[0059] FIG. **18** is a diagram of a structure of a fingerprint recognition module according to an embodiment of this application; and
[0060] FIG. **19** is a diagram of a structure of an electronic device according to an embodiment of this application.

DESCRIPTION OF EMBODIMENTS

[0061] The following describes in detail the ultrasonic transducer, the fingerprint recognition module, and the electronic device provided in embodiments of this application with reference to accompanying drawings.
[0062] An ultrasonic transducer in the conventional technology usually includes a lower electrode layer, a piezoelectric material layer, and an upper electrode layer that are sequentially stacked. The piezoelectric material layer and the upper electrode layer each are of an entire-layer structure, and the lower electrode layer includes a plurality of mutually independent electrode blocks. The piezoelectric material layer can emit an ultrasonic wave under driving of an electrical signal applied by the upper electrode layer. After the ultrasonic wave is transmitted to a detected object, the ultrasonic wave can be reflected by the detected object to the piezoelectric material layer. The piezoelectric material layer may further convert the reflected ultrasonic wave into an electrical signal. Because strength of ultrasonic waves reflected from different positions of the detected object may be different, strength of electrical signals generated in different positions of the piezoelectric material layer is also different. Correspondingly, the strength of the electrical signals may be detected via the plurality of mutually independent electrode blocks at the lower electrode layer, to implement detection on the detected object. However, there may be interference between the ultrasonic waves reflected from different positions of the detected object. Therefore, accuracy of ultrasonic detection is low.
[0063] FIG. **1** is a diagram of a structure of an ultrasonic transducer according to an embodiment of this application. The ultrasonic transducer can effectively reduce crosstalk between reflected ultrasonic waves, and ensure high detection accuracy. As shown in FIG. **1**, the ultrasonic transducer includes a first electrode layer **01**, a piezoelectric material layer **02**, and a second electrode layer **03** that are sequentially stacked.
[0064] The first electrode layer **01** includes a plurality of spaced first electrode blocks **011**, that is, there is a gap between any two first electrode blocks **011**. In addition, a thickness of each first electrode block **011** is greater than a thickness threshold, and the thickness threshold is positively correlated with a wavelength of an ultrasonic wave emitted by the piezoelectric material layer **02**. For example, the thickness threshold may be ⅛ of the wavelength of the ultrasonic wave. The first electrode layer **01** may also be referred to as an upper electrode layer.
[0065] The second electrode layer **03** includes a plurality of spaced second electrode blocks **031**, that is, there is a gap between any two second electrode blocks **031**. In addition, the second

electrode layer **03** may also be referred to as a lower electrode layer or a pixel electrode layer.
[0066] FIG. **2** is a sectional view of the ultrasonic transducer according to an embodiment of this application. As shown in FIG. **2**, orthographic projection of each first electrode block **011** on the second electrode layer **03** overlaps at least one second electrode block **031**. In other words, there is an overlapping area between the orthographic projection of each first electrode block **011** and an area in which the at least one second electrode block **031** is located. There may be the following several cases in which there is an overlapping area between orthographic projection and an area in which an electrode block is located: The orthographic projection completely coincides with the area in which the electrode block is located, the orthographic projection covers the area in which the electrode block is located, the orthographic projection is located in the area in which the electrode block is located, and the orthographic projection partially overlaps the area in which the electrode block is located.
[0067] In an example, the plurality of first electrode blocks **011** at the first electrode layer **01** are configured to drive the piezoelectric material layer **02** to emit the ultrasonic wave, and the plurality of second electrode blocks **031** at the second electrode layer **03** are configured to detect an electrical signal generated by the piezoelectric material layer **02** based on a reflected ultrasonic wave. In addition, when the plurality of first electrode blocks **011** drive the piezoelectric material layer **02** to emit the ultrasonic wave, the plurality of second electrode blocks **031** may all be grounded; and when the plurality of second electrode blocks **031** receive the electrical signal, the plurality of first electrode blocks **011** may all be grounded.
[0068] In another example, in the first electrode layer **01** and the second electrode layer **03**, one electrode layer (for example, the second electrode layer **03**) is configured to: drive the piezoelectric material layer **02** to emit the ultrasonic wave, and detect the electrical signal generated based on the reflected ultrasonic wave; and the other electrode layer (for example, the first electrode layer **01**) is configured to be grounded.
[0069] The reflected ultrasonic wave may be reflected by a detected object (for example, a finger of a user). In addition, because signal strength of ultrasonic waves reflected from different positions of the detected object may be different, strength of electrical signals detected by different electrode blocks (for example, the plurality of second electrode blocks **031**) may also be different.
[0070] It may be understood that the first electrode layer **01** includes the plurality of spaced first electrode blocks **011**, that is, the first electrode layer **01** is disposed in a discretized manner, and the thickness of each first electrode block **011** is greater than the thickness threshold (⅛ of the wavelength of the ultrasonic wave), so that a plurality of waveguide structures that can limit propagation paths of emitted ultrasonic waves and reflected ultrasonic waves can be formed at the first electrode layer **01**. Therefore, crosstalk between the ultrasonic waves reflected from different positions of the detected object can be effectively reduced.
[0071] It may be further understood that the wavelength of the ultrasonic wave emitted by the piezoelectric material layer **02** may be a wavelength of an ultrasonic wave emitted by the piezoelectric material layer **02** when the ultrasonic transducer operates at a resonance frequency. If the ultrasonic transducer has a plurality of different modes and has different resonance frequencies in different modes, test simulation may be performed on detection effect (for example, receiving sensitivity) of the ultrasonic transducer on reflected ultrasonic waves at different resonance frequencies. Then, the thickness of the first electrode block **011** may be determined based on a wavelength corresponding to a resonance frequency with optimal detection effect. In other words, the wavelength of the ultrasonic wave emitted by the piezoelectric material layer **02** may be the wavelength corresponding to the resonance frequency with the optimal detection effect.
[0072] This embodiment of this application provides an ultrasonic transducer. A first electrode layer in the ultrasonic transducer includes a plurality of spaced first electrode blocks, a second electrode layer includes a plurality of spaced second electrode blocks, and orthographic projection of each first electrode block on the second electrode layer overlaps at least one second electrode

block. The first electrode layer is disposed in a discretized manner, and a thickness of each first electrode block is greater than a thickness threshold, so that a plurality of waveguide structures that can limit propagation paths of ultrasonic waves can be formed at the first electrode layer. Therefore, crosstalk between ultrasonic waves reflected from different positions of a detected object can be effectively reduced, and a signal-to-noise ratio of the ultrasonic transducer can be further improved, thereby ensuring high detection accuracy of the ultrasonic transducer.

[0073] In this embodiment of this application, materials of both the first electrode layer **01** and the second electrode layer **03** may be conductive materials, and the materials of the two electrode layers may be the same or may be different. The conductive material may include a metal material and/or a conductive polymer material. The metal material may include at least one of aluminum (Al), gold (Au), silver (Ag), platinum (Pt), copper (Cu), molybdenum (Mo), titanium (Ti), and the like. The conductive polymer material may include indium tin oxide (ITO) and the like.

[0074] A material of the piezoelectric material layer **02** may be an organic polymer material, a piezoelectric ceramic material, an inorganic piezoelectric material, or the like. The organic polymer material may include at least one of the following materials: polyvinylidene difluoride (PVDF), a copolymer of PVDF (PVDF-TRFE), a blend of PVDF (for example, PVDF-graphene), and the like. The piezoelectric ceramic material may include at least one of the following materials: lead zirconate titanate piezoelectric ceramics (PZT), an alloy material of PZT, potassium-sodium niobate ceramics (KNN, for example, KxNa1-xNbO3), ferroelectric lead magnesium niobate-lead titanate (PMN-PT), and the like. The alloy material of PZT may include lead lanthanum zirconate titanate (PLZT), lead niobate zirconate titanate (PNZT), and the like. The inorganic piezoelectric material may include at least one of the following materials: aluminum nitride (AlN) and an alloy material thereof, zinc oxide (ZnO) and an alloy material thereof, and the like. The alloy material of AlN may include scandium-doped aluminum nitride (ScxAl1-xN) and the like, and the alloy material of ZnO may include vanadium-doped zinc oxide (VxZn1-xO) and the like.

[0075] Optionally, as shown in FIG. **2**, the orthographic projection of each first electrode block **011** on the second electrode layer **03** may overlap one second electrode block **031**. For example, the plurality of first electrode blocks **011** included in the first electrode layer **01** may be in one-to-one correspondence with the plurality of second electrode blocks **031** included in the second electrode layer **03**, and the orthographic projection of each first electrode block **011** overlaps one corresponding second electrode block **031**. Based on this, it can be ensured that an electrical signal detected by each second electrode block **031** is generated based on a reflected ultrasonic wave transmitted by one first electrode block **011**, thereby effectively reducing the crosstalk between the ultrasonic waves transmitted at the first electrode layer **01**, and ensuring a high signal-to-noise ratio of the electrical signal detected by the second electrode block **031**.

[0076] Each first electrode block **011**, one second electrode block **031** corresponding to the first electrode block **011**, and a piezoelectric material between the two may also be referred to as one ultrasonic transducer unit. Correspondingly, the ultrasonic transducer may be an ultrasonic transducer array including a plurality of ultrasonic transducer units.

[0077] It may be understood that each second electrode block **031** at the second electrode layer **03** may alternatively correspond to at least two first electrode blocks **011**. In other words, orthographic projection of the at least two first electrode blocks **011** may overlap a same second electrode block **031**.

[0078] Each first electrode block **011** at the first electrode layer **01** and each second electrode block **031** at the second electrode layer **03** may be in a shape of a cylinder, a prism, or the like. The prism may be a cuboid, a cube, or the like. In addition, the first electrode block **011** and the second electrode block **031** may be in a same shape or different shapes. This is not limited in embodiments of this application.

[0079] FIG. **3** is a diagram of a structure of the first electrode layer according to an embodiment of this application. As shown in FIG. **3**, the first electrode layer **01** may further include a plurality of first connection structures **012**, and each first connection structure **012** is configured to connect at least two first electrode blocks **011** arranged in a first direction.

[0080] It may be understood that the first electrode layer **01** further needs to be connected to a drive circuit through a leading wire, and may drive, based on a drive signal provided by the drive circuit, the piezoelectric material layer **02** to emit the ultrasonic wave. After the first electrode layer **01** is disposed in a discretized manner, a quantity of leading wires and wiring complexity are greatly increased. However, in this embodiment of this application, because the at least two first electrode blocks **011** arranged in the first direction may be connected by using the plurality of first connection structures **012**, the quantity of leading wires can be effectively reduced, and the wiring complexity can be reduced.

[0081] In this embodiment of this application, the plurality of second electrode blocks **031** at the second electrode layer **03** may be arranged in an array, and each second electrode block **031** may be referred to as one pixel electrode. Correspondingly, as shown in FIG. **3**, the first direction may be a pixel electrode row direction x, that is, the at least two first electrode blocks **011** arranged in the row direction x at the first electrode layer **01** are interconnected by using the first connection structure **012**. Alternatively, as shown in FIG. **4**, the first direction may be a pixel electrode column direction y, that is, the at least two first electrode blocks **011** arranged in the column direction y at the first electrode layer **01** are interconnected by using the first connection structure **012**.

[0082] Optionally, as shown in FIG. **5**, the first electrode layer **01** may further include a plurality of second connection structures **013**, and each second connection structure **013** is configured to connect at least two first electrode blocks **011** arranged in a second direction. The second direction intersects the first direction. For example, the second direction is perpendicular to the first direction. In the example shown in FIG. **5**, the first direction is the pixel electrode row direction x, and the second direction is the column direction y.

[0083] The plurality of second connection structures **013** are disposed so that the plurality of first electrode blocks **011** can be interconnected in a staggered manner in the first direction and the second direction. Therefore, the quantity of leading wires that need to be disposed can be further reduced, and the wiring complexity can be further reduced.

[0084] Optionally, as shown in FIG. **3** to FIG. **5**, each first connection structure **012** may be located between two adjacent first electrode blocks **011**. Alternatively, as shown in FIG. **6**, each first connection structure **012** may be located on a side that is of at least two first electrode blocks **011** and that is close to or away from the piezoelectric material layer **02**. In FIG. **6**, an example in which the first connection structure **012** is located on a side that is of the first electrode block **011** and that is away from the piezoelectric material layer **02** is used for description.

[0085] It may be understood that, if the first electrode layer **01** further includes the plurality of second connection structures **013**, the second connection structure **013** may also be located between two adjacent first electrode blocks **011**, or may be located on a side that is of at least two first electrode blocks **011** and that is close to or away from the piezoelectric material layer **02**.

[0086] In this embodiment of this application, thicknesses of the connection structures (for example, the first connection structure **012** and the second connection structure **013**) may be less than or equal to the thickness of the first electrode block **011**. In addition, to effectively reduce crosstalk signals propagated in the connection structure, a width of the connection structure may be less than a width of the first electrode block **011**, and may be as small as possible within a range allowed by a process. For example, the width of the connection structure may be a minimum width limit of the process. A width direction of the connection structure and the first electrode block **011** is perpendicular to a thickness direction of the first electrode layer **01**, and is perpendicular to an arrangement direction of the at least two first electrode blocks **011** connected to the connection structure. The thickness direction is a stacking direction of the first electrode layer **01**, the piezoelectric material layer **02**, and the second electrode layer **03**.

[0087] The foregoing descriptions are provided by using an example in which each first electrode

block **011** is a block-shaped electrode. Optionally, as shown in FIG. **7**, each first electrode block **011** may alternatively be a bar-shaped electrode, and orthographic projection of the bar-shaped electrode on the second electrode layer **03** overlaps at least two second electrode blocks **031**.
[0088] In an example, the first electrode blocks **011** may extend in a first direction, and the first electrode blocks **011** may be arranged in a second direction. Correspondingly, orthographic projection of each bar-shaped electrode on the second electrode layer **03** may overlap a plurality of second electrode blocks **031** arranged in the first direction. As shown in FIG. **7**, the first direction may be the row direction x, or may be the column direction y.
[0089] In another example, the plurality of first electrode blocks **011** may be grouped into two groups. In the first group, the first electrode blocks **011** extend in a first direction, and the first electrode blocks **011** are arranged in the second direction. In the second group, the first electrode blocks **011** extend in a second direction, and the first electrode blocks **011** are arranged in the first direction. Correspondingly, orthographic projection of each bar-shaped electrode in the first group may overlap the second electrode blocks **031** arranged in the first direction, and orthographic projection of each bar-shaped electrode in the second group may overlap the second electrode blocks **031** arranged in the second direction. The first direction intersects the second direction. For example, the first direction may be the row direction x, and the second direction may be the column direction y.
[0090] The bar-shaped first electrode block **011** can effectively isolate some crosstalk signals. In addition, because a manufacturing process of the bar-shaped electrode is simple, complexity and manufacturing costs of a manufacturing process of the ultrasonic transducer can be effectively reduced.
[0091] Optionally, the thickness of each first electrode block **011** at the first electrode layer **01** may be n/4 times the wavelength of the ultrasonic wave emitted by the piezoelectric material layer **02**, and n is a positive integer. For example, n may be an odd number. For example, the thickness of the first electrode block **011** may be about 50 μm. In the solution provided in this embodiment of this application, permitted by a process condition and an overall thickness, the thickness of the first electrode block **011** may be increased. Therefore, convergence effect of the first electrode block **011** on the ultrasonic wave can be effectively increased, and the crosstalk between the ultrasonic waves can be effectively reduced.
[0092] It may be understood that n/4 times the wavelength of the ultrasonic wave in this embodiment of this application may be obtained by modifying n/4 times a theoretical wavelength of the ultrasonic wave based on non-ideality during ultrasonic wave transmission, for example, by modifying n/4 times the theoretical wavelength based on a simulation result, so as to determine the thickness of the first electrode block **011**. An error exists between a correction result and n/4 times the theoretical wavelength, and the error is less than a preset threshold. For example, assuming that n=1, and ¼ times the theoretical wavelength is 60 m, the thickness of the first electrode block **011** determined after ¼ times the theoretical wavelength is modified may be 50 μm.
[0093] FIG. **8** is a diagram of a structure of another ultrasonic transducer according to an embodiment of this application. As shown in FIG. **8**, the ultrasonic transducer may further include a lens layer **04** located on a side that is of the first electrode layer **01** and that is away from the piezoelectric material layer **02**. As shown in FIG. **8** and FIG. **9**, the lens layer **04** includes a plurality of spaced lenses **041**, that is, there is a gap between any two lenses **041**. Orthographic projection of each lens **041** on the second electrode layer **03** overlaps at least one second electrode block **031**.
[0094] Each lens **041** may be configured to focus on the ultrasonic wave emitted by the piezoelectric material layer **02** and the ultrasonic wave reflected by the detected object, thereby effectively reducing the crosstalk between the ultrasonic waves, improving sensitivity of detecting the reflected ultrasonic wave, and increasing a penetration capability of the ultrasonic wave. In a preparation process of the ultrasonic transducer, a physical focus of the lens **041** may be changed

by adjusting a geometric form and/or a material of the lens **041**, so that the physical focus is located on a surface in contact with the detected object. It is assumed that the ultrasonic transducer is used in a fingerprint recognition module, and the physical focus may be located on a surface of a penetrating medium of the fingerprint recognition module, where the penetrating medium is a medium used to be in contact with a finger of a user. It may be understood that a curvature of the lens **041** can be adjusted by adjusting the geometric form of the lens **041**, and a refractive index of the lens **041** can be adjusted by adjusting the material of the lens **041**.

[0095] It may be further understood that the plurality of lenses **041** included in the lens layer **04** may be in one-to-one correspondence with the plurality of second electrode blocks **031** at the second electrode layer **03**, and orthographic projection of each lens **041** overlaps one corresponding second electrode block **031**. Alternatively, each lens **041** at the lens layer **04** may correspond to at least two second electrode blocks **031** at the second electrode layer **03**, and the orthographic projection of each lens **041** overlaps the at least two corresponding second electrode blocks **031**. Alternatively, each second electrode block **031** at the second electrode layer **03** may correspond to at least two lenses **041**. In other words, orthographic projection of the at least two lenses **041** may overlap a same second electrode block **031**.

[0096] Optionally, as shown in FIG. **8**, the orthographic projection of each lens **041** on the second electrode layer **03** overlaps one second electrode block **031**, and orthographic projection of each lens **041** on the first electrode layer **01** overlaps one first electrode block **011**. In other words, the plurality of lenses **041**, the plurality of first electrode blocks **011**, and the plurality of second electrode blocks **031** may be in one-to-one correspondence. Based on this, a plurality of waveguide structures that are in one-to-one correspondence with the plurality of second electrodes **031** can be formed at the first electrode layer **01** and the lens layer **04**, so that the crosstalk between the ultrasonic waves can be effectively reduced.

[0097] Optionally, as shown in FIG. **8**, a coupling medium **300** (which may also be referred to as a functional layer) may be further disposed on a side that is of the lens layer **04** and that is away from the first electrode layer **01**. The coupling medium **300** may have at least one of the following functions: acoustic impedance matching, electromagnetic shielding, stress isolation, gluing, and the like. In addition, the coupling medium **300** may be of a single-layer or multi-layer structure.

[0098] If the coupling medium **300** has an acoustic impedance matching function, a material of the coupling medium **300** may be determined based on acoustic impedance of a material of an adjacent layer. The adjacent layer of the coupling medium **300** may include a lens layer **04**, and may further include a penetrating medium. The penetrating medium may be a medium used to be in contact with the detected object, and a material of the penetrating medium may be metal, glass, or the like. If the coupling medium **300** has an electromagnetic shielding function, a material of the coupling medium **300** may include a metal material, for example, may include a copper foil. If the coupling medium **300** has a stress isolation function, a material of the coupling medium **300** may include a soft material, for example, a colloidal material. If the coupling medium **300** has a gluing function, a material of the coupling medium **300** may include a gluing material.

[0099] It may be understood that a shape of the lens **041** may be determined based on a value relationship between a refractive index of the lens **041** and a refractive index of an adjacent layer. For example, if the refractive index of the lens **041** is less than refractive indexes of adjacent layers (the first electrode layer **01** and the coupling medium **300**) of the lens **041**, as shown in FIG. **8**, the shape of the lens **041** may be a convex lens. If the refractive index of the lens **041** is greater than refractive indexes of adjacent layers (the first electrode layer **01** and the coupling medium **300**) of the lens **041**, as shown in FIG. **10**, the shape of the lens **041** may be a concave lens.

[0100] As shown in FIG. **8** and FIG. **10**, a surface that is of the lens **041** and that is close to the first electrode layer **01** may be a plane, so that it can be ensured that a manufacturing process is simple. Alternatively, a surface that is of the lens **041** and that is close to the first electrode layer **01** may be a curved surface. In other words, the convex lens may be a double-sided convex lens, and the

concave lens may be a double-sided concave lens.
[0101] It may be further understood that, as shown in FIG. **8** and FIG. **10**, a width of a cross section of each lens **041** may be equal to a width of a cross section of the first electrode block **011**. Alternatively, as shown in FIG. **11**, a width of a cross section of each lens **041** may be slightly greater than a width of a cross section of the first electrode block **011**. The width of the cross section of the lens **041** is not limited in embodiments of this application, provided that it is ensured that the orthographic projection of the lens **041** overlaps the corresponding first electrode block **011** and the corresponding second electrode block **031**.
[0102] Optionally, as shown in FIG. **12**, the piezoelectric material layer **02** in the ultrasonic transducer may be of an entire-layer structure. Alternatively, refer to FIG. **8** to FIG. **11**. The piezoelectric material layer **02** may include a plurality of spaced piezoelectric blocks **021**, that is, there is a gap between any two piezoelectric blocks **021**. Orthographic projection of each piezoelectric block **021** on the second electrode layer **03** overlaps at least one second electrode block **031**.
[0103] It may be understood that the plurality of piezoelectric blocks **021** included in the piezoelectric material layer **02** may be in one-to-one correspondence with the plurality of second electrode blocks **031** at the second electrode layer **03**, and the orthographic projection of each piezoelectric block **021** overlaps one corresponding second electrode block **031**. Alternatively, each piezoelectric block **021** may correspond to at least two second electrode blocks **031**, and the orthographic projection of each piezoelectric block **021** overlaps the at least two corresponding second electrode blocks **031**. Alternatively, each second electrode block **031** may correspond to at least two piezoelectric blocks **021**, that is, orthographic projection of the at least two piezoelectric blocks **021** may overlap a same second electrode block **031**.
[0104] Optionally, as shown in FIG. **8**, FIG. **10**, and FIG. **11**, the orthographic projection of each piezoelectric block **021** on the second electrode layer **03** overlaps one second electrode block **031**, and orthographic projection of each piezoelectric block **021** on the first electrode layer **01** overlaps one first electrode block **011**. In other words, the plurality of piezoelectric blocks **021**, the plurality of first electrode blocks **011**, and the plurality of second electrode blocks **031** may be in one-to-one correspondence. Based on this, a plurality of waveguide structures that are in one-to-one correspondence with the plurality of second electrodes **031** can be formed at the first electrode layer **01** and the piezoelectric material layer **02** so that the crosstalk between the ultrasonic waves can be effectively reduced.
[0105] In this embodiment of this application, a thickness of the piezoelectric material layer **02** may be determined based on the resonance frequency of the ultrasonic transducer. For example, it is assumed that the ultrasonic transducer is used in a fingerprint recognition module, and to ensure a longitudinal resolution of fingerprint recognition, the resonance frequency of the ultrasonic transducer is about 8 megahertz (MHz) to 20 MHz. Correspondingly, the thickness of the piezoelectric material layer **02** may be several micrometers to dozens of micrometers.
[0106] FIG. **13** is a diagram of a structure of a further ultrasonic transducer according to an embodiment of this application. As shown in FIG. **13**, the ultrasonic transducer may further include a waveguide layer **05** located on the side that is of the first electrode layer **01** and that is away from the piezoelectric material layer **03**. The waveguide layer **05** may include a plurality of spaced waveguide blocks **051**, that is, there is a gap between any two waveguide blocks **051**. Orthographic projection of each waveguide block **051** on the first electrode layer **01** may overlap at least one first electrode block **011**.
[0107] The plurality of waveguide blocks **051** included in the waveguide layer **05** may be in one-to-one correspondence with the plurality of first electrode blocks **011** at the first electrode layer **01**, and the orthographic projection of each waveguide block **051** overlaps one corresponding first electrode block **011**. Alternatively, each waveguide block **051** may correspond to at least two first electrode blocks **011** at the first electrode layer **01**, and the orthographic projection of each

waveguide block **051** overlaps the at least two corresponding first electrode blocks **011**. Alternatively, each first electrode block **011** may correspond to at least two waveguide blocks **051**. In other words, orthographic projection of the at least two waveguide blocks **051** may both overlap a same first electrode block **011**.

[0108] Optionally, as shown in FIG. **13**, orthographic projection of each waveguide block **051** on the second electrode layer **03** overlaps one second electrode block **031**, and the orthographic projection of each waveguide block **051** on the first electrode layer **01** overlaps one first electrode block **011**. In other words, the plurality of waveguide blocks **051**, the plurality of first electrode blocks **011**, and the plurality of second electrode blocks **031** may be in one-to-one correspondence. Based on this, a plurality of waveguide structures that are in one-to-one correspondence with the plurality of second electrodes **031** can be formed at the waveguide layer **05** and the first electrode layer **01** so that the crosstalk between the ultrasonic waves can be effectively reduced.

[0109] It may be understood that a material of the waveguide layer **05** may be different from a material of the first electrode layer **01**, and acoustic impedance of the material of the waveguide layer **05** may be similar to acoustic impedance of the material of the first electrode layer **01** (for example, an acoustic impedance difference between the two is less than a first threshold), to avoid reflection of the ultrasonic wave on an interface between the waveguide layer **05** and the first electrode layer **01**. In this embodiment of this application, a material that has low costs and is easy to process may be alternatively selected as the material of the waveguide layer **05**. Therefore, the manufacturing costs and the complexity of the manufacturing process of the ultrasonic transducer can be effectively reduced while a thickness of the waveguide structure is ensured.

[0110] It may be further understood that, as shown in FIG. **13**, in a scenario in which the ultrasonic transducer further includes the lens layer **04**, the waveguide layer **05** may be located between the lens layer **04** and the first electrode layer **01**.

[0111] Optionally, as shown in FIG. **14**, the material of the waveguide layer **05** may be the same as a material of the lens layer **04**, and the material of the lens layer **04** may be a polymer material, like resin. In addition, the plurality of waveguide blocks **051** included in the waveguide layer **05** may be in one-to-one correspondence with the plurality of lenses **041** at the lens layer **04**, and orthographic projection of each waveguide block **051** on the lens layer **04** overlaps one corresponding lens **041**. Because the material of the waveguide layer **05** is the same as the material of the lens layer **04**, each waveguide block **051** and a lens **041** corresponding to the waveguide block **051** may be of an integrated structure.

[0112] In this embodiment of this application, as shown in FIG. **8** and FIG. **10** to FIG. **14**, the gap between the plurality of first electrode blocks **011** and the gap between the plurality of second electrode blocks **031** may be vacuum or air. Alternatively, as shown in FIG. **15**, the ultrasonic transducer may further include a filling material **06** filled between the plurality of first electrode blocks **011** and filled between the plurality of second electrode blocks **031**.

[0113] It may be understood that if the piezoelectric material layer **03**, the lens layer **04**, and/or the waveguide layer **05** in the ultrasonic transducer are/is also of discretized structures/a discretized structure, a gap between the discretized structures may also be vacuum, air, or the filling material **06**.

[0114] If the gap between the discretized structures is vacuum, because acoustic impedance of the vacuum is almost 0, it can be ensured that an acoustic reflectivity of an interface between the waveguide structure and the vacuum is large, and propagation effect of the ultrasonic wave is good. Each waveguide structure may include at least one first electrode block **011**. Alternatively, in addition to the first electrode block **011**, at least one of the piezoelectric block **021**, the waveguide block **051**, and the lens **041** may be included.

[0115] In this embodiment of this application, the filling material **06** may be a polymer material, and a difference between acoustic impedance of the filling material **06** and acoustic impedance of a material (mainly a material of the first electrode block **011**) of the waveguide structure may be as large as possible (for example, a difference between the two is greater than a second threshold), to ensure that an interface between the two has a large acoustic reflectivity. For example, the polymer material may be a gluing material (like an adhesive) that penetrates from the coupling medium **300** into the gap when the coupling medium **300** is prepared.

[0116] FIG. **16** is a diagram of a structure of the second electrode layer according to an embodiment of this application. As shown in FIG. **16**, the plurality of second electrode blocks **031** included in the second electrode layer **03** may be grouped into a plurality of electrode groups **030** arranged in the first direction, and each electrode group **030** includes at least two second electrode blocks **031** arranged in the second direction.

[0117] The first direction intersects the second direction. For example, in the example shown in FIG. **16**, the first direction is the row direction x, and the second direction is the column direction y. Certainly, the first direction may alternatively be the column direction y, and the second direction may be the row direction x.

[0118] Optionally, as shown in (a) in FIG. **16**, every two adjacent electrode groups **030** are arranged in an aligned manner. Alternatively, as shown in (b) in FIG. **16**, every two adjacent electrode groups **030** are arranged in a staggered manner. The second electrode blocks **031** are arranged in the staggered manner, so that a density of the second electrode blocks **031** in the ultrasonic transducer can be effectively increased, thereby effectively improving detection precision of the ultrasonic transducer.

[0119] If the ultrasonic transducer is used in a fingerprint recognition module, the plurality of second electrode blocks **031** at the second electrode layer **03** may implement pixelized receiving of echo signals of valleys and ridges of a fingerprint. To ensure a fingerprint recognition resolution, a distance between centers of two adjacent second electrode blocks **031** is usually less than 100 μm. In addition, the second electrode layer **03** is thin. For example, a thickness of the second electrode layer **03** may be at a nanometer level, to reduce impact on flatness of the piezoelectric material layer **02** deposited on a surface of the second electrode layer **03**.

[0120] It may be understood that, if the plurality of waveguide structures in the ultrasonic transducer are in one-to-one correspondence with the plurality of second electrode blocks **031** included in the second electrode layer **03**, the plurality of waveguide structures may alternatively be arranged in the staggered manner in the manner shown in (b) in FIG. **16**.

[0121] Optionally, as shown in FIG. **8** and FIG. **10** to FIG. **15**, the ultrasonic transducer may further include a substrate **00** located on a side that is of the second electrode layer **03** and that is away from the piezoelectric material layer **02**. The substrate **00** may include a base plate and a circuit layer located on the base plate. A material of the base plate may be glass or silicon. The circuit layer may include a thin film transistor (TFT) circuit, or may include a complementary metal-oxide-semiconductor (CMOS) circuit. In addition, the circuit layer is connected to the second electrode layer **03** and is configured to perform related processing on the electrical signals detected by the second electrode blocks **031** at the second electrode layer **03**.

[0122] It may be further understood that the waveguide layer **05** may be further located on the side that is of the second electrode layer **03** and that is away from the piezoelectric material layer **03**. In addition, the coupling medium **300** is formed on a side that is of the waveguide layer **05** and that is away from the second electrode layer **03**. That is, the waveguide layer **05** may be coupled to the penetrating medium through the coupling medium **300**. If the ultrasonic transducer further includes the lens layer **04**, the lens layer **04** may be located on the side that is of the waveguide layer **05** and that is away from the second electrode layer **03**.

[0123] This embodiment of this application provides an ultrasonic transducer. A first electrode layer in the ultrasonic transducer includes a plurality of spaced first electrode blocks, a second electrode layer includes a plurality of spaced second electrode blocks, and an orthographic projection of each first electrode block on the second electrode layer overlaps at least one second electrode block. The first electrode layer is disposed in a discretized manner and a thickness of each first electrode block is greater than a thickness threshold so that a plurality of waveguide structures that limit propagation paths of ultrasonic waves can be formed at the first electrode layer. Therefore, crosstalk between ultrasonic waves reflected from different positions of a detected object can be effectively reduced, ensuring high detection accuracy of the ultrasonic transducer. In addition, because the ultrasonic transducer can reuse the first electrode layer to implement a waveguide function, processing costs and complexity are greatly reduced, and this helps reduce an overall thickness of the ultrasonic transducer.

[0124] An embodiment of this application further provides another ultrasonic transducer. As shown in FIG. **17**, the ultrasonic transducer includes a second electrode layer **11**, a piezoelectric material layer **12**, a first electrode layer **13**, a waveguide layer **14**, and a lens layer **15**. The second electrode layer **11**, the piezoelectric material layer **12**, and the first electrode layer **13** are sequentially stacked, and the waveguide layer **14** and the lens layer **15** are sequentially stacked on a side that is of the second electrode layer **11** or the first electrode layer **13** and that is away from the piezoelectric material layer **12**.

[0125] The first electrode layer **13** may be of an entire-layer structure, that is, the first electrode layer **13** may be a sheet-shaped electrode, and the first electrode layer **13** may also be referred to as an upper electrode layer.

[0126] The second electrode layer **11** includes a plurality of spaced second electrode blocks **111**, and the second electrode layer **11** may also be referred to as a lower electrode layer or a pixel electrode layer.

[0127] The waveguide layer **14** includes a plurality of spaced waveguide blocks **141**, and an orthographic projection of each waveguide block **141** on the second electrode layer **11** overlaps at least one second electrode block **111**.

[0128] The lens layer **15** includes a plurality of spaced lenses **151**, and an orthographic projection of each lens **151** on the second electrode layer **11** also overlaps at least one second electrode block **111**.

[0129] The first electrode layer **13** may be configured to drive the piezoelectric material layer **12** to emit an ultrasonic wave, and the plurality of second electrode blocks **111** at the second electrode layer **11** may be configured to detect an electrical signal generated by the piezoelectric material layer **12** based on a reflected ultrasonic wave. Alternatively, the plurality of second electrode blocks **111** at the second electrode layer **11** are configured to drive the piezoelectric material layer **12** to emit the ultrasonic wave and detect the electrical signal. The first electrode layer **13** is configured to be grounded.

[0130] It may be understood that the plurality of waveguide blocks **141** included in the waveguide layer **14** may be in one-to-one correspondence with the plurality of second electrode blocks **111** at the second electrode layer **11**, and orthographic projection of each waveguide block **141** overlaps one corresponding second electrode block **111**. Alternatively, each waveguide block **141** may correspond to at least two second electrode blocks **111**, and the orthographic projection of each waveguide block **141** overlaps the at least two corresponding second electrode blocks **111**. Alternatively, each second electrode block **111** may correspond to at least two waveguide blocks **141**. In other words, orthographic projection of the at least two waveguide blocks **141** may both overlap a same second electrode block **111**.

[0131] Similarly, the plurality of lenses **151** included in the lens layer **15** may be in one-to-one correspondence with the plurality of second electrode blocks **111** at the second electrode layer **03**, and orthographic projection of each lens **151** overlaps one corresponding second electrode block **111**. Alternatively, each lens **151** may correspond to at least two second electrode blocks **111**, and the orthographic projection of each lens **151** overlaps the at least two corresponding second electrode blocks **111**. Alternatively, each second electrode block **111** may correspond to at least two lenses **151**. In other words, orthographic projection of the at least two lenses **151** may both overlap a same second electrode block **111**.

[0132] It may be further understood that a material of the waveguide layer **14** may be different from a material of an adjacent electrode layer (for example, the first electrode layer **13** or the second electrode layer **11**), and acoustic impedance of the material of the waveguide layer **14** may be similar to acoustic impedance of the material of the adjacent electrode layer to avoid reflection of the ultrasonic wave on an interface between the waveguide layer **14** and the electrode layer. In this embodiment of this application, a material that has low costs and is easy to process may be alternatively selected as the material of the waveguide layer **14** so that manufacturing costs and complexity of a manufacturing process of the ultrasonic transducer can be effectively reduced.
[0133] For example, the waveguide layer **14** may be located between the first electrode layer **13** and the lens layer **15**, the material of the waveguide layer **14** may be the same as a material of the lens layer **15**, and the material of the lens layer **15** may be a polymer material like resin.
[0134] Optionally, a thickness of each waveguide block **141** at the waveguide layer **14** may be greater than a thickness threshold, and the thickness threshold is positively correlated with a wavelength of the ultrasonic wave. For example, the thickness threshold may be equal to ⅛ of the wavelength of the ultrasonic wave. For example, the thickness of each waveguide block **141** may be n/4 times the wavelength of the ultrasonic wave, and n is a positive integer. Therefore, it can be ensured that convergence effect of the waveguide layer **14** on the ultrasonic wave is good, and crosstalk between the ultrasonic waves can be effectively reduced. The wavelength of the ultrasonic wave may be a wavelength of an ultrasonic wave emitted by the piezoelectric material layer **12** when the ultrasonic transducer operates at a resonance frequency. If the ultrasonic transducer has a plurality of different resonance frequencies, the wavelength of the ultrasonic wave may be a wavelength corresponding to a resonance frequency when detection effect of the ultrasonic transducer on the reflected ultrasonic wave is optimal.
[0135] Optionally, as shown in FIG. **17**, the orthographic projection of each waveguide block **141** on the second electrode layer **11** may overlap one second electrode block **111**, and overlap orthographic projection of one lens **151** on the second electrode layer **11**. In other words, the plurality of lenses **151** and the plurality of waveguide blocks **141** may be in one-to-one correspondence with the plurality of second electrode blocks **111**. Based on this, a plurality of waveguide structures that are in one-to-one correspondence with the plurality of second electrodes **111** can be formed at the waveguide layer **14** and the lens layer **15** so that the crosstalk between the ultrasonic waves can be effectively reduced. Each waveguide structure includes one waveguide block **141** and one lens **151**.
[0136] As shown in FIG. **17**, the ultrasonic transducer may further include a substrate **00** located on the side that is of the second electrode layer **11** and that is away from the piezoelectric material layer **12**. The substrate **00** may include a base plate and a circuit layer located on the base plate. A material of the base plate may be a glass material or a silicon material. The circuit layer may be a TFT circuit or a CMOS circuit. In addition, the circuit layer is connected to the second electrode layer **11** and is configured to perform related processing on the electrical signals detected by the second electrode blocks **111** at the second electrode layer **11**.
[0137] It may be understood that for structures of the second electrode layer **11**, the waveguide layer **14**, and the lens layer **15**, refer to the related descriptions in the foregoing embodiments. Details are not described herein again.
[0138] It may be further understood that, during preparation of the ultrasonic transducer provided in this embodiment of this application, in an example, film layers may be sequentially formed on the substrate **00**, for example, the second electrode layer, the piezoelectric material layer, the first electrode layer, the waveguide layer, and the lens layer may be sequentially formed.
[0139] In another example, the second electrode layer, the piezoelectric material layer, and the first electrode layer may be sequentially formed on one side of the substrate **00** and the other side of the substrate **00** is etched to form the waveguide layer. Correspondingly, the waveguide layer may be located on the side that is of the second electrode layer and that is away from the piezoelectric

material layer. Then, after the substrate **00** on which the film layers are formed is rotated by 180°, the lens layer is formed on a surface of the substrate **00** (namely, a surface of the waveguide layer).

[0140] This embodiment of this application provides an ultrasonic transducer. A lens layer in the ultrasonic transducer includes a plurality of spaced lenses, a waveguide layer includes a plurality of spaced waveguide blocks, and orthographic projection of each lens and each waveguide block on the second electrode layer both overlaps at least one second electrode block. The lens layer and the waveguide layer disposed in a discretized manner are used so that a plurality of waveguide structures (that can limit propagation paths of ultrasonic waves) can be formed at the lens layer and the waveguide layer. Therefore, crosstalk between ultrasonic waves reflected from different positions of a detected object can be effectively reduced, thereby ensuring high detection accuracy of the ultrasonic transducer.

[0141] An embodiment of this application provides a fingerprint recognition module. As shown in FIG. **18**, the fingerprint recognition module includes the ultrasonic transducer **100** provided in the foregoing embodiments and a fingerprint recognition circuit **200**. The fingerprint recognition circuit **200** is configured to: provide a drive signal for the ultrasonic transducer **100** to drive the ultrasonic transducer **100** to emit an ultrasonic wave; receive an electrical signal generated by the ultrasonic transducer **100** based on a received reflected ultrasonic wave; and perform fingerprint recognition based on the electrical signal.

[0142] Optionally, as shown in FIG. **18**, a control unit in the fingerprint recognition circuit **200** can control a pulse generator to generate an excitation voltage signal and the excitation voltage signal can be transmitted to the ultrasonic transducer **100** (for example, can be transmitted to a first electrode layer) via a transceiver switch to drive the ultrasonic transducer **100** to transmit the ultrasonic wave. After the ultrasonic wave passes through a coupling medium **300** and a penetrating medium **400** and arrives at a surface of a finger, valleys and ridges on the surface of the finger respectively generate echo reflected signals of different strength. The echo reflected signals are received by the ultrasonic transducer **100** and converted into electrical signals after passing through the penetrating medium **400** and the coupling medium **300**.

[0143] The electrical signals can be transmitted to an echo channel of the fingerprint recognition circuit **200** via the transceiver switch. The echo channel sequentially performs amplification and filtering, sampling and holding, and analog-to-digital conversion (ADC) processing on the electrical signals, and then converts the electrical signals into digital signals. Then the fingerprint recognition circuit **200** can sequentially perform digital signal processing and feature extraction on the digital signals and compare an extracted feature with pre-stored fingerprint information to implement fingerprint recognition.

[0144] Optionally, the fingerprint recognition circuit **200** may be a circuit independent of the ultrasonic transducer **100**, for example, may be an independent fingerprint recognition chip. Alternatively, some or all circuits in the fingerprint recognition circuit **200** may be integrated into a substrate **00** of the ultrasonic transducer **100**. In other words, a circuit layer in the substrate **00** may implement some or all functions of the fingerprint recognition circuit **200**.

[0145] This embodiment of this application provides a fingerprint recognition module. An ultrasonic transducer in the fingerprint recognition module has a waveguide structure, and the waveguide structure can effectively reduce crosstalk between echo signals and improve a signal-to-noise ratio of the echo signal. Therefore, it can be ensured that the fingerprint recognition module has high detection sensitivity and high detection accuracy.

[0146] An embodiment of this application further provides an electronic device. The electronic device may include a display and the fingerprint recognition module located on a side of the display, provided in the foregoing embodiments. The fingerprint recognition module may be located on a non-display side of the display, that is, the electronic device may implement in-display fingerprint recognition of a full-view display. The display may also be referred to as a display module, and may be an organic light-emitting diode (OLED) display, a liquid crystal display

(LCD), or the like.

[0147] For example, as shown in FIG. **18** and FIG. **19**, if a device in which the fingerprint recognition module is used is an electronic device having a display, a penetrating medium **400** in the device is the display, and the display **400** may be coupled to the ultrasonic transducer **100** provided in the foregoing embodiments via a coupling medium **300**. The ultrasonic transducer **100** may also be referred to as an acoustic stack.

[0148] It may be understood that the fingerprint recognition module provided in embodiments of this application may be further used in another device, for example, may be used in an access control device. Correspondingly, the penetrating medium **400** may be a glass medium, a metal medium, or the like.

[0149] It may be further understood that the ultrasonic transducer provided in embodiments of this application may be further used in another field other than fingerprint recognition, for example, may be further used in a field like ultrasonic imaging or industrial flaw detection.

[0150] Optionally, as shown in FIG. **19**, a device in which the ultrasonic transducer **100** is used may further include a functional layer **500**, and the functional layer **500** is located on a side that is of a substrate **00** and that is away from a second electrode layer **03**. The functional layer **500** may have at least one of the following functions: acoustic reflection, acoustic absorption, mechanical support, and the like, and the functional layer **500** may be of a single-layer or multi-layer structure. If the functional layer **500** has an acoustic reflection or acoustic absorption function, a material of the functional layer **500** may include a polymer material, a porous material, and the like. If the functional layer **500** has a mechanical support function, a material of the functional layer **500** may include a metal material, for example, a steel sheet.

[0151] In embodiments of this application, terms “first”, “second”, and “third” are merely used for description, but shall not be understood as an indication or implication of relative importance. A term “at least one” means one or more, and “a plurality of” means two or more. For example, the at least one second electrode block refers to one second electrode block or a plurality of second electrode blocks.

[0152] A term “and/or” in this application describes only an association relationship between associated objects and indicates that three relationships may exist. For example, A and/or B may indicate the following three cases: Only A exists, both A and B exist, and only B exists. In addition, a character “/” in this specification usually indicates an “or” relationship between the associated objects.

[0153] The foregoing descriptions are merely optional embodiments of this application, but are not intended to limit this application. Any modification, equivalent replacement, improvement, or the like made within the concept and principle of this application shall fall within the protection scope of this application.

## Claims

**1**. An ultrasonic transducer, comprising: a first electrode layer, the first electrode layer comprising a plurality of spaced first electrode blocks; a piezoelectric material layer; and a second electrode layer, the second electrode layer comprising a plurality of spaced second electrode blocks, wherein the second electrode layer, the piezoelectric material layer, and the first electrode layer are sequentially stacked; an orthographic projection of each first electrode block on the second electrode layer overlaps at least one second electrode block, a thickness of each first electrode block is greater than a thickness threshold, and the thickness threshold is positively correlated with a wavelength of an ultrasonic wave emitted by the piezoelectric material layer.

**2**. The ultrasonic transducer according to claim 1, wherein the orthographic projection of each first electrode block on the second electrode layer overlaps one second electrode block.

**3**. The ultrasonic transducer according to claim 1, wherein the first electrode layer further comprises a plurality of first connection structures, and each first connection structure is configured to connect at least two first electrode blocks arranged in a first direction.

**4**. The ultrasonic transducer according to claim 3, wherein the first electrode layer further comprises a plurality of second connection structures, and each second connection structure is configured to connect at least two first electrode blocks arranged in a second direction, wherein the second direction intersects the first direction.

**5**. The ultrasonic transducer according to claim 3, wherein each first connection structure is located between two adjacent first electrode blocks; or each first connection structure is located on a side that is of at least two first electrode blocks and that is close to or away from the piezoelectric material layer.

**6**. The ultrasonic transducer according to claim 1, wherein each first electrode block is a bar-shaped electrode, and an orthographic projection of the bar-shaped electrode on the second electrode layer overlaps at least two second electrode blocks.

**7**. The ultrasonic transducer according to claim 1, wherein the thickness threshold is ⅛ of the wavelength of the ultrasonic wave emitted by the piezoelectric material layer.

**8**. The ultrasonic transducer according to claim 7, wherein the thickness of each first electrode block is n/4 times the wavelength of the ultrasonic wave, and n is a positive integer.

**9**. The ultrasonic transducer according to claim 1, wherein the ultrasonic transducer further comprises a lens layer located on a side of the first electrode layer that is away from the piezoelectric material layer; and the lens layer comprises a plurality of spaced lenses, and an orthographic projection of each lens on the second electrode layer overlaps at least one second electrode block.

**10**. The ultrasonic transducer according to claim 9, wherein the orthographic projection of each lens on the second electrode layer overlaps one second electrode block, and an orthographic projection of each lens on the first electrode layer overlaps one first electrode block.

**11**. The ultrasonic transducer according to claim 9, wherein: a refractive index of the lens layer is less than a refractive index of an adjacent layer of the lens layer, and all the plurality of lenses are convex lenses; or a refractive index of the lens layer is greater than a refractive index of an adjacent layer of the lens layer, and all the plurality of lenses are concave lenses.

**12**. The ultrasonic transducer according to claim 1, wherein the piezoelectric material layer comprises a plurality of spaced piezoelectric blocks; and an orthographic projection of each piezoelectric block on the second electrode layer overlaps at least one second electrode block.

**13**. The ultrasonic transducer according to claim 12, wherein the orthographic projection of each piezoelectric block on the second electrode layer overlaps one second electrode block, and an orthographic projection of each piezoelectric block on the first electrode layer overlaps one first electrode block.

**14**. The ultrasonic transducer according to claim 1, wherein the ultrasonic transducer further comprises a waveguide layer, and the waveguide layer is located on a side that is of the first electrode layer or the second electrode layer and that is away from the piezoelectric material layer; and the waveguide layer comprises a plurality of spaced waveguide blocks, and an orthographic projection of each waveguide block on the first electrode layer overlaps at least one first electrode block.

**15**. The ultrasonic transducer according to claim 14, wherein if the ultrasonic transducer further comprises the lens layer, the waveguide layer is located between the first electrode layer and the lens layer, and a material of the waveguide layer is the same as a material of the lens layer.

**16**. The ultrasonic transducer according to claim 1, wherein a gap between the plurality of first electrode blocks and a gap between the plurality of second electrode blocks are vacuum or air; or the ultrasonic transducer further comprises a filling material filled between the plurality of first electrode blocks and filled between the plurality of second electrode blocks.

**17**. The ultrasonic transducer according to claim 1, wherein the plurality of second electrode blocks comprise a plurality of electrode groups arranged in the first direction, and each electrode group comprises at least two second electrode blocks arranged in the second direction, wherein every two adjacent electrode groups are arranged in a staggered manner.

**18**. A fingerprint recognition module, the fingerprint recognition module comprising: an ultrasonic transducer, the ultrasonic transducer comprising: a first electrode layer, the first electrode layer comprising a plurality of spaced first electrode blocks; a piezoelectric material layer; and a second electrode layer, the second electrode layer comprising a plurality of spaced second electrode blocks, wherein the second electrode layer, the piezoelectric material layer, and the first electrode layer are sequentially stacked; wherein an orthographic projection of each first electrode block on the second electrode layer overlaps at least one second electrode block, a thickness of each first electrode block is greater than a thickness threshold, and the thickness threshold is positively correlated with a wavelength of an ultrasonic wave emitted by the piezoelectric material layer; and a fingerprint recognition module coupled to the ultrasonic transducer, the fingerprint recognition circuit being configured to: provide a drive signal for the ultrasonic transducer to drive the ultrasonic transducer to emit an ultrasonic wave; and receive an electrical signal generated by the ultrasonic transducer based on a received reflected ultrasonic wave, and perform fingerprint recognition based on the electrical signal.

**19**. An electronic device, comprising: a display; a fingerprint recognition module located on a side of the display, the fingerprint recognition module comprising: an ultrasonic transducer, the ultrasonic transducer comprising: a first electrode layer, the first electrode layer comprising a plurality of spaced first electrode blocks; a piezoelectric material layer; and a second electrode layer, the second electrode layer comprising a plurality of spaced second electrode blocks, wherein the second electrode layer, the piezoelectric material layer, and the first electrode layer are sequentially stacked; wherein an orthographic projection of each first electrode block on the second electrode layer overlaps at least one second electrode block, a thickness of each first electrode block is greater than a thickness threshold, and the thickness threshold is positively correlated with a wavelength of an ultrasonic wave emitted by the piezoelectric material layer; and a fingerprint recognition module coupled to the ultrasonic transducer, the fingerprint recognition circuit being configured to: provide a drive signal for the ultrasonic transducer to drive the ultrasonic transducer to emit an ultrasonic wave; and receive an electrical signal generated by the ultrasonic transducer based on a received reflected ultrasonic wave, and perform fingerprint recognition based on the electrical signal.