

N-POLAR PLANE ALGaN-BASED ULTRAVIOLET PHOTODETECTOR EPITAXIAL STRUCTURE AND PREPARATION METHOD THEREOF

TECHNICAL FIELD

5 The present invention relates to the technical field of photodevice detectors, and in particular to an N-polar plane AlGaN-based ultraviolet photodetector epitaxial structure and a preparation method thereof.

BACKGROUND

10 III-nitride materials, represented by GaN, are hot spot materials of the new-generation photoelectric devices. Due to their relatively wide band gap, high working speed, excellent electrical and thermal conductivity and extremely low loss, they are regarded as excellent alternative materials for realizing miniaturized high-performance photoelectric devices. However, the traditional metal polar AlGaN photodetector
15 epitaxial structure has low thermal stability at high temperature and are susceptible to the polarization field inside the material, and the preparation technique of N-polar plane III-nitride materials is increasingly mature. As a result, the N-polar III-nitride materials are regarded as alternative materials for traditional metal polar AlGaN-based photodetectors. Compared with the traditional metal polar plane, N-polar plane AlGaN
20 has an opposite built-in field direction and a more active surface state. Therefore, at present, the traditional methods for growing the N-polar plane AlGaN materials cannot effectively improve the surface quality of the N-polar plane AlGaN.

SUMMARY

25 In order to overcome the defects in the prior art, the present invention provides an N-polar plane AlGaN-based ultraviolet photodetector epitaxial structure and a preparation method thereof. The N-polar plane AlGaN-based ultraviolet photodetector has high working responsivity and high sensitivity.

A first object of the present invention is to provide an N-polar plane AlGa_N-based ultraviolet photodetector epitaxial structure.

A second object of the present invention is to provide a preparation method of the N-polar plane AlGa_N-based ultraviolet photodetector epitaxial structure.

5 The first object of the present invention can be achieved by the following technical solution:

 An N-polar plane AlGa_N-based ultraviolet photodetector epitaxial structure, including an undoped N-polar plane AlN buffer layer, a carbon-doped semi-insulated N-polar AlN buffer layer, a carbon-doped N-polar plane graded-composition Al_yGa_{1-y}N
10 buffer layer and an undoped N-polar plane Al_xGa_{1-x}N layer sequentially grown on a silicon substrate; where $x=0.5$ to 0.8 and $y=0.75$ to 0.95 .

 Further, the undoped N-polar plane AlN buffer layer includes a low-temperature grown undoped N-polar plane AlN buffer layer and a high-temperature grown undoped N-polar plane AlN buffer layer, the low-temperature grown undoped N-polar plane AlN
15 buffer layer being grown on the silicon substrate, and the high-temperature grown undoped N-polar plane AlN buffer layer being grown on the low-temperature grown undoped N-polar plane AlN buffer layer.

 Further, the low-temperature grown undoped N-polar plane AlN buffer layer has a thickness of 100-150 nm, and the high-temperature grown undoped N-polar plane AlN
20 buffer layer has a thickness of 250-380 nm.

 Further, the carbon-doped semi-insulated N-polar AlN buffer layer has a thickness of 380-440 nm and a doping concentration of 6.0×10^{17} - 4.0×10^{18} cm⁻³.

 Further, the carbon-doped N-polar plane graded-composition Al_yGa_{1-y}N buffer layer has a thickness of 480-630 nm and a doping concentration of 5.0×10^{16} - 2.0×10^{17}
25 cm⁻³.

 Further, the undoped N-polar plane Al_xGa_{1-x}N layer has a thickness of 300-450 nm.

 Further, the silicon substrate is a monocrystalline silicon substrate with an Si(111) close-packed plane as an epitaxy plane and an AlN[0001] orientation as an epitaxial growth orientation of the material.

The second object of the present invention can be achieved by the following technical solution:

A preparation method of the N-polar plane AlGa_N-based ultraviolet photodetector epitaxial structure. The method includes:

5 carrying out ultrasonic cleaning on the silicon substrate, and then carrying out blow-drying;

using pulsed laser deposition process, putting the silicon substrate into a vacuum chamber, and epitaxially growing an undoped N-polar plane AlN buffer layer on the silicon substrate, thereby obtaining prepared N-polar plane AlN sample;

10 using metal organic chemical vapor deposition method, putting the N-polar plane AlN sample into a growth chamber, and introducing NH₃, N₂, H₂, CH₄ and trimethylaluminum into the chamber, thereby epitaxially growing a carbon-doped semi-insulated N-polar AlN buffer layer on the undoped N-polar plane AlN buffer layer;

after the growth of the carbon-doped semi-insulated N-polar AlN buffer layer is
15 completed, reducing a temperature of the growth chamber, and introducing trimethylgallium into the growth chamber, thereby growing in situ a carbon-doped N-polar plane graded-composition AlGa_N buffer layer on the carbon-doped semi-insulated N-polar AlN buffer layer; and

after the growth of the carbon-doped N-polar plane graded-composition AlGa_N
20 buffer layer is completed in metal organic chemical vapor deposition equipment, closing a gas path of the CH₄, increasing the temperature of the growth chamber, and growing in situ an undoped N-polar plane AlGa_N layer on the carbon-doped N-polar plane graded-composition AlGa_N buffer layer while controlling the change of the composition Al of the film by adjusting a flow rate of the trimethylaluminum and a growth temperature.

25 Further, the epitaxially growing the undoped N-polar plane AlN buffer layer on the silicon substrate, thereby obtaining prepared the N-polar plane AlN sample specifically includes:

growing a low-temperature grown undoped N-polar plane AlN buffer layer on the silicon substrate under N-rich conditions by using an AlN high-purity ceramic target as

an Al source; and

after the growth of the low-temperature grown undoped N-polar plane AlN buffer layer is completed, increasing the temperature of the system, keeping a vacuum, a laser energy, a laser frequency and a nitrogen flow rate in the vacuum chamber unchanged, and growing a high-temperature grown undoped N-polar plane AlN buffer layer on the low-temperature grown undoped N-polar plane AlN buffer layer, thereby obtaining prepared the N-polar plane AlN sample.

Further, the silicon substrate is a monocrystalline silicon substrate with an Si(111) close-packed plane as an epitaxy plane and an AlN[0001] orientation as an epitaxial growth orientation of the material.

Compared with the prior art, the present invention has the following advantages:

1. According to the N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure provided by the present invention, the carbon-doped stepwise N-polar AlGaIn film is grown under the undoped N-polar plane AlGaIn layer. By increasing the mobility of charge carriers, the production of the photocurrent of the undoped N-polar AlGaIn film can be effectively increased, and the power and detectivity of the AlGaIn-based ultraviolet detectors can be improved.

2. Compared with the metal polar AlGaIn material, the N-polar AlGaIn used as the base material of the device can effectively improve the high-temperature stability of the device structure, reduce the influence of the polarization field inside the AlGaIn, effectively improve the photoelectric responsivity of the ultraviolet photodetector, and effectively reduce the processing difficulty of subsequent devices.

3. By using the two-step growing method of low-temperature pulsed laser deposition and high-temperature MOCVD to grow the material required by the N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure and through the structural design of the stepwise AlGaIn epitaxy buffer layer, the etching reaction in furnace between the III-nitrides and the silicon substrate at high temperature and the heterostructures of large lattice mismatch can be effectively inhibited, thereby reducing the dislocation density and surface roughness of the N-polar AlGaIn epitaxial layer grown

by high-temperature MOCVD.

BRIEF DESCRIPTION OF DRAWINGS

In order to more clearly illustrate the embodiments of the present invention or the technical solutions in the prior art, the accompanying drawings used in the description of the embodiments or the prior art will be briefly described below. Apparently, the accompanying drawings in the following description are only some embodiments of the present invention, and those skilled in the art can obtain other drawings according to the structures shown in these drawings without any creative work.

FIG. 1 is a schematic diagram of an N-polar plane AlGa_N-based ultraviolet photodetector epitaxial structure according to an embodiment of the present invention;

FIG. 2 is an atomic force microscopy image showing surface topography of an N-polar AlGa_N epitaxial wafer according to an embodiment of the present invention; and

FIG. 3 is an X-ray rocking curve test chart of an N-polar AlGa_N (0002) film according to an embodiment of the present invention.

In FIG. 1:

1-silicon substrate, 2-low-temperature grown undoped N-polar plane AlN buffer layer, 3-high-temperature grown undoped N-polar plane AlN buffer layer, 4-carbon-doped semi-insulated N-polar AlN buffer layer, 5-carbon-doped N-polar plane graded-composition AlGa_N buffer layer, 6-undoped N-polar plane AlGa_N layer.

DETAILED DESCRIPTION OF EMBODIMENTS

In order to make the objectives, technical solutions and advantages of the embodiments of the present invention clearer, the technical solutions in the embodiments of the present invention will be clearly and completely described below in conjunction the accompanying drawings in the embodiments of the present invention. It is apparent that the described embodiments are a part of the embodiments, rather than all of the embodiments of the present invention. All other embodiments obtained by those of ordinary skill in the art based on the embodiments in the present invention without

creative work are within the protection scope of the present invention. It should be understood that the specific embodiments described herein are merely illustrative of this application and are not intended to limit this application.

Embodiments:

5 This embodiment provides a preparation method of an N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure. The method includes:

 The silicon substrate is a monocrystalline silicon substrate with an Si(111) close-packed plane as an epitaxy plane and an AlN[0001] orientation as an epitaxial growth orientation of the material.

10 The silicon substrate is sequentially subjected to ultrasonic cleaning in three media, namely acetone, anhydrous ethanol and deionized water, then rinsed with deionized water and blow-dried with hot high-purity nitrogen.

 Pulsed laser deposition process is used, the silicon substrate is put into a vacuum chamber. The temperature is increased to 420-500°C, and the vacuum chamber is
15 evacuated to a vacuum of 2.0×10^{-4} - 4.0×10^{-4} torr. Under the conditions of a laser energy of 250-320 mJ, a laser frequency of 15-30 Hz and a nitrogen flow rate of 2-10 sccm, an N-polar AlN film is grown under N-rich conditions by using an AlN high-purity ceramic target as an Al source.

 After the growth of the N-polar AlN film is completed, the temperature is increased
20 to 850°C, the vacuum, the laser energy, the laser frequency and the nitrogen flow rate in the vacuum chamber are kept unchanged, and a high-temperature grown undoped N-polar plane AlN buffer layer is epitaxially grown on the N-polar AlN film, thereby obtaining prepared the N-polar plane AlN sample.

 Metal organic chemical vapor deposition method (MOCVD technology) is used.
25 The N-polar plane AlN sample is put into a growth chamber. The growth chamber is evacuated to a vacuum of 2.0×10^{-6} - 4.0×10^{-6} torr, the temperature is increased to 1000-1100°C, and NH_3 , N_2 , H_2 , CH_4 and trimethylaluminum are introduced into the growth chamber, thereby epitaxially growing a carbon-doped semi-insulated N-polar AlN buffer layer on the epitaxial wafer of the high-temperature undoped N-polar plane AlN buffer

layer. During the vapor deposition, the pressure of the reaction chamber is 180-220 torr, and the flow rates of the NH_3 , the H_2 , the CH_4 and the trimethylaluminum are respectively 30-50 slm, 60-100 slm, 10-20 slm and 350-440 sccm.

After the growth of the carbon-doped semi-insulated N-polar AlN buffer layer is completed, the temperature of the growth chamber is reduced to 770-800°C, and trimethylgallium is introduced into the growth chamber, thereby growing in situ a carbon-doped N-polar plane graded-composition AlGaN buffer layer on the epitaxial wafer. During the vapor deposition, the pressure in the reaction chamber is 180-240 torr, and the flow rates of the NH_3 , the H_2 , the CH_4 , the trimethylaluminum and the trimethylgallium are respectively 30-50 slm, 60-100 slm, 15-24 slm, 400-450 sccm and 100-150 sccm.

After the growth of the carbon-doped N-polar plane graded-composition AlGaN buffer layer is completed in the MOCVD, a gas path of the CH_4 is closed, the temperature of the growth chamber is increased to 820-850°C, and an undoped N-polar plane AlGaN layer is grown in situ on the epitaxial wafer. During the vapor deposition, the pressure of the reaction chamber is 180-240 torr, and the flow rates of the NH_3 , the H_2 , the trimethylaluminum and the trimethylgallium are respectively 30-50 slm, 60-100 slm, 400-450 sccm and 100-150 sccm. At the same time, the change of the composition Al of the film is controlled by adjusting the flow rate of the trimethylaluminum and the growth temperature.

The N-polar plane AlGaN-based ultraviolet photodetector epitaxial structure prepared in this embodiment is shown in FIG. 1.

In one embodiment, a preparation method of an N-polar plane AlGaN-based ultraviolet photodetector epitaxial structure specifically included:

(1) Selection of substrate and crystal orientation of the substrate: The substrate was a monocrystalline silicon substrate with an Si(111) close-packed plane as an epitaxy plane and an AlN[0001] orientation as an epitaxial growth orientation of the material.

(2) Surface cleaning of substrate: The silicon substrate was sequentially subjected to ultrasonic cleaning for 5 min in three media, namely acetone, anhydrous ethanol and

deionized water, then rinsed with deionized water and blow-dried with hot high-purity nitrogen.

(3) Low-temperature epitaxial growth of undoped N-polar plane AlN buffer layer: Pulsed laser deposition process was used, the clean substrate was put into a vacuum chamber. The temperature of the substrate was increased to 450°C, and the vacuum chamber was evacuated to a vacuum of 2.0×10^{-4} torr. Under the conditions of a laser energy of 300 mJ, a laser frequency of 15 Hz and a nitrogen flow rate of 4 sccm, an N-polar AlN film was grown under N-rich conditions by using an AlN high-purity ceramic target as an Al source.

(4) High-temperature epitaxial growth of undoped N-polar plane AlN buffer layer: The temperature was increased to 850°C, and other parameters were the same as in step (3).

(5) Epitaxial growth of carbon-doped N-polar AlN layer: MOCVD technology was used. The prepared N-polar plane AlN sample was put into a growth chamber. The growth chamber was evacuated to a vacuum of 3.0×10^{-6} torr, the temperature was increased to 1050°C, and NH₃, N₂, H₂, CH₄ and trimethylaluminum were introduced into the growth chamber, thereby epitaxially growing the carbon-doped N-polar plane AlN layer on the epitaxial wafer obtained in step (4). During the vapor deposition, the pressure of the reaction chamber was 200 torr, and the flow rates of the NH₃, the H₂, the CH₄ and the trimethylaluminum were respectively 40 slm, 75 slm, 17 slm and 400 sccm.

(6) Epitaxial growth of carbon-doped N-polar plane graded-composition Al_yGa_{1-y}N layer: After the growth of the film in step (5) was completed in the MOCVD, the temperature of the growth chamber was reduced to 780°C, and trimethylgallium was introduced into the growth chamber, thereby growing in situ the carbon-doped N-polar plane graded-composition AlGaN buffer layer on the epitaxial wafer. During the vapor deposition, the pressure of the reaction chamber was 210 torr, and the flow rates of the NH₃, the H₂, the CH₄, the trimethylaluminum and the trimethylgallium were respectively 40 slm, 80 slm, 20 slm, 400 sccm, and 20/100 sccm (when y=0.95, the flow rate was 20 sccm; when y=0.75, the flow rate was 100 sccm).

(7) Epitaxial growth of undoped N-polar $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer: After the growth of the film in step (6) was completed in the MOCVD, a gas path of the CH_4 was closed, the temperature of the growth chamber was increased to 830°C , and the undoped N-polar plane AlGa N layer was grown in situ on the epitaxial wafer. During the vapor deposition, the pressure of the reaction chamber was 210 torr, and the flow rates of the NH_3 , the H_2 , the trimethylaluminum and the trimethylgallium were respectively 40 slm, 80 slm, 430 sccm and 120 sccm. At the same time, the change of the composition Al of the film was controlled by adjusting the flow rate of the trimethylaluminum and the growth temperature.

The N-polar plane AlGa N -based ultraviolet photodetector epitaxial structure obtained in this embodiment included the undoped N-polar plane AlN buffer layer (including the low-temperature grown undoped N-polar plane AlN buffer layer 2 and the high-temperature grown undoped N-polar plane AlN buffer layer 3), the carbon doped N-polar plane AlN layer 4, the carbon-doped N-polar plane graded-composition $\text{Al}_y\text{Ga}_{1-y}\text{N}$ buffer layer 5 and the undoped N-polar plane $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer 6 sequentially grown on the silicon substrate 1. The undoped N-polar plane AlN buffer layer had a thickness of 420 nm. The low-temperature grown undoped N-polar plane AlN buffer layer had a thickness of 120 nm, and the high-temperature grown undoped N-polar plane AlN buffer layer had a thickness of 300 nm. The carbon-doped N-polar plane AlN layer had a thickness of 380 nm and a doping concentration of $2.0 \times 10^{18} \text{ cm}^{-3}$. The carbon-doped N-polar plane graded-composition $\text{Al}_y\text{Ga}_{1-y}\text{N}$ (the value of y changed from 0.95 to 0.75 from bottom to top) buffer layer had a thickness of 500 nm and a doping concentration of $1.5 \times 10^{17} \text{ cm}^{-3}$. The undoped N-polar plane $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer had a thickness of 300 nm.

The N-polar plane AlGa N -based ultraviolet photodetector epitaxial structure prepared in this embodiment is shown in FIG. 1. In the epitaxial structure grown under such growth conditions, an atomic force microscopy image of the surface of the AlGa N film is shown in FIG. 2. As can be seen, the AlGa N film has good surface quality. An X-ray rocking curve test result of the N-polar AlGa N (0002) film is shown in FIG. 3. As can be seen, the film has good crystal quality.

In one embodiment, a preparation method of an N-polar plane AlGaN-based ultraviolet photodetector epitaxial structure specifically included:

(1) Selection of substrate and crystal orientation of the substrate: The substrate was a monocrystalline silicon substrate with an Si(111) close-packed plane as an epitaxy
5 plane and an AlN[0001] orientation as an epitaxial growth orientation of the material.

(2) Surface cleaning of substrate: The silicon substrate was sequentially subjected to ultrasonic cleaning for 5 min in three media, namely acetone, anhydrous ethanol and deionized water, then rinsed with deionized water and blow-dried with hot high-purity nitrogen.

10 (3) Low-temperature epitaxial growth of undoped N-polar plane AlN buffer layer: Pulsed laser deposition was used. The clean substrate was put into a vacuum chamber. The temperature of the substrate was increased to 420°C, and the vacuum chamber was evacuated to a vacuum of 2.0×10^{-4} torr. Under the conditions of a laser energy of 250mJ, a laser frequency of 15 Hz and a nitrogen flow rate of 2 sccm, an N-polar AlN film was
15 grown under N-rich conditions by using an AlN high-purity ceramic target as an Al source.

(4) High-temperature epitaxial growth of undoped N-polar plane AlN buffer layer: The temperature was increased to 950°C, and other parameters were the same as in step (3).

20 (5) Epitaxial growth of carbon-doped N-polar AlN layer: MOCVD technology was used. The prepared N-polar plane AlN sample was put into a growth chamber. The growth chamber was evacuated to a vacuum of 2.0×10^{-6} torr, the temperature was increased to 1000°C, and NH₃, N₂, H₂, CH₄ and trimethylaluminum were introduced into the growth chamber, thereby epitaxially growing the carbon-doped N-polar plane AlN layer on the
25 epitaxial wafer obtained in step (4). During the vapor deposition, the pressure of the reaction chamber was 180 torr, and the flow rates of the NH₃, the H₂, the CH₄ and the trimethylaluminum were respectively 30 slm, 65 slm, 13 slm and 380 sccm.

(6) Epitaxial growth of carbon-doped N-polar plane graded-composition Al_yGa_{1-y}N layer: After the growth of the film in step (5) was completed in the MOCVD, the

temperature of the growth chamber was reduced to 780°C, and trimethylgallium was introduced into the growth chamber, thereby growing in situ the carbon-doped N-polar plane graded-composition AlGa_xN buffer layer on the epitaxial wafer. During the vapor deposition, the pressure of the reaction chamber was 210 torr, and the flow rates of the NH₃, the H₂, the CH₄, the trimethylaluminum and the trimethylgallium were respectively 30 slm, 60 slm, 15 slm, 420 sccm, and 20/100 sccm (when y=0.95, the flow rate was 20 sccm; when y=0.75, the flow rate was 100 sccm).

(7) Epitaxial growth of undoped N-polar Al_xGa_{1-x}N layer: After the growth of the film in step (6) was completed in the MOCVD, a gas path of the CH₄ was closed, the temperature of the growth chamber was increased to 830°C, and the undoped N-polar plane AlGa_xN layer was grown in situ on the epitaxial wafer. During the vapor deposition, the pressure of the reaction chamber was 210 torr, and the flow rates of the NH₃, the H₂, the trimethylaluminum and the trimethylgallium were respectively 40 slm, 80 slm, 430 sccm and 120 sccm. At the same time, the change of the composition Al of the film was controlled by adjusting the flow rate of the trimethylaluminum and the growth temperature.

The N-polar plane AlGa_xN-based ultraviolet photodetector epitaxial structure obtained in this embodiment included the undoped N-polar plane AlN buffer layer, the carbon doped N-polar plane AlN layer, the carbon-doped N-polar plane graded-composition Al_yGa_{1-y}N buffer layer (y=0.95 to 0.75 from bottom to top) and the undoped N-polar plane Al_xGa_{1-x}N layer sequentially grown on the silicon substrate. The undoped N-polar plane AlN buffer layer had a thickness of 420 nm. The low-temperature grown undoped N-polar plane AlN buffer layer had a thickness of 120 nm, and the high-temperature grown undoped N-polar plane AlN buffer layer had a thickness of 300 nm. The carbon-doped N-polar plane AlN layer had a thickness of 380 nm and a doping concentration of 6.0×10^{17} - 4.0×10^{18} cm⁻³. The carbon-doped N-polar plane graded-composition Al_yGa_{1-y}N (y=0.95 to 0.75 from bottom to top) buffer layer had a thickness of 500 nm and a doping concentration of 5.0×10^{16} - 2.0×10^{17} cm⁻³. The undoped N-polar plane Al_xGa_{1-x}N layer had a thickness of 300 nm.

The test result of the N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure prepared in this embodiment is shown in FIG. 3.

In one embodiment, a preparation method of an N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure specifically included:

5 (1) Selection of substrate and crystal orientation of the substrate: The substrate was a monocrystalline silicon substrate with an Si(111) close-packed plane as an epitaxy plane and an AlN[0001] orientation as an epitaxial growth orientation of the material.

(2) Surface cleaning of substrate: The silicon substrate was sequentially subjected to ultrasonic cleaning for 5 min in three media, namely acetone, anhydrous ethanol and
10 deionized water, then rinsed with deionized water and blow-dried with hot high-purity nitrogen.

(3) Low-temperature epitaxial growth of undoped N-polar plane AlN buffer layer: Pulsed laser deposition process was used, the clean substrate was put into a vacuum chamber. The temperature of the substrate was increased to 500°C, and the vacuum
15 chamber was evacuated to a vacuum of 2.0×10^{-4} torr. Under the conditions of a laser energy of 320mJ, a laser frequency of 25Hz and a nitrogen flow rate of 10 sccm, an N-polar AlN film was grown under N-rich conditions by using an AlN high-purity ceramic target as an Al source.

(4) High-temperature epitaxial growth of undoped N-polar plane AlN buffer layer:
20 The temperature was increased to 1000°C, and other parameters were the same as in step (3).

(5) Epitaxial growth of carbon-doped N-polar AlN layer: MOCVD technology was used. The prepared N-polar plane AlN sample was put into a growth chamber. The growth chamber was evacuated to a vacuum of 4.0×10^{-6} torr, the temperature was increased to
25 1100°C, and NH_3 , N_2 , H_2 , CH_4 and trimethylaluminum were introduced into the growth chamber, thereby epitaxially growing the carbon-doped N-polar plane AlN layer on the epitaxial wafer obtained in step (4). During the vapor deposition, the pressure of the reaction chamber was 200 torr (180-220), and the flow rates of the NH_3 , the H_2 , the CH_4 and the trimethylaluminum were respectively 50 slm, 85 slm, 20 slm and 440 sccm.

(6) Epitaxial growth of carbon-doped N-polar plane graded-composition $\text{Al}_y\text{Ga}_{1-y}\text{N}$ layer: After the growth of the film in step (5) was completed in the MOCVD, the temperature of the growth chamber was reduced to 780°C , and trimethylgallium was introduced into the growth chamber, thereby growing in situ the carbon-doped N-polar plane graded-composition AlGa_N buffer layer on the epitaxial wafer. During the vapor deposition, the pressure of the reaction chamber was 210 torr, and the flow rates of the NH_3 , the H_2 , the CH_4 , the trimethylaluminum and the trimethylgallium were respectively 50 slm, 100 slm, 24 slm, 450 sccm, and 20/100 sccm (when $y=0.95$, the flow rate was 20 sccm; when $y=0.75$, the flow rate was 100 sccm).

(7) Epitaxial growth of undoped N-polar $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer: After the growth of the film in step (6) was completed in the MOCVD, a gas path of the CH_4 was closed, the temperature of the growth chamber was increased to 850°C , and the undoped N-polar plane AlGa_N layer was grown in situ on the epitaxial wafer. During the vapor deposition, the pressure of the reaction chamber was 240 torr, and the flow rates of the NH_3 , the H_2 , the trimethylaluminum and the trimethylgallium were respectively 50 slm, 100 slm, 450 sccm and 120 sccm. At the same time, the change of the composition Al of the film was controlled by adjusting the flow rate of the trimethylaluminum and the growth temperature.

The N-polar plane AlGa_N-based ultraviolet photodetector epitaxial structure obtained in this embodiment included the undoped N-polar plane AlN buffer layer, the carbon doped N-polar plane AlN layer, the carbon-doped N-polar plane graded-composition $\text{Al}_y\text{Ga}_{1-y}\text{N}$ buffer layer ($y=0.95$ to 0.75 from bottom to top) and the undoped N-polar plane $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer sequentially grown on the silicon substrate. The undoped N-polar plane AlN buffer layer had a thickness of 500 nm. The low-temperature grown undoped N-polar plane AlN buffer layer had a thickness of 150 nm, and the high-temperature grown undoped N-polar plane AlN buffer layer had a thickness of 350 nm. The carbon-doped N-polar plane AlN layer had a thickness of 400 nm and a doping concentration of $2.0 \times 10^{18} \text{ cm}^{-3}$. The carbon-doped N-polar plane graded-composition $\text{Al}_y\text{Ga}_{1-y}\text{N}$ ($y=0.95$ to 0.75 from bottom to top) buffer layer had a thickness of 550 nm

and a doping concentration of $1.5 \times 10^{17} \text{ cm}^{-3}$. The undoped N-polar plane $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer had a thickness of 350 nm.

The test result of the N-polar plane AlGaN-based ultraviolet photodetector epitaxial structure prepared in this embodiment is shown in FIG. 3.

5 The foregoing descriptions are merely preferred embodiments of the present invention, but the protection scope of the present invention is not limited thereto. Any equivalent substitution or change made based on the technical solution and inventive concept of the present invention by those skilled in the art within the scope disclosed in the present invention shall fall within the protection scope of the present invention.

CLAIMS

1. An N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure, characterized in that, the N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure comprises: an undoped N-polar plane AlN buffer layer, a carbon-doped semi-insulated N-polar AlN buffer layer, a carbon-doped N-polar plane graded-composition $\text{Al}_y\text{Ga}_{1-y}\text{N}$ buffer layer and an undoped N-polar plane $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer sequentially grown on a silicon substrate; wherein $x=0.5$ to 0.8 and $y=0.75$ to 0.95 .

2. The N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure according to claim 1, wherein the undoped N-polar plane AlN buffer layer comprises a low-temperature grown undoped N-polar plane AlN buffer layer and a high-temperature grown undoped N-polar plane AlN buffer layer, the low-temperature grown undoped N-polar plane AlN buffer layer being grown on the silicon substrate, and the high-temperature grown undoped N-polar plane AlN buffer layer being grown on the low-temperature grown undoped N-polar plane AlN buffer layer.

3. The N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure according to claim 2, wherein the low-temperature grown undoped N-polar plane AlN buffer layer has a thickness of $100\text{-}150\text{ nm}$, and the high-temperature grown undoped N-polar plane AlN buffer layer has a thickness of $250\text{-}380\text{ nm}$.

4. The N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure according to claim 1, wherein the carbon-doped semi-insulated N-polar AlN buffer layer has a thickness of $380\text{-}440\text{ nm}$ and a doping concentration of $6.0\times 10^{17}\text{-}4.0\times 10^{18}\text{ cm}^{-3}$.

5. The N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure according to claim 1, wherein the carbon-doped N-polar plane graded-composition $\text{Al}_y\text{Ga}_{1-y}\text{N}$ buffer layer has a thickness of $480\text{-}630\text{ nm}$ and a doping concentration of $5.0\times 10^{16}\text{-}2.0\times 10^{17}\text{ cm}^{-3}$.

6. The N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure according to claim 1, wherein the undoped N-polar plane $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer has a thickness of $300\text{-}450\text{ nm}$.

7. The N-polar plane AlGaIn-based ultraviolet photodetector epitaxial structure according to any of claims 1 to 6, wherein the silicon substrate is a monocrystalline silicon substrate with an Si(111) close-packed plane as an epitaxy plane and an AlN[0001] orientation as an epitaxial

growth orientation of the material.

8. A preparation method of the N-polar plane AlGa_N-based ultraviolet photodetector epitaxial structure according to any of claims 1 to 7, comprising:

carrying out ultrasonic cleaning on the silicon substrate, and then carrying out blow-drying;

using pulsed laser deposition process, putting the silicon substrate into a vacuum chamber, and epitaxially growing an undoped N-polar plane AlN buffer layer on the silicon substrate, thereby obtaining prepared N-polar plane AlN sample;

using metal organic chemical vapor deposition method, putting the N-polar plane AlN sample into a growth chamber, and introducing NH₃, N₂, H₂, CH₄ and trimethylaluminum into the chamber, thereby epitaxially growing a carbon-doped semi-insulated N-polar AlN buffer layer on the undoped N-polar plane AlN buffer layer;

after the growth of the carbon-doped semi-insulated N-polar AlN buffer layer is completed, reducing a temperature of the growth chamber, and introducing trimethylgallium into the growth chamber, thereby growing in situ a carbon-doped N-polar plane graded-composition AlGa_N buffer layer on the carbon-doped semi-insulated N-polar AlN buffer layer; and

after the growth of the carbon-doped N-polar plane graded-composition AlGa_N buffer layer is completed in metal organic chemical vapor deposition equipment, closing a gas path of the CH₄, increasing the temperature of the growth chamber, and growing in situ an undoped N-polar plane AlGa_N layer on the carbon-doped N-polar plane graded-composition AlGa_N buffer layer while controlling the change of the composition Al of the film by adjusting a flow rate of the trimethylaluminum and a growth temperature.

9. The preparation method according to claim 8, wherein the epitaxially growing the undoped N-polar plane AlN buffer layer on the silicon substrate, thereby obtaining prepared N-polar plane AlN sample specifically comprises:

growing a low-temperature grown undoped N-polar plane AlN buffer layer on the silicon substrate under N-rich conditions by using an AlN high-purity ceramic target as an Al source; and

after the growth of the low-temperature grown undoped N-polar plane AlN buffer layer is completed, increasing the temperature of the system, keeping a vacuum, a laser energy, a laser frequency and a nitrogen flow rate in the vacuum chamber unchanged, and growing a high-temperature grown undoped N-polar plane AlN buffer layer on the low-temperature grown undoped N-polar plane AlN buffer layer, thereby obtaining prepared N-polar plane AlN sample.

10. The preparation method according to claim 8, wherein the silicon substrate is a monocrystalline silicon substrate with an Si(111) close-packed plane as an epitaxy plane and an AlN[0001] orientation as an epitaxial growth orientation of the material.