

It is therefore an object of the invention to provide a GaN layer with a reduced defect density grown on a silicon substrate.

Summary of the invention

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The present invention relates to a semiconductor wafer comprising the following layers in the given order:

- a monocrystalline substrate wafer consisting essentially of silicon and having a (111) surface orientation,
- 10 - a monocrystalline layer of Sc_2O_3 having a (111) surface orientation,
- a monocrystalline layer of ScN having a (111) surface orientation, and
- a monocrystalline layer of $\text{Al}_z\text{Ga}_{1-z}\text{N}$ with $0 \leq z \leq 1$ having a
- 15 (0001) surface orientation, characterised in that the layer of ScN has a thickness of 2 to 500 nm.

The invention also relates to a process for the production of said semiconductor wafer, comprising the following steps in the given

20 order:

- a) providing the substrate wafer,
- c) epitaxially depositing the layer of Sc_2O_3 ,
- d) producing the layer of ScN, and
- 25 f) epitaxially depositing the layer of $\text{Al}_z\text{Ga}_{1-z}\text{N}$, characterised in that the layer of ScN has a thickness of 2 to 500 nm.

As mentioned above, Sc_2O_3 buffer layers have already been known for the subsequent deposition of GaN. According to the bulk crystal

30 lattices, an Sc_2O_3 buffer layer theoretically allows to reduce the lattice misfit between GaN and the substrate from 17 % (GaN/Si) to 8 % (GaN/ Sc_2O_3). However, the remaining lattice mismatch still leads to the generation of a high density of defects (mainly

35 dislocations) in the GaN layer and therefore limits the quality of this layer.

the Si surface. A poor quality ScN layer on a silicon substrate may not fully cover the silicon, such that the silicon may be exposed to the Ga and NH_3 during the growth of the GaN top layer. The crystallinity of the ScN buffer layer was shown to affect the morphology, residual strain and crystallinity of the subsequently grown GaN.

In the stack of layers according to an embodiment of the present invention, the lattice misfit of ScN on Sc_2O_3 is reduced compared to that of ScN on Si. Therefore, the crystal quality of ScN is improved and the above-described effects of a poor quality ScN layer do not occur. A GaN layer with high quality can finally be grown on the ScN layer according to the embodiment of the present invention.

Short description of the figures

Fig. 1 schematically illustrates an embodiment of the present invention.

Fig. 2 shows the result of a specular $\theta/2\theta$ XRD measurement demonstrating the growth of (111) oriented ScN in rock-salt structure on a $\text{Sc}_2\text{O}_3(111)$ / $\text{Y}_2\text{O}_3(111)$ / $\text{Si}(111)$ heterostructure.

Fig. 3 shows the result of an XRD ϕ -scan over a family of {111} Si and ScN lattice planes demonstrating the twin-free growth of ScN(111).

Detailed description of the invention and the preferred embodiments

In the first **step a)** (cf. Fig. 1), a monocrystalline substrate wafer 1 is provided, which consists essentially of monocrystalline silicon, preferably it consists of 90 % to 100 % silicon, more preferably of 98 % to 100 % silicon. The

Claims

1. A semiconductor wafer comprising the following layers in the given order:

- 5 - a monocrystalline substrate wafer (1) consisting essentially of silicon and having a (111) surface orientation,
- a monocrystalline layer (3) of Sc_2O_3 having a (111) surface orientation,
- a monocrystalline layer (4) of ScN having a (111) surface
10 orientation, and
- a monocrystalline layer (6) of $\text{Al}_z\text{Ga}_{1-z}\text{N}$ with $0 \leq z \leq 1$ having a (0001) surface orientation.

2. The semiconductor wafer according to claim 1, additionally
15 comprising a monocrystalline metal oxide layer (2) between the substrate wafer (1) and the layer (3) of Sc_2O_3 .

3. The semiconductor wafer according to claim 2, wherein the metal oxide layer (2) has a cubic Ia-3 crystal structure and a
20 composition of $(\text{Me}_1\text{Me}_2)_{2\text{O}_3}$ with $0 \leq w \leq 1$, wherein Me1 is a first metal and Me2 is a second metal, wherein the metal oxide layer (2) is located between the substrate wafer (1) and the layer (3) of Sc_2O_3 , and wherein Me1, Me2 and w are selected such that the lattice constant of the metal oxide layer (2) is equal
25 to or smaller than the lattice constant of the substrate wafer (1) and equal to or larger than the lattice constant of the layer (3) of Sc_2O_3 .

4. The semiconductor wafer according to one of claims 1 to 3,
30 wherein the layer (3) of Sc_2O_3 has a thickness of 2 to 500 nm.

5. The semiconductor wafer according to one of claims 1 to 4, wherein the layer (4) of ScN has a thickness of 2 to 500 nm.

6. The semiconductor wafer according to any one of claims 1 to 5, additionally comprising a monocrystalline metal nitride layer (5) having a composition of $(\text{Al}_x\text{Ga}_{1-x})_y\text{Sc}_{1-y}\text{N}$ with $0 \leq x \leq 1$ and $0 < y < 1$, the metal nitride layer (5) being located
5 between the layer (4) of ScN and the layer (6) of $\text{Al}_z\text{Ga}_{1-z}\text{N}$.

7. The semiconductor wafer according to any one of claims 1 to 6, wherein $z = 0$.

10 8. A process for the production of the semiconductor wafer according to claim 1, comprising the following steps in the given order:

- a) providing the substrate wafer (1),
- c) epitaxially depositing the layer (3) of Sc_2O_3 ,
- 15 d) producing the layer (4) of ScN, and
- f) epitaxially depositing the layer (6) of $\text{Al}_z\text{Ga}_{1-z}\text{N}$.

9. The process according to claim 8, wherein a monocrystalline metal oxide layer (2) is epitaxially deposited in an additional
20 step b) after step a) and prior to step c).

10. The process according to any one of claims 8 or 9, wherein step c) is performed by means of CVD, MBE, PLD or sputtering techniques.

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11. The process according to any one of claims 8 to 10, wherein in step d) the layer (4) of ScN is produced by converting the surface of the layer (3) of Sc_2O_3 into ScN by exposing the surface to an atmosphere comprising a nitrogen source at a
30 temperature of 200 to 1200 °C.

12. The process according to any one of claims 8 to 10, wherein in step d) the layer (4) of ScN is produced by depositing a layer of Sc on the surface of the layer (3) of Sc_2O_3 and
35 subsequently exposing the surface of the layer of Sc to an

atmosphere comprising a nitrogen source at a temperature of 200 to 1200 °C and thus converting the layer of Sc into the layer (4) of ScN.

5 13. The process according to any one of claims 8 to 10, wherein in step d) the layer (4) of ScN is produced by epitaxially depositing the layer (4) of ScN on the surface of the layer (3) of Sc_2O_3 .

10 14. The process according to any one of claims 8 to 13, wherein a monocrystalline metal nitride layer (5) having a composition of $(\text{Al}_x\text{Ga}_{1-x})_y\text{Sc}_{1-y}\text{N}$ with $0 \leq x \leq 1$ and $0 < y < 1$ is epitaxially deposited in an additional step e) after step d) and prior to step f).

15 15. The process according to any one of claims 8 to 14, wherein step f) is performed by means of MOCVD or MBE.

Claims

1. A semiconductor wafer comprising the following layers in the given order:

- a monocrystalline substrate wafer consisting essentially of silicon and having a (111) surface orientation,
- a monocrystalline layer of Sc_2O_3 having a (111) surface orientation,
- a monocrystalline layer of ScN having a (111) surface orientation, and
- a monocrystalline layer of $\text{Al}_z\text{Ga}_{1-z}\text{N}$ with $0 \leq z \leq 1$ having a (0001) surface orientation,

characterised in that the layer of ScN has a thickness of 2 to 500 nm.

2. The semiconductor wafer according to claim 1, additionally comprising a monocrystalline metal oxide layer between the substrate wafer and the layer of Sc_2O_3 .

3. The semiconductor wafer according to claim 2, wherein the metal oxide layer has a cubic Ia-3 crystal structure and a composition of $(\text{Me}_1\text{Me}_{2(1-w)})_2\text{O}_3$ with $0 \leq w \leq 1$, wherein Me1 is a first metal and Me2 is a second metal, wherein the metal oxide layer is located between the substrate wafer and the layer of Sc_2O_3 , and wherein Me1, Me2 and w are selected such that the lattice constant of the metal oxide layer is equal to or smaller than the lattice constant of the substrate wafer and equal to or larger than the lattice constant of the layer of Sc_2O_3 .

4. The semiconductor wafer according to one of claims 1 to 3, wherein the layer of Sc_2O_3 has a thickness of 2 to 500 nm.

5. The semiconductor wafer according to any one of claims 1 to 4, additionally comprising a monocrystalline metal nitride

layer having a composition of $(\text{Al}_x\text{Ga}_{1-x})_y\text{Sc}_{1-y}\text{N}$ with $0 \leq x \leq 1$ and $0 < y < 1$, the metal nitride layer being located between the layer of ScN and the layer of $\text{Al}_z\text{Ga}_{1-z}\text{N}$.

5 6. The semiconductor wafer according to any one of claims 1 to 5, wherein $z = 0$.

7. A process for the production of the semiconductor wafer according to claim 1, comprising the following steps in the
10 given order:

- a) providing the substrate wafer,
- c) epitaxially depositing the layer of Sc_2O_3 ,
- d) producing the layer of ScN, and
- f) epitaxially depositing the layer of $\text{Al}_z\text{Ga}_{1-z}\text{N}$,

15 characterised in that the layer of ScN has a thickness of 2 to 500 nm.

8. The process according to claim 7, wherein a monocrystalline metal oxide layer is epitaxially deposited in an additional
20 step b) after step a) and prior to step c).

9. The process according to any one of claims 7 or 8 wherein step c) is performed by means of CVD, MBE, PLD or sputtering techniques.

25 10. The process according to any one of claims 7 to 9 wherein in step d) the layer of ScN is produced by converting the surface of the layer of Sc_2O_3 into ScN by exposing the surface to an atmosphere comprising a nitrogen source at a temperature
30 of 200 to 1200 °C.

11. The process according to any one of claims 7 to 9 wherein in step d) the layer of ScN is produced by depositing a layer of Sc on the surface of the layer of Sc_2O_3 and subsequently
35 exposing the surface of the layer of Sc to an atmosphere

comprising a nitrogen source at a temperature of 200 to 1200 °C and thus converting the layer of Sc into the layer of ScN.

12. The process according to any one of claims 7 to 9 wherein
5 in step d) the layer of ScN is produced by epitaxially depositing the layer of ScN on the surface of the layer of Sc_2O_3 .

13. The process according to any one of claims 7 to 12 wherein
10 a monocrystalline metal nitride layer having a composition of $(\text{Al}_x\text{Ga}_{1-x})_y\text{Sc}_{1-y}\text{N}$ with $0 \leq x \leq 1$ and $0 < y < 1$ is epitaxially deposited in an additional step e) after step d) and prior to step f).

14. The process according to any one of claims 7 to 13 wherein
15 step f) is performed by means of MOCVD or MBE.