Several techniques have been developed in an attempt to relieve the stress in the layer structure and to create crack-free GaN-on-Si. This includes the incorporation of superlattices or low-temperature AlN interlayers in the GaN layer. Although these methods are useful for LED applications, in the case of HEMT they give rise to multilayers of two-dimensional electron gas (2DEG) interfaces which cause the device to become leaky and less efficient as line defect density increases. Further, the incorporation of these features cause the growth time of the layers to increase, limiting the time and cost efficiency of the production of the device.

There is therefore a need to provide a high-performance, cost-effective GaN-on-Si device that overcomes, or at least ameliorates, one or more of the disadvantages described above.

Summary

There is provided a device comprising a substrate, a group(III)-nitride layer, a metal-group(III)-nitride layer deposited between the substrate and group(III)-nitride layer and a metal nitride layer deposited between the SOI and the metal-group(III)-nitride layer.

Advantageously, such a semiconductor device may have improved properties suitable for use in high-power applications. Further advantageously, by having a thicker, crack-free and homogeneous group(III)-nitride layer, wherein the group(III)-nitride comprises GaN, grown over a thick metal group(III)-nitride layer wherein the metal group(III)-nitride comprises AlGaN, and a thick metal nitride layer, wherein the metal nitride comprises AlN, low structure bowing may be achieved. The low structure

bowing may result in the improvement in uniformity of the layers and consequently the electrical properties of the device. Further advantageously, this may circumvent the use of conventional techniques that may compromise the performance of the device.

In one example, such a device may comprise an AlN layer that may have a thickness dimension selected to reduce bowing of the structure. Advantageously, the AlN layer may reduce the strain induced by thermal mismatch between the GaN and SOI layer. Further advantageously, the AlN layer may provide a better interface for deposition of the AlGaN layer. The AlGaN layer may be deposited as a gradient, further contributing to the reduction of strain in the epilayers, resulting in prevention of bowing of the structure and cracking of the GaN layer.

Advantageously, such a device provided may have superior crystalline quality in the epilayers and improved electrical properties for use as a high electron mobility (HEMT) device.

There is also provided a method of making a semiconductor device, the method comprising the steps of: (a) providing a substrate, (b) depositing a metal-nitride layer on the substrate, (c) depositing a metal-group(III)-nitride layer on the metal-nitride layer and (d) depositing a group(III)-nitride layer on the metal-group(III)-nitride layer.

According to a second aspect, there is provided a method of making a semiconductor device, the method comprising the steps of: (a) providing a silicon-on-insulator (SOI) substrate, wherein the step of providing the silicon-on-insulator (SOI) substrate comprises providing the SOI substrate that is comprised of a bulk Si (111) handle substrate; (b) depositing a metal-nitride layer on the substrate, comprising the step of depositing

a low-temperature metal-nitride layer on the substrate at a temperature in the range of 900°C to 1000°C and at a thickness in the range of 30 nm to 50 nm, and depositing a high temperature metal-nitride layer directly onto the low-temperature metal-nitride layer at a temperature in the range of 1050°C to 1075°C and at a thickness greater than 300 nm; (c) depositing a metal-group(III)-nitride layer on the metal-nitride layer; and (d) depositing a high pressure group(III)-nitride layer directly on the metal-group(III)-nitride layer at a pressure in the range of 200 Torr to 400 Torr and depositing a low pressure group (III)-nitride layer at a pressure in the range of 150 Torr to 190 Torr directly adjacent to the high pressure group (III)-nitride layer to form a compositionally homogeneous group (III)-nitride layer, wherein the compositionally homogeneous group (III)-nitride layer has a thickness dimension greater than a thickness dimension of a combination of the metal-nitride layer and the metal-group (III)-nitride layer.

Advantageously, this method of making the semiconductor device may allow the use of a Si(111) handle SOI as the substrate, decreasing the production cost of the semiconductor device by up to 70 percent compared to traditional substrates such as sapphire and SiC. Further advantageously, this method may offer versatility in post-growth processing, mitigating the use of thick Si substrates.

Further advantageously, this method of making the semiconductor device may shorten the production time of the device by up to 30 percent compared to traditional methods by careful selection of temperature and pressures for the deposition of each epilayer. This may allow each epilayer to be of sufficient thickness and homogeneity, facilitating cost- and time-effective manufacture of the device

There is also provided a use of the semiconductor device.

Definitions

The following words and terms used herein shall have the meaning indicated:

The term ‘thick’, for the purposes of referring to GaN in this disclosure, refers to GaN layers with thicknesses of at least 1.7 mu.m.

The term ‘step-graded’, for the purposes of referring to the manufacture of the semiconductor device in this disclosure, is to be interpreted broadly to refer to layers of homogeneous compositions wherein the percentage composition of at least one of the components of the composition gradually increases or decreases in discrete steps between adjacent consecutive layers.

The term ‘bowing’ is to be interpreted broadly to refer to bending or curving of a material both in the concave and convex directions about a longitudinal axis.

The word “substantially” does not exclude “completely” e.g. a composition which is “substantially free” from Y may be completely free from Y. Where necessary, the word “substantially” may be omitted from the definition of the invention.

Claims

1. A method of making a semiconductor device, the method comprising the steps of:

(a) providing a silicon-on-insulator (SOI) substrate, wherein the step of providing the silicon-on-insulator (SOI) substrate comprises providing the SOI substrate that is comprised of a bulk Si (111) handle substrate;

(b) depositing a metal-nitride layer on the substrate, comprising the step of depositing a low-temperature metal-nitride layer on the substrate at a temperature in the range of 900°C to 1000°C and at a thickness in the range of 30 nm to 50 nm, and depositing a high temperature metal-nitride layer directly onto the low-temperature metal-nitride layer at a temperature in the range of 1050°C to 1075°C and at a thickness greater than 300 nm;

(c) depositing a metal-group(III)-nitride layer on the metal-nitride layer; and

(d) depositing a high pressure group(III)-nitride layer directly on the metal-group(III)-nitride layer at a pressure in the range of 200 Torr to 400 Torr and depositing a low pressure group (III)-nitride layer at a pressure in the range of 150 Torr to 190 Torr directly adjacent to the high pressure group (III)-nitride layer to form a compositionally homogeneous group (III)-nitride layer, wherein the compositionally homogeneous group (III)-nitride layer has a thickness dimension greater than a thickness dimension of a combination of the metal-nitride layer and the metal-group (III)-nitride layer.

2. The method as claimed in claim 1, wherein the homogeneous group(III)-nitride layer comprises gallium nitride (GaN) to form a GaN layer, the metal-group (III) nitride layer comprises aluminium gallium nitride (AlGaN) to form a AlGaN layer, the metal-nitride layer comprises aluminium nitride (AlN) to form a AlN layer and the step of depositing the AlN layer in step (b) and the step of depositing the AlGaN layer in step (c) comprises the depositing of Al in the AlN layer and in the AlGaN layer in an amount to reduce strain between the GaN layer and SOI substrate.

3. The method as claimed in claim 2, comprising the step of reducing the amount of Al in the AlGaN layer during step (c).

4. The method as claimed in claim 3, wherein the reducing step comprises depositing discrete layers of decreasing Al content in the AlGaN layer.

5. The method as claimed in claim 2, wherein depositing the AlN layer is performed using an alkyl metal in the presence of a nitrogen source.

6. The method as claimed in claim 2, wherein step (c) comprises the steps of;

measuring the curvature of the substrate; and

adjusting the amount of AlGaN being deposited during deposition.

7. The method as claimed in claim 1, wherein all the deposition steps are performed using metal organic chemical vapour deposition (MOCVD).

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