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METHOD OF FABRICATING SEMICONDUCTOR DEVICE

Abstract

A method of forming a semiconductor device, the semiconductor device includes a substrate, a gate structure and an epitaxial structure. The gate structure is disposed on the substrate, and the epitaxial structure is disposed in the substrate, at one side of the gate structure. The epitaxial structure includes a portion being protruded from a top surface of the substrate, and the portion includes a discontinuous sidewall, with a distance between a turning point of the discontinuous sidewalls and the gate structure being a greatest distance between the epitaxial structure and the gate structure.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation application of U.S. application Ser. No. 18/218,098, filed on Jul. 4, 2023, which is a continuation application of U.S. application Ser. No. 17/330, 443, filed on May 26, 2021, which is a division of U.S. application Ser. No. 16/205,233, filed on Nov. 30, 2018. The contents of these applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention generally relates to the field of a semiconductor device and a method of forming the same, and more particularly to a semiconductor device having an epitaxial structure and a method of forming the same.

2. Description of the Prior Art

[0003] For the sake of increasing the carrier mobility of the semiconductor structure, a compressive stress or tensile stress can be optionally applied to the gate channel. In conventional arts, a selective epitaxial growth (SEG) process is used to form a compressive stress. For example, after the formation of a gate on a silicon substrate, a silicon-germanium (SiGe) epitaxial structure is formed in the predetermined location, in which the lattice arrangement of silicon (Si) and germanium (Ge) are similar to each other. Since the lattice constant of the SiGe layer is larger than a lattice constant of Si, accordingly, the band structure of Si may be changed, and the compressive stress is then formed and applied to the channel region of a PMOS transistor, thereby increasing the carrier mobility in the channel region, as well as increasing the efficiency of the PMOS transistor. On the other hand, a silicon carbide (SiC) epitaxial structure can be optionally formed in the silicon substrate of a NMOS transistor, to apply the tensile stress to the channel region of the NMOS transistor.

[0004] While the foregoing method can improve the carrier mobility in the channel region, said method also has led to the difficulty of the overall fabrication process and the process control, especially under the trend of miniaturization of semiconductor device dimensions. Hence, there is a need of proving a novel fabrication method of a semiconductor device, to obtain more reliable semiconductor device.

SUMMARY OF THE INVENTION

[0005] One object of the present invention is to provide a semiconductor device and a method of forming the same, in which, the epitaxial structure is separated from the gate structure by a certain distance at a portion thereof protruded from a top surface of the substrate. That is, the electrical performance of the semiconductor device may no longer be affected thereby.

[0006] To achieve the purpose described above, the present invention provides a semiconductor device including a substrate, a gate structure and an epitaxial structure. The gate structure is

disposed on the substrate and an epitaxial structure is disposed in the substrate, at one side of the gate structure. The epitaxial structure comprises a portion being protruding from a top surface of the substrate, and the portion comprises a discontinuous sidewall, with a distance between a turning point on the discontinuous sidewall and the gate structure being a maximum distance between the epitaxial structure and the gate structure.

[0007] To achieve the purpose described above, the present invention provides a method of forming a semiconductor device including the following steps. Firstly, a substrate is provided, and a gate structure is formed on the substrate. Then, an epitaxial structure is formed in the substrate, at one side of the gate structure, the epitaxial structure comprises a portion being protruding from a top surface of the substrate, and the portion comprises a discontinuous sidewall, with a distance between a turning point on the discontinuous sidewall and the gate structure being a maximum distance between the epitaxial structure and the gate structure.

[0008] In summary, the method of the present invention utilizes two deposition layers formed in the two deposition processes to respectively define the profile of the portion of the epitaxial structure protruded from the substrate or the fin structure. That is, the portion of the epitaxial structure may therefore obtain a discontinuous sidewall, and a distance between a turning point on the discontinuous sidewall and the adjacent gate structure may be a maximum distance between the epitaxial structure and the gate structure. Preferably, the maximum distance may be adjacent to the top surface of the substrate or the fin structure as much as possible, with the maximum distance being about **200** angstroms or more than **200** angstroms. In this way, it is sufficient to avoid the arrangement of the epitaxial structure getting interference with the current-intensive regions such as a light doped source/drain region in the substrate or the fin structure, at both two sides of the gate structure, so as to gain a better performance and functions to the semiconductor device of the present invention.

[0009] These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 to FIG. 6 are schematic diagrams illustrating a method of forming a semiconductor device according to a first preferred embodiment of the present invention, in which:

[0011] FIG. 1 shows a cross-sectional view of a semiconductor device at the beginning of the forming process;

[0012] FIG. 2 shows a cross-sectional view of a semiconductor device after forming an epitaxial layer;

[0013] FIG. 3 shows a cross-sectional view of a semiconductor device after forming a deposition material layer;

[0014] FIG. 4 shows a cross-sectional view of a semiconductor device after performing an etching process;

[0015] FIG. 5 shows a cross-sectional view of a semiconductor device after forming another epitaxial layer; and

[0016] FIG. 6 shows a cross-sectional view of a of a semiconductor device after forming an epitaxial structure.

[0017] FIG. 7 to FIG. 8 are schematic diagrams illustrating a method of forming a semiconductor device according to a second preferred embodiment of the present invention, in which:

[0018] FIG. 7 shows a cross-sectional view of a semiconductor device after forming an epitaxial layer; and

[0019] FIG. **8** shows a cross-sectional view of a semiconductor device after forming an epitaxial structure.

[0020] FIG. **9** is a schematic diagram illustrating a semiconductor device according to another preferred embodiment of the present invention.

[0021] FIG. **10** is a schematic diagram illustrating a method of forming a semiconductor device according to a third preferred embodiment of the present invention.

DETAILED DESCRIPTION

[0022] To provide a better understanding of the present invention, preferred embodiments will be described in detail. The preferred embodiments of the present invention are illustrated in the accompanying drawings with numbered elements.

[0023] Referring to FIGS. **1-6**, FIGS. **1-6** illustrate a method of forming a semiconductor device according to the first preferred embodiment of the present invention. In the present embodiment, a substrate **300**, such as a silicon substrate, an epitaxial layer, a silicon germanium substrate, a silicon carbide substrate or silicon on insulator (SOI) substrate, is provided. Furthermore, a fin structure **320** may be firstly formed in the substrate **300**, for example through a general photolithography-etching process (PEP) or a multi-patterning process, to make the substrate **300** as a nonplanar substrate, but not limited thereto. In another embodiment, the fin structure **320** may also be omitted, to directly provide a planar substrate (not shown in the drawings).

[0024] Then, at least one gate structure **340** is formed on the substrate **300**, across the fin structure **320**. In the present embodiment, although three gate structures **340** are formed on one fin structure **320** as an example, the practical number of the gate structure **340** and the fin structure **320** is not limited thereto and may further be adjustable according to the product requirements. For example, one or more than one gate structure **340** may also be formed across the same fin structure **320**.

Precisely, each of the gate structure **340** includes a stacked structure (not shown in the drawings) and a spacer **344** surrounding the stacked structure, and the stacked structure includes a gate dielectric layer **341** such as including silicon oxide, a gate layer **342** such as including polysilicon or amorphous silicon, a capping layer **343** such as including silicon oxide, silicon nitride or silicon oxynitride (SiON), and a mask layer **345** such as silicon carbonitride (SiCN) stacked on one over another. In one embodiment, the formation of the gate structure **340** may be accomplished by sequentially forming a dielectric material layer (not shown in the drawings), a gate material layer (not shown in the drawings), a capping material layer (not shown in the drawings) and a mask material layer on the substrate **300**, and patterning the aforementioned material layers to form the stacked structure. Next, a light doped source/drain region **346** is formed at two sides of the stacked structure in the fin structure **320**, and the spacer **344** such as including silicon oxide is then formed on sidewalls of the stacked structure, thereby forming the gate structure **340**. In the present embodiment, although the spacer **344** is exemplify by having a monolayer structure, the practical structure thereof is not limited thereto and may further be adjustable according to the product requirements. In another embodiment, a spacer (not shown in the drawings) having a multilayer structure may also be formed.

[0025] Then, a deposition process is performed, to additionally form a deposition layer **351** on the spacer **344** of each of the gate structures **340**. In one embodiment, the deposition layer **351** for example includes a material having an etching selectivity related to that of the spacer **344**, such as silicon nitride or silicon carbonitride. At first, the deposition layer **351** is entirely deposited on the fin structure **320** (namely the substrate **300**), to cover a top surface of the fin structure **320** and each gate structure **340**, and then, an etching back process is performed to form the deposition layer **351** as shown in FIG. **1**.

[0026] Next, an epitaxial structure **370** is formed in the fin structure **320** at two sides of each gate structure **340**, to serve as a source/drain region. Firstly, an etching process such as a dry etching, a wet etching or a sequent performed dry and wet etching process is firstly performed, to form at least one recess **360** in the fin structure **320** at two sides of each gate structure **340**, and a selectivity

epitaxial growth (SEG) process is formed in the recess **360**, to form an epitaxial layer **371** being protruded from the top surface of the fin structure **320**. It is noted that, the epitaxial layer **371** defines a formation position through the deposition layer **351** in advance, so that, the epitaxial layer **371** may therefore have a gradually shrinking portion **371a** being gradually shrunk upwardly to at least partially protrude from the top surface of the fin structure **320**, as shown in FIG. 2. Precisely, the gradually shrinking portion **371a** has a tapered sidewall **371b**, and the tapered sidewall **371b** is continuously tapered along a direction being away from the gate structure. That is, the tapered sidewall **371b** is gradually away from the deposition layer **351** to not in contact with the deposition layer **351** directly, and the gradually shrinking portion **371a** may obtain a width (not shown in the drawings) being continuously expanded downwardly. In other words, a bottom surface (not shown in the drawings) of the gradually shrinking portion **371a** has a width **W1** being greater than a width **W2** (not shown in the drawings) of a top surface of the gradually shrinking portion **371a**. Through this arrangement, a gap **g1** may be further interposed between the deposited layer **351** and one side of the epitaxial layer **371** adjacent to the deposited layer **351**.

[0027] The epitaxial layer **371** includes a material which may be adjusted according to the type of the MOS transistor formed in the subsequent steps. For example, the epitaxial layer **371** may include silicon germanium (SiGe) or silicon carbide (SiC), but not limited thereto. Also, according to the conductive type of the MOS transistor formed in the subsequent steps, a suitable P-type dopant or a suitable N-type dopant may be implanted either through an in-situ implanted process while performing the SEG process, or through an additionally performed ion implantation process before or after the SEG process. For example, in the present embodiment, a PMOS transistor is formed while the epitaxial layer **371** includes silicon germanium with in-situ implanted a particular concentration of boron (B), but not limited thereto.

[0028] Then, another deposition process is performed, to additionally form a deposition material layer **352** on each gate structure **340**, to entirely cover the top surface of the fin structure **320** (namely the substrate **300**), each gate structure **340** and the epitaxial layer **371**, as shown in FIG. 3. In the present embodiment, the deposition material layer **352** preferably includes a same material as that of the deposition layer **351**, for example both including silicon nitride, and the deposition material layer **352** preferably includes a relative greater thickness (not shown in the drawings) than that of the deposition layer **351**, such as being about 90-100 angstroms, to fill up the gap **g1** and to further cover on the top surface of the epitaxial layer **371**. After that, another etching back process such as a dry etching process is performed, to remove most of the deposition material layer **352** to form a deposition layer **352a** for exposing the top surface of the epitaxial layer **371**. In the present embodiment, the deposition material layer **352** is preferably removed until being lower than the top surface of the epitaxial layer **371**, as shown in FIG. 4. That is, the deposition layer **352a** may only partially fill up the gap **g1** between the epitaxial layer **371** and the deposition layer **351**, but not limited thereto. In another embodiment, the deposition material layer **352** may also be removed until being coplanar with the top surface of the epitaxial layer **371**, so that, a deposition layer (not shown in the drawings) formed thereby may barely fill up the gap **g1** between the epitaxial layer **371** and the deposition layer **351**.

[0029] Following these, another SEG process is performed from the top surface of the epitaxial layer **371**, to form an epitaxial layer **372** having a uniform thickness **t1** entirely. In the present embodiment, the epitaxial layer **372** is grown from the top surface of the epitaxial layer **371** which is exposed from the deposited layer **352a**, so that, the entire epitaxial layer **372** is gradually expanded upwardly to perform like a gradually expanding portion. The gradually expanding portion also includes a tapered sidewall **372b**, and the tapered sidewall **372b** is continuously tapered along a direction being toward the gate structure **340**. That is, the gradually expanding portion may obtain a width (not shown in the drawings) being continuously expanded upwardly, as shown in FIGS. 5-6. In other words, a top surface (not shown in the drawings) of the gradually expanding portion (the epitaxial layer **372**) has a width **W3** being greater than the width **W2** of a

bottom surface (not shown in the drawings) of the gradually expanding portion, which is the same as that of the top surface of the gradually shrinking portion **371a** as shown in FIG. 2, and the width **W3** of the top surface of the gradually expanding portion is smaller than the width **W1** of the bottom surface of the gradually shrinking portion **371a**. Furthermore, the epitaxial layer **372** also includes a material and a dopant which may be adjusted according to the type of the MOS transistor formed in the subsequent steps, and the material and the dopant of the epitaxial layer **372** are preferably the same as that of the epitaxial layer **371**. In other words, the epitaxial layer **372** of the present embodiment may also include silicon germanium with in-situ implanted a particular concentration of boron, and a doped concentration of boron in the epitaxial layer **372** is preferably greater than that of the epitaxial layer **371**.

[0030] Then, an etching process is performed to completely remove the remained deposition layer **352a** and the deposition layer **351**, so that, the epitaxial layer **372** and a upper portion of the epitaxial layer **371** protruded from the top surface of the fin structure **320** (namely the substrate **300**) may be further away from the gate structures **340** on both two sides, with a gap between the gate structure **340** and the position of the epitaxial layers **371**, **372** adjacent to the top surface of the fin structure **320** being pulled apart by about **200** angstroms, as shown in FIG. 6. Accordingly, the epitaxial layers **371**, **372** may together form the epitaxial structure **370**, thereby to configure as a source/drain region (not shown in the drawings) of the MOS transistor formed in the subsequent steps. Precisely, a portion of the epitaxial layer **370** protruded from the top surface of the fin structure **320** (namely the substrate **300**) is consisted of the epitaxial layer **372** and a portion of the epitaxial layer **371** (namely a portion of the gradually shrinking portion **371a**), and the epitaxial layer **372** and the portion of the epitaxial layer **371** include the continuously tapered sidewalls **372b**, **371b** respectively. That is, the portion of the epitaxial layer **370** protruded from the top surface of the fin structure **320** may obtain a discontinuous sidewall (not shown in the drawings) thereby. A lower portion of the discontinuous sidewall is namely the sidewall **371b** of the epitaxial layer **371** (the gradually shrinking portion **371a**). As the formation of the sidewall **371b** is limited by the deposition layer **351**, the sidewalls **371b** is continuously tapered away from the gate structure **340**. On the other hand, an upper portion of the discontinuous sidewall is namely the sidewall **372b** of the epitaxial layer **372** (namely the gradually expanding portion), and the sidewall **372b** is continuously tapered toward the gate structure **340** due to being formed through the exposed top surface of the epitaxial layer **371**, as shown in FIG. 6. With this performance, a distance between the adjacent gate structure **340** and a turning point (not shown in the drawings) being between the epitaxial layer **371** (the gradually shrinking portion) and the epitaxial layer **372** (the gradually expanding portion), may be a maximum distance **d1** between the epitaxial structure **370** and the adjacent gate structure **340**, for example being about 200-250 angstroms, as shown in FIG. 6. Also, in one embodiment, the maximum distance is preferably adjacent to the top surface of the fin structure **320** (substrate **300**) as closer as possible, so as to pull apart the distance on the fin structure **320**, between the epitaxial structure **370** and the gate structure **340**. In this way, it is sufficient to avoid the arrangement of the epitaxial structure **370** getting interference with the current-intensive regions such as the light doped source/drain region **346** in the fin structure **320**, at both two sides of the gate structure **340**.

[0031] Accordingly, the semiconductor device of the first preferred embodiment is obtained. The forming method of the present embodiment mainly uses two deposition layers **351**, **352** formed by two deposition processes to respectively define the formation of the portion of the epitaxial structure **370** protruded from the substrate **300**, to pull apart the distance between the epitaxial structure **370** and the gate structure **340** as much as possibly, with the gap between the gate structure **340** and the position of the epitaxial structure **370** adjacent to the top surface of the substrate **300** being pulled apart by about **200** angstroms. That is, the performance of the semiconductor device may be improved by avoiding the arrangement of the epitaxial structure **370** getting interference with the current-intensive regions (such as the light doped source/drain region

346) in the substrate **300**, at both two sides of the gate structure **340**.

[0032] However, people in the art should easily understand that the forming method of the present invention is not limited to the aforementioned embodiment and may further include other examples, so as to meet the requirements of the practical products. The following description will detail the different embodiments of the forming method of the semiconductor device of the present invention. To simplify the description, the following description will detail the dissimilarities among the different embodiments and the identical features will not be redundantly described. In order to compare the differences between the embodiments easily, the identical components in each of the following embodiments are marked with identical symbols.

[0033] Please refers to FIGS. **7-8**, which are schematic diagrams illustrating a method of forming a semiconductor device according to the second embodiment of the present invention. The formal steps of the present embodiment are substantially similar to those in the aforementioned first preferred embodiment, and may not be redundantly described herein. The differences between the present embodiment and the aforementioned embodiment is mainly in that, a spacer **344a** having a tapered profile is formed additionally, to further define the portion of an epitaxial layer **373** protruded from the top surface of the fin structure **320**.

[0034] Precisely speaking, the spacer **344a** of the present embodiment includes a tapered profile for example at the lower portion thereof, as shown in FIG. **7**. Otherwise, in another embodiment, the entire spacer may include a continuous tapered profile (not shown in the drawings), but is not limited thereto. Accordingly, a deposition layer **355** deposited on the spacer **344a** may conformally have a tapered profile. With this arrangement, the formation of the epitaxial layer **373** may be further limited by the spacer **344a** and the deposition layer **355**, so that, the tapered sidewall **373b** of the gradually shrinking portion **373a** may be further tapered, to have a relative greater inclination angle than that of the epitaxial layer **371** in the aforementioned embodiment. Also, a relative greater gap **g2** is obtained between the epitaxial layer **373** and the deposition layer **355**, as shown in FIG. **7**. Following these, the forming processes as shown in FIGS. **3-5** of the aforementioned embodiment is performed, to form a deposition layer **356a** at least partially filled the gap **g2**, and to form an epitaxial layer **374**. Then, an etching process is performed to completely remove the deposition layer **356a** and the deposition layer **355**, and the epitaxial layer **374** and the epitaxial layer **373** may together form an epitaxial structure **370a** to configure as the source/drain region of the MOS transistor in the present embodiment.

[0035] It is noted that, the epitaxial layer **374** of the present embodiment is also grown from the top surface of the epitaxial layer **373** which is exposed from the deposited layer **356a**, to make the entire epitaxial layer **374** being gradually expanded upwardly to perform like a gradually expanding portion. Moreover, the gradually expanding portion includes a tapered sidewall **374b**, and the tapered sidewall **374b** is continuously tapered along a direction being toward the gate structure **340**. That is, the gradually expanding portion may obtain a width (not shown in the drawings) being continuously expanded upwardly, as shown in FIGS. **7-8**, namely, with a width **W3'** of a top surface of the gradually expanding portion (the epitaxial layer **374**) being greater than a width **W2'** both of a bottom surface of the gradually expanding portion and a top surface of the gradually shrinking portion **373a**, and with the width **W3'** of the top surface of the gradually expanding portion being smaller than a width **W1'** of a bottom surface of the gradually shrinking portion **373a**. On the other hand, the epitaxial layer **374** of the present embodiment also has a uniform thickness **t2**, and the thickness **t2** is smaller than a thickness (not shown in the drawings) of the whole of the gradually shrinking portion **373a**, and is preferably greater than a thickness (not shown in the drawings) of a portion of the gradually shrinking portion **373a** protruded from the top surface of the fin structure **320** (namely the substrate **300**) underneath, but not limited thereto.

[0036] The epitaxial structure **370a** of the present embodiment substantially includes the same features as that of the epitaxial structure **370**. precisely, a portion of the epitaxial layer **370a** protruded from the top surface of the fin structure **320** (namely the substrate **300**) is consisted of

the epitaxial layer **374** and a portion of the epitaxial layer **373** (namely a portion of the gradually shrinking portion **373a**), and the epitaxial layer **374** and the portion of the epitaxial layer **373** include the continuously tapered sidewalls **374b**, **373b** respectively. That is, the portion of the epitaxial layer **370** protruded from the top surface of the fin structure **320** may obtain a discontinuous sidewall (not shown in the drawings) thereby. A lower portion of the discontinuous sidewall is namely the sidewall **373b** of the epitaxial layer **373** (the gradually shrinking portion **373a**), and an upper portion of the discontinuous sidewall is namely the sidewall **374b** of the epitaxial layer **374** (namely the gradually expanding portion), as shown in FIG. **8**. With this performance, a distance between the adjacent gate structure **340** and a turning point (not shown in the drawings) being between the epitaxial layer **373** (the gradually shrinking portion **373a**) and the epitaxial layer **374** (the gradually expanding portion), may be a maximum distance d_2 between the epitaxial structure **370a** and the adjacent gate structure **340**, for example being about 250-270 angstroms. In this way, it is sufficient to further pull apart the distance between the epitaxial layer **370a** and the gate structure **340**, with the distance between the gate structure **340** and the position of the epitaxial structure **370a** adjacent to the top surface of the fin structure **320** being pulled apart by more than **200** angstroms, as shown in FIG. **8**.

[0037] The portion of the epitaxial structure **370a** of the present embodiment protruded from the top surface of the fin structure **320** (namely the substrate **300**) has a discontinuous sidewall with a relative greater inclination angle, so that, the distance between the adjacent gate structure **340** and the turning point may be further pull apart. That is, an additional gap g_3 is interposed between the epitaxial layer **374** and a portion of the epitaxial layer **373** (namely a portion of the gradually shrinking portion **373a**), as shown in FIG. **8**. It is noted that, air is easy to remain in the gap g_3 while forming the interlayer dielectric layer (not shown in the drawings) on the fin structure **320** (namely the substrate **300**) in the subsequent process, so as to form void (not shown in the drawings) in the gap g_3 for improving the isolation between the epitaxial structure **370a** and the gate structure **340**. Then, the semiconductor device of the present embodiment may therefore provide better functions and performances.

[0038] Accordingly, the semiconductor device of the second preferred embodiment is obtained. The forming method of the present embodiment uses the tapered profile of the spacer **344a** to further define the inclination angle of the portion of the epitaxial layer **373** protruded from the top surface of the substrate **300**, to make the sidewall **373b** of the epitaxial layer **373** further tapered away from the gate structure **340**. That is, the distance between the epitaxial structure **370a** and the gate structure **340** may be further pull apart thereby, especially at the position of the epitaxial layer **370a** adjacent to the top surface of the substrate **300**. In this way, the performance of the semiconductor device may be further improved by avoiding the arrangement of the epitaxial structure **370** getting interference with the current-intensive regions (such as the light doped source/drain region **346**) in the substrate **300**, at both two sides of the gate structure **340**.

[0039] In addition, although the another SEG process of the aforementioned embodiment is exemplified by forming the epitaxial layer **372/374** upwardly from the top surface of the epitaxial layer **371/373** exposed from the deposition layer **352a/356a**, the practical process of the present invention is not limited thereto. In other words, the another SEG process of the present invention may also be performed by simultaneously growing the epitaxy upwardly and laterally from both two sides, to form an epitaxial layer **376** in a suspended platform like shape instead of forming the epitaxial layer **372/374** in a reverse trapezoid shape. The epitaxial layer **376** is suspended disposed on the epitaxial layer **371/373**, as shown in FIG. **9**, with the epitaxial layer **376** includes a uniform thickness t_3 . Meanwhile, a bottom surface of a gradually shrinking portion (not shown in the drawings) of the epitaxial layer **373** also has the width W_1' being greater than the width W_2' of a top surface of the gradually shrinking portion of the epitaxial layer **373**, and a bottom surface of the epitaxial layer **376** may have a width W_4 being substantially the same or smaller than a width W_5 of a top surface of the epitaxial layer **376**, with both of the widths W_4 , W_5 being greater than the

width W2' and being smaller than the width W1, as shown in FIG. 9.

[0040] Please refers to FIG. 10, which is a schematic diagram illustrating a method of forming a semiconductor device according to the third embodiment of the present invention. The formal steps of the present embodiment are substantially similar to those in the aforementioned second preferred embodiment, and may not be redundantly described herein. The differences between the present embodiment and the aforementioned second embodiment is mainly in that, a metal gate structure may be directly formed optionally, while forming the gate structure 340, and the metal gate structure at least includes a high dielectric constant (high-k) layer 314a for example including hafnium oxide (HfO₂), hafnium silicon oxide (HfSiO₄) or hafnium silicon oxynitride (HfSiON), and a metal gate 3421 for example including a metal material like aluminum (Al), titanium (Ti) or tungsten (W). Otherwise, in another embodiment, a replacement metal gate (RMG) process may be performed additionally after forming the interlayer dielectric layer, to replace the gate layer 342 of the gate structure 340 by a metal gate 342a, as shown in FIG. 10.

[0041] Overall speaking, the forming method of the present invention two deposition layers formed in the two deposition processes to respectively define the profile of the portion of the epitaxial structure protruded from the substrate or the fin structure. That is, the portion of the epitaxial structure may therefore obtain a discontinuous sidewall, and a distance between a turning point on the discontinuous sidewall and the adjacent gate structure may be a maximum distance between the epitaxial structure and the gate structure. Preferably, the maximum distance may be adjacent to the top surface of the substrate or the fin structure as much as possible, with the maximum distance being about 200 angstroms or more than 200 angstroms. In this way, it is sufficient to avoid the arrangement of the epitaxial structure getting interference with the current-intensive regions such as a light doped source/drain region in the substrate or the fin structure, at both two sides of the gate structure, so as to gain a better performance and functions to the semiconductor device of the present invention.

[0042] Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

Claims

1. A method of forming a semiconductor device, comprising: providing a substrate; forming a gate structure on the substrate; forming a first epitaxial layer; forming a multilayer deposition structure on sidewalls of the gate structure; after partially removing the multilayer deposition structure, forming a deposition portion which has a top surface being coplanar with a top surface of the first epitaxial layer; and forming a second epitaxial layer on the first epitaxial layer.
2. The method of forming the semiconductor device according to claim 1, wherein the multilayer deposition structure comprises a spacer, a first deposition layer and a second deposition stacked sequentially on the sidewalls of the gate structure.
3. The method of forming the semiconductor device according to claim 2, wherein forming the deposition portion comprises: partially removing the second deposition layer, to form the deposition portion being sandwiched between the first epitaxial layer and the first deposition layer.
4. The method of forming the semiconductor device according to claim 1, wherein a bottom surface of the second epitaxial layer is equal to the top surface of the first epitaxial layer.
5. The method of forming the semiconductor device according to claim 2, further comprising: after forming the second epitaxial layer, removing the deposition portion and the first deposition layer.
6. The method of forming the semiconductor device according to claim 2, wherein each of the spacer and the first deposition layer comprises a tapered sidewall.
7. The method of forming the semiconductor device according to claim 6, wherein the deposition

portion directly contacts the tapered sidewall of the first deposition layer.

8. The method of forming the semiconductor device according to claim 6, wherein a bottom surface of the second epitaxial layer is coplanar with the top surface of the deposition portion.

9. The method of forming the semiconductor device according to claim 6, wherein two opposite ends of second epitaxial layer are not extended over two opposite ends of the first epitaxial layer in a horizontal direction.

10. The method of forming the semiconductor device according to claim 9, wherein each of the two opposite ends of second epitaxial layer is not extended over an end of the deposition portion.

11. The method of forming the semiconductor device according to claim 1, wherein the second epitaxial layer is formed after forming the deposition portion.

12. The method of forming the semiconductor device according to claim 1, wherein the second epitaxial layer comprises a suspended platform having a uniform thickness.

13. The method of forming the semiconductor device according to claim 12, wherein a bottom surface of the second epitaxial layer is larger than the top surface of the first epitaxial layer.

14. The method of forming the semiconductor device according to claim 12, wherein two opposite ends of the second epitaxial layer are vertically aligned with two opposite ends of the first epitaxial layer.

15. The method of forming the semiconductor device according to claim 2, wherein the multilayer deposition structure is partially formed before forming the first epitaxial layer and partially formed after forming the first epitaxial layer.

16. The method of forming the semiconductor device according to claim 15, wherein the spacer and the first deposition layer of the multilayer deposition structure are formed before forming the first epitaxial layer and the second deposition layer is formed after forming the first epitaxial layer.
