SHALLOW TRENCH ISOLATION PROCESS FOR STRAINED SILICON PROCESSES

FIELD OF THE INVENTION

The present invention is related to integrated circuit (IC) devices and to processes of making IC devices. More particularly, the present invention relates to a method of forming trench isolation structures on substrates or layers including germanium.

BACKGROUND OF THE INVENTION

Integrated circuits (ICs) include a multitude of transistors formed on a semiconductor substrate. Various methods of forming transistors on a semiconductor substrate are known in the art. Generally, transistors are isolated from each other by insulating or isolation structures.

One method of forming transistors on a silicon substrate involves the well-known Local Oxidation of Silicon (LOCOS) process. A conventional LOCOS process typically includes the following simplified steps. First, a silicon nitride layer is thermally grown on the silicon substrate. Generally, conventional LOCOS processes require a high quality, thermally grown silicon nitride layer to avoid delamination and other processing problems. Next, using a lithography and etch process, the nitride layer is selectively removed to produce a pattern where transistor source/drain areas are to be located. After patterning the source/drain areas, a field oxide is grown. As oxide growth is inhibited where the nitride layer still remains, the oxide only grows on the silicon substrate exposed during the source/drain patterning step. Finally, after oxide growth is complete, the remaining portions of the nitride layer are removed, leaving only the oxidized source/drain areas on the exposed silicon substrate.

Another process for forming insulating structures and defining source and drain regions is a shallow trench isolation (STI) process. A conventional STI process typically includes the following simplified steps. First, a silicon nitride layer is thermally grown or deposited onto the silicon substrate. Next, using a lithography and etch process, the silicon nitride layer is selectively removed to produce a pattern where transistor source/drain areas are to be located. After patterning the source/drain areas, the substrate is etched to form trenches. After the trenches are formed, a liner is thermally grown on the exposed surfaces of the trench. The liner oxide is typically formed at a very high temperature in a hydrochloric (HCl) acid ambient. An insulative material, such as, silicon dioxide (SiO_2), is blanket deposited over the nitride layer and the liner oxide within the trench. The insulative material is polished to create a planar surface. The nitride layer is subsequently removed to leave the oxide structures within the trenches.

Shallow trench isolation (STI) structures are utilized in strained silicon (SMOS) processes. SMOS processes are utilized to increase transistor (MOSFET) performance by increasing the carrier mobility of silicon, thereby reducing resistance and power consumption and increasing drive current, frequency response and operating speed. Strained silicon is typically formed by growing a layer of silicon on a silicon germanium substrate or layer.

The silicon germanium lattice associated with the silicon germanium substrate is generally more widely spaced than a pure silicon lattice, with spacing becoming wider with a higher percentage of germanium. Because the silicon lattice aligns with the larger silicon germanium lattice, a tensile strain is created in the silicon layer. The silicon atoms are essentially pulled apart from one another.

Relaxed silicon has a conductive band that contains six equal valence bands. The application of tensile strain to the silicon causes four of the valence bands to increase in energy and two of the valence bands to decrease in energy. As a result of quantum effects, electrons effectively weigh 30 percent less when passing through the lower energy bands. Thus, the lower energy bands offer less resistance to electron flow. In addition, electrons meet with less vibrational energy from the nucleus of the silicon atom, which causes them to scatter at a rate of 500 to 1000 times less than in relaxed silicon. As a result, carrier mobility is dramatically increased in strained silicon compared to relaxed silicon, providing an increase in mobility of 80% or more for electrons and 20% or more for holes. The increase in mobility has been found to persist for current fields up to 1.5 megavolts/centimeter. These factors are believed to enable a device speed increase of 35% without further reduction of device size, or a 25% reduction in power consumption without a reduction in performance.

The use of germanium in SMOS processes can cause germanium contamination problems for IC structures, layers, and equipment. In particular, germanium outgassing or outdiffusion can contaminate various components associated with the fabrication equipment and integrated circuit structures associating with the processed wafer. Further, germanium outgassing can negatively impact the formation of thin films. In addition, germanium outdiffusion can cause germanium accumulation or "pile-up" at the interface of the liner, thereby causing reliability issues for the STI structure.

Germanium outgassing can be particularly problematic at the very high temperatures and HCl ambient environments associated with the liner of a shallow trench isolation (STI) structure. For example, conventional STI liner oxide processes can utilize temperatures of approximately 1000°C which enhance germanium outgassing.

Thus, there is a need for an STI liner which can be formed in a low temperature process. Further still, there is a need for a process of forming high quality oxides with good compatibility and yet are not susceptible to germanium outgassing. Further still, there is a need for an SMOS trench liner formation process. Yet further, there is a need for a liner formation process that is not as susceptible to germanium outgassing. Further still, there is a need for an STI process that does not utilize high temperature to thermally grow liners.

SUMMARY OF THE INVENTION

An exemplary embodiment relates to a method of manufacturing an integrated circuit. The integrated circuit includes trench isolation regions in a substrate including germanium. The method includes forming a silicon nitride layer above the substrate, and selectively etching the silicon nitride layer to form

apertures associated with locations of the trench isolation (STI) regions. The method also includes forming trenches in the substrate at the locations, and forming oxide liners in the trenches of the substrate in a low temperature process.

Yet another exemplary embodiment relates to a method of forming shallow trench isolation regions in a semiconductor layer. The method includes providing a hard mask layer above the semiconductor layer, providing a photoresist layer above the hard mask layer, and selectively removing portions of the photoresist layer in a photolithographic process. The method further includes removing the hard mask layer at locations, forming trenches in the hard mask layer under the locations and forming a liner in the trenches in an ultra-violet light process.

Yet another exemplary embodiment relates to a method of forming a liner in a trench in a germanium containing layer. The method includes selectively etching the germanium containing layer to form the trench and providing the liner in the trench in a low temperature process.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments will become more fully understood from the following detailed description, taken in conjunction with the accompanying drawings, wherein like reference numerals refer to like parts, and wherein:

FIGURE 1 is a cross-sectional view schematic drawing of a portion of a silicon germanium substrate including a strained silicon layer, an oxide layer, a hard mask layer and a photoresist layer in accordance with an exemplary embodiment of a shallow trench isolation (STI) process;

FIGURE 2 is a cross-sectional view of the portion illustrated in FIGURE 1, showing a lithographic patterning step;

FIGURE 3 is a cross-sectional view of the portion illustrated in FIGURE 2, showing a selective etching step for the hard mask layer;

FIGURE 4 is a cross-sectional view of the portion illustrated in FIGURE 3, showing a selective etching step for the oxide layer;

FIGURE 5 is a cross-sectional view of the portion illustrated in FIGURE 4, showing a selective etching step for the strained silicon layer;

FIGURE 6 is a cross-sectional view of the portion illustrated in FIGURE 5, showing a selective etching step for the germanium silicon substrate;

FIGURE 7 is a cross-sectional view of the portion illustrated in FIGURE 6, showing a low temperature liner formation step;

FIGURE 8 is a cross-sectional view of the portion illustrated in FIGURE 7, showing a gate formation step;

FIGURE 9 is a general block diagram showing a shallow trench isolation process for the portion illustrated in FIGURE 1.

FIGURE 10 is a cross-sectional view schematic drawing of a portion of a silicon germanium substrate including a strained silicon layer, an oxide layer, a hard mask layer and a photoresist layer in accordance with another exemplary embodiment of a shallow trench isolation (STI) process;

FIGURE 11 is a cross-sectional view of the portion illustrated in FIGURE 10, showing a lithographic patterning step;

FIGURE 12 is a cross-sectional view of the portion illustrated in FIGURE 11, showing a selective etching step for the hard mask layer;

FIGURE 13 is a cross-sectional view of the portion illustrated in FIGURE 12, showing a selective etching step for the oxide layer;

FIGURE 14 is a cross-sectional view of the portion illustrated in FIGURE 13, showing a selective etching step for the strained silicon layer;

FIGURE 15 is a cross-sectional view of the portion illustrated in FIGURE 14, showing a selective etching step for the germanium silicon substrate;

FIGURE 16 is a cross-sectional view of the portion illustrated in FIGURE 15, showing a semiconductor deposition step;

FIGURE 17 is a cross-sectional view of the portion illustrated in FIGURE 16, showing a liner formation step;

FIGURE 18 is a cross-sectional view of the portion illustrated in FIGURE 17, showing a selective liner removal step;

FIGURE 19 is a cross-sectional view of the portion illustrated in FIGURE 18, showing a trench fill step;

FIGURE 20 is a cross-sectional view of the portion illustrated in FIGURE 19, showing a gate formation step; and

FIGURE 21 is a general block diagram showing a shallow trench isolation process for the portion illustrated in FIGURE 10 in accordance with another exemplary embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGURES 1 through 9 illustrate a method of manufacturing an integrated circuit (IC) in accordance with an exemplary embodiment. The method illustrated in FIGURES 1 through 9 reduces germanium outgassing and outdiffusion problems associated with silicon germanium layers or structures. The process can be used in a shallow trench isolation (STI) process or any process requiring a liner oxide and utilizing germanium or other substance prone to outgassing at high temperature. Advantageously, a liner oxide layer can be formed at low temperature and yet provide a high quality oxide with good compatibility. For the purposes of the embodiment described with reference to FIGURES 1-9, a low temperature process refers to a process performed at a temperature of less than approximately 700°C.

Referring to FIGURES 1 through 9, a cross-sectional view of a portion 12 of an integrated circuit (IC) is illustrated. Portion 12 is subjected to process 100 (FIGURE 9) to form a shallow trench isolation (STI) structure. Portion 12 includes an oxide layer 18 provided over a strained silicon layer 16. Layer 16 is provided over a semiconductor substrate 14 or a germanium-containing layer or substrate. Substrate 14 can be provided above a substrate 13.

Substrate 13 is optional and portion 12 can be provided with substrate 14 as the bottom-most layer. The embodiment described with reference to FIGURES 10-21 shows a substrate 114 without a substrate, such as, substrate 13 (FIGURE 1) beneath it. Substrate 13 can be the same material or a different material than substrate 14. In one embodiment, substrate 13 is a semiconductor substrate such as a silicon substrate upon which silicon germanium substrate 14 has been grown.

Portion 12 can be any type of semiconductor device, or portion thereof, made from any of the various semiconductor processes, such as a complementary metal oxide semiconductor (CMOS) process, a bipolar process, or another semiconductor process. Portion 12 may be an entire IC or a portion of an IC, and may include a multitude of electronic component portions.

Substrate 14 is preferably silicon germanium or another semiconductor material including germanium, and can be doped with P-type dopants or N-type dopants. Substrate 14 can be an epitaxial layer provided on a semiconductor or an insulative base, such as substrate 13. Furthermore, substrate 14 is preferably a composition of silicon germanium (Si_{1-x} Ge_x, where X is approximately 0.2 and is more generally in the range of 0.1-0.4). Substrate 14 can be grown or deposited.

In one embodiment, substrate 14 is grown above substrate 13 by chemical vapor deposition (CVD) using disilane (Si_2H_6) and germane (GeH_4) as source gases with a substrate temperature of approximately 650^{0}C, a disilane partial pressure of approximately 30 mPa and a germane partial pressure of approximately 60 mPa. Growth of silicon germanium material may be initiated using these ratios, or alternatively, the partial pressure of germanium may be gradually increased beginning from a lower pressure or zero pressure to form a gradient composition. Alternatively, a silicon layer can be doped by ion implantation with germanium or other processes can be utilized to form substrate 14. Preferably, substrate 14

is grown by epitaxy to a thickness of less than approximately 5000 Å (and preferably between approximately 1500 anti-reflective and 4000 Å).

A strained silicon layer 16 is formed above substrate 14 by an epitaxial process. Preferably, layer 16 is grown by CVD at a temperature of 600°C. Layer 16 can be a pure silicon layer and have a thickness of between approximately 50 and 150 Å.

Pad oxide film or oxide layer 18 is provided on layer 16. Layer 18 is optional. Layer 18 is preferably thermally grown on top of substrate 16 to a thickness of between approximately 100 and 300 Å. Layer 18 serves as a buffer layer and can be thermally grown in a conventional high temperature process by heating to approximately 1000°C in an oxygen atmosphere. Germanium outdiffusion or outgassing are not a problem at this point due to the presence of layer 16.

A barrier or hard mask layer 22 is provided over oxide layer 18. Preferably, mask layer 22 is silicon nitride (Si_3N_4) provided at a thickness of between approximately 300 and 1000 Å by a deposition or thermal growth process. Preferably, mask layer 22 is provided in a CVD or growth process. A low pressure, plasma enhanced chemical vapor deposition (PECVD) process can also be utilized. A conventional thermal nitride process using a dichlorosilane (SiH_2Cl_2), ammonia (NH_3) and nitrogen (N_2) mixture at a high temperature (e.g., 600°C or above) can be used. The PECVD process for depositing nitride uses silane (SiH_4), nitrogen (N_2), and ammonia (NH_3) with a power of between approximately 550 and 650 watts at 500°C. An ammonia (NH_3) silane (SiH_4/N_2) mixture plasma, as opposed to a $N_2/NH_3/SiCl_2H_2$ associated with conventional CVD or growth process, can be used to form mask layer 22.

A photoresist layer 24 is spun on top of mask layer 22. Preferably, photoresist layer 24 is any commercially available i-line or deep UV photoresist such as (Shipley Corp., MA) SPR 955 (i-line) UV5 (deep UV). In FIGURES 1 and 2, photoresist layer 24 is selectively removed via photolithographic process to leave apertures 34 in accordance with a step 102 (FIGURE 9) of process 100 using a mask or reticle 28. In FIGURE 3, mask layer 22 is etched via a dry-etching process so that apertures 34 reach oxide layer 18 in accordance with a step 104 of process 100 (FIGURE 9). The dry-etching process is selective to silicon nitride with respect to oxide layer 24. Layer 24 can be stripped after layer 22 is etched.

In FIGURE 4, the etch process is changed to etch through silicon dioxide material and layer 18 is etched so that apertures 34 reach layer 16 in accordance with step 104 of process 100 (FIGURE 9). Layer 18 can be etched in a dry etching process. Alternatively, other etching techniques can be utilized to remove selected portions of layer 18. Photoresist layer 24 (FIGURE 1) can be removed before or after oxide layer 18 is etched.

In FIGURE 5, the etch process is changed to etch through silicon material. Strained silicon layer 16 can be removed in accordance with a dry-etching process so that apertures 34 reach substrate 14.

In FIGURE 6, substrate 14 is etched through apertures 34 to form trenches for shallow trench isolation structures in accordance with a step 106 of process 100 (FIGURE 9). The trenches preferably

have a width corresponding to that of apertures 34. The trenches preferably have a depth of between approximately 1500 and 4000 Å and a width of 0.18-1.50 nm or less. The trenches can have a trapezoidal cross-sectional shape with the narrower portion being at the bottom. The embodiment discussed with reference to FIGURES 10-21 shows trenches having a trapezoidal cross-sectional shape. Substrate 14 is preferably etched in a dry-etching process to form the trenches. Substrate 14 can be etched in the same step as layer 16.

Although described as being etched in a dry etching process, the trenches can be formed in any process suitable for providing apertures in substrate 14. In one embodiment, the apertures for the trenches are provided all the way through substrate 14 to substrate 13. Alternatively, the bottom of the trenches associated with apertures 34 may not reach substrate 13, depending upon the thickness of substrate 14. In an embodiment in which substrate 13 is not provided, substrate 14 is deeper than the trenches associated with apertures 34.

In FIGURE 7, liners 38 are formed in the trenches associated with apertures 34. Preferably, liners 38 are oxide (e.g., silicon oxide or silicon dioxide) material formed in a low temperature process. In one embodiment, liners 38 are between approximately 200 and 500 Å thick and are provided over the bottom and side walls of the trench. In one embodiment, layers 18 and 22 are stripped before the formation of liners 38. In a preferred embodiment, layers 18 and 22 are not stripped until after the trenches are filled.

Liners 38 can be formed on layers 16, 18, and 22, although they are shown in FIGURE 8 as being formed on substrate 14 only. The embodiment discussed with reference to FIGURES 10-21 shows liners 138 formed on layers 116, 118, and 122 and also above layer 122.

According to one embodiment, liners 38 are formed in an advantageous ultraviolet light ozone (UVO) process. In one embodiment, portion 12 including the trenches associated with apertures 34 are provided in an oxygen atmosphere and subjected to ultraviolet light. In one embodiment, the trenches upon being exposed to UV light react to form ozone (O_3) and atomic oxygen (O) by absorbing UV light having a wavelength of approximately 185 nm. Once formed, the ozone can undergo further decomposition to form additional atomic oxygen by absorbing UV light having a wavelength of about 254 nm.

The atomic oxygen acts as a strong oxidizing agent. Both atomic oxygen and ozone may react with the silicon associated with substrate 14 and/or layer 16 to form an oxide layer. Although liners 38 are shown only with substrate 14, liners 38 can also be grown on side walls associated with layer 16. Exemplary UVO processes are discussed in United States Patent No. 6,168,961 issued to Vaccari on January 2, 2001. Any technique utilizing any UVO technique can be utilized according to this embodiment including adjustments of UVO energies and oxygen environments.

Advantageously, the UVO process is a low temperature process, thereby reducing germanium outdiffusion. Preferably, the UVO process is performed at a temperature of less than approximately 600°C. Although a low temperature is utilized, high quality and good compatibility liners 38

can be produced. In a most preferred embodiment, the UVO temperature process is performed at a temperature well below 600°C (e.g., below 550°C).

According to another embodiment, a dual frequency RF power PECVD process is utilized to form liners 38 at a temperature of between approximately 500 and 550°C. Preferably, the chemical vapor deposition process is performed at a low temperature (e.g., less than 700°C) and utilizes SiH_4 and O_2 gases. After the formation of a 200-500 Å thick layer for liners 38, a quick rapid thermal anneal (RTA) using an N_2 ambient is performed at a temperature between approximately 900 and 1000°C (e.g., 950°C) for approximately 30 seconds. Applicant believes that the relatively short RTA time will not cause significant germanium outdiffusion or outgassing.

In yet another embodiment, liners 38 can be formed by an atomic layer deposition (ALD) technique. Preferably, the ALD technique utilizes a temperature of approximately 700°C with a silane and oxygen atmosphere. According to an exemplary embodiment, a pulse cycle process is utilized for the ALD technique in which SiH_4 and O_2 gas flows are alternately turned on and off (pulsed) for between approximately 10 and 30 seconds.

In still another embodiment, liners 38 can be formed in a high density plasma oxide deposition (HDP) process similar to the CVD process discussed above. Preferably, the deposition processes do not utilize NH_3, instead utilizing silane at a temperature below 700°C. The HDP process preferably utilizes SiH_4 and O_2 gases and a temperature of between approximately 600 and 650°C. The HDP process utilizes high RF power (e.g., between approximately 4000 and 5000 watts).

In FIGURE 8, a layer of insulative material 40 is blanket deposited over layer 16 and within the trenches associated with apertures 34. Insulative material 40 is preferably silicon dioxide deposited in a HDP process. Preferably, insulative material 40 is deposited in a silane (SiH_4) process. Alternatively, a boron phosphate silicon glass (BPSG) process can be utilized. Insulative material 40 is preferably between approximately 2000 and 8000 Å thick.

Insulative material 40 is removed by polishing/etching until a top surface of layer 16 is reached. The removal of insulative material 40 leaves oxide material within the trenches associated with apertures 34. Insulative material 40 can be removed by a number of stripping or etching processes. Preferably, insulative material 40 is removed from above layer 16 by chemical-mechanical polishing (CMP).

In one embodiment, insulative material 40 is deposited after the trenches are formed and before layer 22 is stripped. The insulative material is polished or etched until layer 22 is reached. Layers 22 and 18 can be stripped in a subsequent process.

Although material is shown in FIGURE 8 as being a single structure formed within the trenches (above the top surface and side surfaces of liners 38) to a top surface of layer 16, insulative material 40 may stop at a top surface of liners 38.

After insulative material 40 is provided in the trenches associated with apertures 34, a gate structure 44 can be provided. Gate structure 44 can be a conventional MOSFET gate structure, such as, a metal over oxide gate structure or polysilicon over oxide gate structure. In one embodiment, gate structure 44 is comprised of a tantalum nitride or titanium nitride gate conductor formed by a plasma vapor deposition sputtering technique. During sputtering, nitrogen (N_2) gas can be provided to modify the metal and nitrogen composition of the gate conductor. This modification can be used to adjust a work function associated with the gate structure 44. For example, a 200 millivolt shift in threshold voltage can be achieved by adjusting the flow of nitrogen gas associated with gate structure 44.

FIGURES 10 through 21 illustrate a method of manufacturing an integrated circuit (IC) in accordance with another exemplary embodiment. The method illustrated in FIGURES 10 through 21 reduces germanium outgassing and outdiffusion problems associated with silicon germanium structures. The process can be used in a shallow trench isolation (STI) process or any process requiring a liner oxide and utilizing germanium or other substance prone to outgassing at high temperature. Advantageously, a liner oxide layer can be formed from another layer formed at low temperature and yet provides a high quality oxide with good compatibility. Low temperature for the embodiment discussed with reference to FIGURES 10-21 is a temperature below approximately 700°C. Similar structures in FIGURES 1-8 have similar reference numerals (differing by 100) to the structures illustrated in FIGURES 10-20.

Referring to FIGURES 10 and 21, a cross-sectional view of a portion 112 of an integrated circuit (IC) is illustrated. Portion 112 (FIGURE 10) is subjected to process 200 (FIGURE 21) to form a shallow trench isolation (STI) structure. Portion 112 includes an oxide layer 118 provided over a strained silicon layer 116. Layer 116 is provided over a semiconductor substrate 114 or a germanium containing layer or substrate. Substrate 114 can be provided above a substrate such as substrate 13 (FIGURE 1).

Portion 112 can be any type of semiconductor device, or portion thereof, made from any of the various semiconductor processes such as a complementary metal oxide semiconductor (COMs) process, bipolar process, or other semiconductor process. Portion 112 may be an entire IC or a portion of an IC including a multitude of electronic component portions.

Substrate 114 is preferably silicon germanium or another semiconductor material including germanium, and can be doped with P-type dopants or N-type dopants. Substrate 114 can be an epitaxial layer provided on a semiconductor or an insulative base, such as substrate 13. Furthermore, substrate 114 is preferably a composition of silicon germanium (Si_{1-X} Ge_X, where X is approximately 0.2 and is more generally in the range of 0.1-0.4). Substrate 114 can be part of a wafer and can be similar to substrate 14 (FIGURE 1).

A strained silicon layer 116 is formed above layer 114 by an epitaxial process. Preferably, layer 118 is grown by CVD at a temperature of 600°C. Layer 118 can be a pure silicon layer and have a thickness of between approximately 50 and 150 Å.

Pad oxide film or oxide layer 118 is provided on layer 116. Layer 118 is optional. Layer 118 is preferably thermally grown on top of layer 118 to a thickness of approximately 100-300 Å. Layer 118

serves as a buffer layer and can be thermally grown in a conventional high temperature process by heating to 1000°C in an oxygen atmosphere. Germanium outdiffusion and outgassing are not a problem at this point due to the presence of layer 118.

A barrier or hard mask layer 122 is provided over oxide layer 118. Preferably, mask layer 122 is silicon nitride (Si_3N_4) provided at a thickness of between approximately 300 and 1000 Å by a deposition or thermal growth process. Preferably, mask layer 122 is provided in a CVD or growth process and can be similar to layer 22 (FIGURE 1).

A photoresist layer 124 is spun on top of mask layer 122. Preferably, photoresist layer 124 is any commercially available i-line or deep UV photoresist such as (Shipley Corp., MA) SPR 955 (i-line) UV5 (deep UV). In FIGURE 11, photoresist layer 124 is selectively removed via a photolithographic process to leave apertures 134 in accordance with a step 202 (FIGURE 21) of process 200 using mask or reticle 128.

In FIGURE 12, mask layer 122 is etched via a dry-etching process so that apertures 134 reach oxide layer 118 in accordance with a step 104 of process 200 (FIGURE 21). The dry-etching process is selective to silicon nitride with respect to oxide layer 124. Layer 124 can be stripped after layer 122 is etched.

In FIGURE 13, the etch process is changed to etch through silicon dioxide material and layer 118 is etched so that apertures 134 reach layer 116 in accordance with step 204 of process 200 (FIGURE 21). Layer 118 can be etched in a dry etching process. Alternatively, other etching techniques can be utilized to remove selected portions of layer 118. Photoresist layer 124 (FIGURE 10) can be removed before or after oxide layer 118 is etched.

In FIGURE 14, the etch process is changed to etch through silicon material. Strained silicon layer 116 can be removed in accordance with a dry-etching process so that apertures 134 reach substrate 114.

In FIGURE 15, substrate 114 is etched through apertures 134 to form trenches for a shallow trench isolation structure in accordance with a step 206 of process 200 (FIGURE 21). The trenches preferably have a width corresponding to apertures 134. The trenches preferably have a depth of between approximately 1500 and 4000 Å and a width of 0.18-1.50 nm or below. The trenches can have a trapezoidal cross-sectional shape with the narrower portion being at the bottom. The trenches can also have other cross-sectional shapes. Substrate 114 is preferably etched in a dry-etching process to form the trenches. Substrate 114 can be etched in the same step as layer 116.

Although described as being etched in a dry etching process, the trenches can be formed in any process suitable for providing an aperture in substrate 114. In one embodiment, the apertures for the trenches are provided all the way through substrate 114 to another substrate (e.g., substrate 13 in FIGURE 1).

In FIGURE 16, a conformal layer 126 is formed in the trenches and above layer 122. In one embodiment, layer 126 is a semiconductor or metal layer that can be formed at a low temperature (e.g., below 600°C). Layer 126 is preferably a layer that can be oxidized to form an insulative material such as an oxide

liner. Most preferably, layer 126 is a 100-200 Å thick amorphous silicon layer deposited by CVD at a temperature of 500-600°C. Layer 126 is deposited in accordance with step 208 of process 200 (FIGURE 21).

Layer 126 is preferably provided in sidewalls of the trenches associated with apertures 134 of substrate 114 and of layers 116, 118 and 122. Layer 126 is also provided on a top surface of layer 122. In FIGURE 17, layer 126 is converted to an insulative material such as a liner oxide material 128. Preferably, layer 126 (FIGURE 16) is formed into liner oxide material 128 in an oxidation process by thermally soaking O_2 at a temperature of between approximately 650 and 700°C. Preferably, the oxidation process can occur at a higher temperature. Germanium outdiffusion is reduced due to the barrier associated with layer 126. Preferably, the entire layer 126 is converted into liner oxide material 128.

In FIGURE 18, layer 122 is planarized or etched to remove liner oxide material 128 from the top surface of layer 122. Alternatively, layer 126 can be removed from top surface of layer 122 before liner oxide material 128 is formed. Liner oxide material 128 remains as liner 138 within the trenches associated with aperture 134.

In FIGURE 18, liners 138 are formed in the trenches associated with apertures 134. Preferably, liners 138 are oxide (e.g., silicon oxide or silicon dioxide) material formed by oxidizing a semiconductor or metal layer. In one embodiment, liners 138 are approximately 200-500 Å thick. In one embodiment, layers 122 and 118 are stripped before the formation of liners 138. In a preferred embodiment, layers 128 and 122 are not stripped until after the trenches are filled.

In FIGURE 19, a layer 142 of insulative material 140 is blanket deposited over layer 116 and within trenches associated with aperture 134. Insulative material 140 is preferably silicon dioxide deposited in an HDP process and is similar to material 40 (FIGURE 8). Preferably, insulative material 140 is deposited in a silane (SiH_4) process. Alternatively, a boron phosphate silicon glass (BPSG) process can be utilized. Insulative material 140 is preferably between approximately 2000 and 8000 Å thick.

Insulative material 140 is removed by polishing/etching until a top surface of layer 122 is reached. The removal of insulative layer leaves oxide material 140 within the trenches associated with apertures 134. Insulative material 140 can be removed by a number of stripping or etching processes. Preferably, insulative material 140 is removed from above layer 122 by dry-etching.

In one embodiment, insulative layer 142 associated with insulative material 140 is deposited after the trenches are formed and layers 122 and 116 are stripped. Insulative layer 142 is polished or etched until layer 122 is reached.

Although material is shown in FIGURE 19 as being a single structure formed within the trenches (above the top surface and side surfaces of liners 138) to a top surface of layer 116, insulative material 140 may stop at a top surface of liners 138.

In FIGURE 20, after insulative material 140 is provided in the trenches associated with apertures 134, a gate structure 156 can be provided. Gate structure 156 can be a conventional MOSFET gate

structure, such as, a metal over oxide gate structure or polysilicon over oxide gate structure. In one embodiment, gate structure 156 is covered with an oxide (e.g., silicon dioxide layer 154) and a silicon carbide (SiC) layer 148. Portion 112 is subjected to an anneal after layers 154 and 148 are provided. Layer 148 can prevent germanium outgassing.

The technique of using layers 148 and 154 can be particularly advantageous if layer 118 is not utilized with portion 112 and gate structure 156 is provided directly over a germanium containing substrate. In another embodiment, layer 148 can be a tantalum nitride (TaN), titanium nitride (TiN), tungsten nitride (WN), titanium/titanium nitride (Ti/TiN) layer of approximately 100 Å thick and layer 154 can be a silicon dioxide layer approximately 100 Å thick. The spacers associated with gate structure 156 can be silicon nitride. According to another embodiment, process 200 can include a step to pre-clean top surface of layer 118 after gate structure 156 is formed and before layers 154 and 148 are deposited. In such an embodiment, a hydrogen (H_2) bake is utilized to reduce native oxide which can prevent solicidation reactions. The hydrogen bake causes less damage than argon sputtering pre-clean steps associated with conventional processes. Following cleaning and the hydrogen baking step at gas flows of approximately 800°C to 900°C, conventional silicidation processes can be utilized. Alternatively, a hydrochloric acid (HCl) environment and low temperature anneal at 700°C can be utilized to eliminate germanium at the surface of the semiconductor wafer.

It is understood that while the detailed drawings, specific examples, and particular values given provide a preferred exemplary embodiment of the present invention, it is for the purpose of illustration only. The shapes and sizes of trenches are not disclosed in a limiting fashion. The method and apparatus of the invention is not limited to the precise details and conditions disclosed. Various changes may be made to the details disclosed without departing from the spirit of the invention, which is defined by the following claims.

CLAIMS

WHAT IS CLAIMED IS:

1. A method of forming a liner in a trench in a germanium containing layer, the method comprising:

selectively etching the germanium containing layer to form the trench;

providing a layer of insulative material in the trench in a low temperature process; and

annealing to form the liner.

2. A method of manufacturing an integrated circuit having trench isolation regions in a substrate including germanium, the method comprising:

forming a silicon nitride layer above the substrate;

selectively etching the silicon nitride layer to form apertures associated with locations of the trench isolation regions;

forming trenches in the substrate at the locations;

forming an oxide layer in the trenches in a low temperature process; and

annealing the oxide layers in the trenches of the substrate.

3. The method of claim 2, further comprising providing an insulative material in the trenches to form the trench isolation regions.

4. The method of claims 1 or 2, wherein the low temperature process is performed at a temperature of less than approximately 700°C.

5. The method of claims 1 or 2, wherein the low temperature process uses an oxygen atmosphere and a silane atmosphere.

6. A method of forming shallow trench isolation regions in a semiconductor layer, the method comprising:

providing a hard mask layer above the semiconductor layer;

providing a photoresist layer above the hard mask layer;

selectively removing portions of the photoresist layer at locations in a photo-lithographic process;

removing the hard mask layer at the locations;

forming trenches in the hard mask layer under the locations; and

forming a liner in the trenches using a deposited oxide layer in the trenches and an anneal.

7. The method of claim 6, further comprising providing a pad oxide layer above a strained silicon layer before the providing a hard mask layer step.

8. The method of claim 7 further comprising removing the pad oxide layer at the locations before the step of forming trenches in the hard mask layer.

9. The method of claim 6, further comprising:

providing an insulative material in the trenches to form the shallow trench isolation regions; and

removing the hard mask layer in a wet bath comprising acid.

10. The method of claim 9, wherein the anneal is a rapid thermal anneal.