range, it is necessary to add special ingenuity to a crystal growth apparatus (for example, Japanese Patent Laying-Open No. 2006-312576 discloses making a temperature gradient of a crystal peripheral portion to be lower than a temperature gradient of a crystal central portion during crystal growth). However, such ingenuity results in a reduction in crystal growth rate (for example, according to Japanese Patent Laying-Open No. 2006-312576, the pulling rate is about 0.3 to 0.6 mm/min). As a result, productivity of the crystal is reduced, and manufacturing cost of silicon wafers is increased as a total, although there is no need for annealing. Further, if the range of V/G is limited to a narrow range, this results in an increase in an area of the crystal which is out of the V/G range due to variations in crystal growth, causing a reduction in crystal yield.

The present invention has been made to solve problems as described above, and one object of the present invention is to provide a method of manufacturing an annealed wafer capable of avoiding residual voids after annealing and deterioration of TDDB characteristics of an oxide film formed on the annealed wafer, and extending the range of nitrogen concentration that can be contained in a silicon single crystal.

A method of manufacturing an annealed wafer in accordance with the present invention includes the steps of: growing a silicon single crystal from a silicon melt to which nitrogen, carbon, and hydrogen are added, by Czochralski method; cutting out a substrate from the silicon single crystal; and heat treating the cut-out substrate. With respect to growth conditions for manufacturing the silicon single crystal by the Czochralski method in the step of growing the silicon single crystal, if a ratio between a crystal

Claims:

1. A method of manufacturing an annealed wafer, comprising the steps of:

growing a silicon single crystal to which nitrogen, carbon, and hydrogen are added, by Czochralski method;

cutting out a substrate from said silicon single crystal; and

heat treating said cut-out substrate,

wherein, with respect to growth conditions for manufacturing the silicon single crystal by the Czochralski method in said step of growing said silicon single crystal,

if a ratio between a crystal pulling rate V (mm/min) and an average temperature gradient G (°C/mm) in a crystal growth axis direction is defined as V/G, and V/G in a case where nitrogen, hydrogen, and carbon are not added to said silicon single crystal is defined as $(V/G)_{crit}$, crystal pulling conditions are controlled such that V/G is not less than $0.9\times(V/G)_{crit}$ and not more than $2.5\times(V/G)_{crit}$ (where V represents the pulling rate [mm/min], G represents the average temperature gradient [°C/mm] in the crystal growth axis direction from a melting point to 1350°C, and said $(V/G)_{crit}$ is a V/G value of a portion corresponding to a boundary between an I region and a V region in the silicon single crystal to which nitrogen, hydrogen, and carbon are not added, said V region being a region into which excessive vacancies are introduced from a solid-liquid interface during crystal growth, and said I region being a region into which excessive interstitials are introduced from the solid-liquid interface during the

crystal growth), and

a hydrogen partial pressure within a crystal pulling furnace is set to not less than 3 Pa and less than 40 Pa,

said silicon single crystal grown in said step of growing said silicon single crystal is a silicon single crystal to which nitrogen, carbon, and hydrogen are added having a nitrogen concentration of more than 5×10^{14} atoms/cm^3 and not more than 6×10^{15} atoms/cm^3, and a carbon concentration of not less than 1×10^{15} atoms/cm^3 and not more than 9×10^{15} atoms/cm^3, and

in said step of heat treating, heat treatment is performed in a noble gas atmosphere having an impurity concentration of not more than 5 ppma, or in a non-oxidizing atmosphere in which a film thickness of an oxide film to be formed on a surface of said substrate after the heat treatment is suppressed to not more than 2 nm, at a heating temperature of not less than 1150°C and not more than 1250°C, for a heating time period of not less than 10 minutes and not more than two hours.

2. The method of manufacturing an annealed wafer according to claim 1, wherein, in said step of growing said silicon single crystal, said nitrogen and carbon are added to a silicon melt.

3. The method of manufacturing an annealed wafer according to claim 1 or 2, wherein, in said step of growing said silicon single crystal, a rate of cooling from 1100°C to 1000°C is not more than 2.5°C/min.

CLAIMS:

1. A method of manufacturing an annealed wafer, comprising the steps of:

a) growing a silicon single crystal by the Czochralski method from a silicon melt to which nitrogen, carbon, and hydrogen are added in a crystal pulling furnace;

b) cutting out a substrate from said silicon single crystal; and

c) heat treating said substrate, wherein, during growth of the silicon single crystal in step a),

a)i) the ratio of a crystal pulling rate V (mm/min) and an average temperature gradient G (°C./mm) in a crystal growth axial direction is defined as V/G, and V/G in a case where nitrogen, hydrogen, and carbon are not added to a silicon single crystal is defined as $(V/G)_{crit}$, crystal pulling conditions are controlled such that V/G is not less than $0.9\times(V/G)_{crit}$ and not more than $2.5\times(V/G)_{crit}$ (where V represents the pulling rate [mm/min], G represents the average temperature gradient [°C./mm] in the crystal growth axial direction from a melting point to 1350°C., and $(V/G)_{crit}$ is the V/G value of a portion corresponding to a boundary between an I region and a V region in the silicon single crystal to which nitrogen, hydrogen, and carbon are not added, said V region being a region into which excessive vacancies are introduced from a solid-liquid interface during crystal growth, and said I region being a region into which excessive interstitials are introduced from the solid-liquid interface during the crystal growth),

a)ii) a hydrogen partial pressure within the crystal pulling furnace is set to not less than 3 Pa and not more than 40 Pa,

a)iii) and the silicon single crystal grown in the step of growing the silicon single crystal is a silicon single crystal having a nitrogen concentration of more than 5×10^{14} atoms/cm^3 and not more than 6×10^{15} atoms/cm^3, and a carbon concentration of not less than 1×10^{15} atoms/cm^3 and not more than 9×10^{15} atoms/cm^3, and during heat treating in step c), heat treatment is performed in a noble gas atmosphere having an impurity concentration of not more than 5 ppma, or in a non-oxidizing atmosphere in which a film thickness of an oxide film to be formed on a surface of

said substrate after the heat treatment is suppressed to not more than 2 nm, at a heating temperature of not less than 1150°C. and not more than 1250°C., for a heating time period of not less than 10 minutes and not more than two hours.

2. The method of manufacturing an annealed wafer of claim 1, wherein, in step a) of growing the silicon single crystal, nitrogen and carbon are added to the silicon melt.

3. The method of manufacturing an annealed wafer of claim 1, wherein, in the step of growing the silicon single crystal, the rate of cooling from 1100°C. to 1000°C. is not more than 2.5°C./min.

4. The method of manufacturing an annealed wafer of claim 2, wherein, in the step of growing the silicon single crystal, the rate of cooling from 1100°C. to 1000°C. is not more than 2.5°C./min.