subject to a relatively short duration of heat treatment, typically crystalline silicon solar cells, are heat treated, the standby time accounts for a relatively high proportion among the overall heat treatment time, which becomes the major cause of restricting the productivity of the heat treatment process. Also in the case of a furnace core tube of the above-mentioned structure, upon replacement of the furnace core tube for periodic cleaning and shelf storage thereof, a thin tubular gas inlet conduit can be broken. Since the core tube of high-purity quartz or the like is expensive, the expenses for repair and purchase of a new one are high. This is one of the factors that cause to increase the running cost of the heat treatment process.

[0008]

Furthermore, when a heat treatment furnace of the continuous mode having inlet and outlet as typified by the belt conveyor or walking beam system is employed, the furnace has low gas tightness due to the presence of the belt or beam, even in the structure provided with shutters at the inlet and outlet, and fails to prevent inflow of ambient air, giving rise to a problem that the carrier lifetime of semiconductor substrates can be significantly reduced by the heat treatment. Such continuous mode heat treatment furnaces of the belt conveyor or walking beam system also have problems including a small number of simultaneously processable workpieces per unit area, and low thermal efficiency.

[0009]

~~An object~~Embodiments of the invention, which has been made under the above-mentioned circumstances, ~~is~~ seek to provide a heat-treatment furnace which ~~is adapted to~~may reduce a standby time between batches during consecutive heat treatment of semiconductor substrates for thereby improving productivity and

~~to~~ may reduce the frequency of breaking of gas inlet conduits for thereby saving the running cost of the heat-treatment process.

Solution to Problem

[0010]

Making extensive investigations to attain the above object, the inventors have found that a furnace core tube for use in heat treatment process is structured as a cylindrical shape tube which is provided at opposite ends with openings having a sufficient size to allow semiconductor substrates to be moved into and out of the core tube, a lid is detachably mounted to the core tube to block each opening to substantially seal the core tube, the core tube or lid is provided with a thin gas inlet conduit for introducing gas into the core tube, whereby the atmosphere within the furnace can be kept clean during heat treatment, and the semiconductor substrates may be moved into and out of the core tube and heat treated therein while the lids at opposite ends are opened and closed as necessary, whereby a standby time between batches during consecutive heat treatment can be reduced for thereby improving productivity. Since the core tube is structured as a simple cylindrical shape, the frequency of breaking of gas inlet conduits ~~is~~ may be reduced and the cost of the core tube itself ~~is~~ may be reduced. As a result, the running cost of the heat-treatment process can be saved. ~~The invention is predicated on these findings.~~

[0011]

Accordingly, embodiments of the invention provide~~s~~ a heat-treatment furnace as defined below.

~~(1)~~ According to a first aspect of the present invention, there is provided ~~A~~ a heat-treatment furnace for use in the heat treatment of semiconductor substrates, comprising a cylindrical core tube which is provided at opposite ends with openings having

a sufficient size to allow a boat having semiconductor substrates rested thereon on standby to be moved into and out of the core tube, a heater for heating the core tube, lids each of which is detachably mounted to the core tube to block the opening to substantially seal the core tube, a first thin gas inlet conduit disposed near the longitudinal center of the core tube for introducing a high-purity gas into the core tube to keep the furnace interior clean during movement of the boat into and out of the core tube, and a second thin gas inlet conduit penetrating through the one of the lids for introducing a process gas into the core tube for heat-treatment during the heat-treatment of the semiconductor substrates,

wherein during continuous implementation of batch heat-treatment which comprises moving a boat having semiconductor substrates into the core tube, performing the heat-treatment of the substrates and moving the boat having the substrates out of the core tube, the operation of moving a first boat having heat-treated semiconductor substrates out of the one of the openings of the core tube and the operation of moving a second boat having next semiconductor substrates into the other of the openings of the core tube are performed at the same time while introducing the high-purity gas into the core tube from the first thin gas inlet conduit to keep the furnace interior clean.

~~(2)~~ According to a second aspect of the present invention, there is provided a method for a heat-treatment of semiconductor substrates using the heat-treatment furnace as defined in the first aspect, the method comprising a step of movement of the boat into and out of the core tube, wherein the operation of moving the first boat having heat-treated semiconductor substrates out of the one of the openings of the core tube and the operation of moving the second boat having next semiconductor substrates into the other of the openings of the core tube are performed at the same time while introducing the high-purity gas into the core tube from the first thin gas inlet conduit to keep the furnace interior clean, and a step of heating the semiconductor substrates in the core tube while introducing the process gas into the core tube

from the second thin gas inlet conduit for the heat-treatment of the semiconductor substrates.

The heat-treatment furnace as disclosed, ~~of (1),~~ which may further ~~comprising~~ comprise lids each of which ~~is~~ may be detachably mounted to the core tube to block the opening to substantially seal the core tube.

~~(3) The~~ The heat-treatment furnace ~~of (1) or (2),~~ as disclosed, which may further ~~comprising~~ comprise thin gas inlet conduits penetrating through the lids for introducing gas into the core tube.

~~(4) The~~ The heat-treatment furnace ~~of any one of (1) to (3),~~ as disclosed, which may further ~~comprising~~ comprise thin gas inlet conduits disposed near opposite ends of the core tube for introducing gas into the core tube.

~~(5) The~~ The heat-treatment furnace ~~of any one of (1) to (4),~~ as disclosed, which may further ~~comprising~~ comprise a thin gas inlet conduit disposed near the longitudinal center of the core tube for introducing gas into the core tube.

~~(6) In The~~ In the heat-treatment furnace ~~of any one of (1) to (5),~~ as disclosed, ~~wherein~~ the opening in the core tube ~~has~~ may have an inner diameter which ~~is~~ may be at least 95% of the inner diameter of the core tube at the center.

~~(7) The~~ The heat-treatment furnace ~~of any one of (1) to (6),~~ as disclosed, which may further ~~comprising~~ comprise at least one boat station disposed outside the core tube and in proximity to the opening in the core tube, the boat station carrying a boat having semiconductor substrates rested thereon on standby.

~~(8) In The~~ In the heat-treatment furnace ~~of any one of (1) to (7),~~ as disclosed, ~~wherein~~ the heat treatment ~~is~~ may be intended to diffuse a p- or n-type dopant into silicon substrates.

~~(9) In The~~ In the heat-treatment furnace ~~of any one of (1) to (7)~~ as disclosed, ~~wherein~~ the heat treatment ~~is~~ may be intended to oxidize silicon substrates.

Advantageous Effects of Invention

[0012]

The invention may reduces a standby time between batches during consecutive heat treatment of semiconductor substrates, thereby improving productivity. The core tube structured as a simple cylindrical shape may reduces the frequency of breaking of gas inlet conduits, thereby saving the running cost of the heat-treatment process.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

FIG. 1 is a schematic cross-sectional view of one embodiment of the invention including a furnace core tube and lids having gas inlet conduits.

FIG. 2 is a schematic cross-sectional view of another embodiment of the invention including a furnace core tube having gas inlet conduits disposed near opposite ends and at the lower side thereof, and lids.

FIG. 3 is a schematic cross-sectional view of a further embodiment of the invention including a furnace core tube having a gas inlet conduit disposed near the center thereof, and lids.

FIG. 4 is a schematic cross-sectional view of one exemplary structure of a conventional furnace core tube.

FIG. 5 is a schematic cross-sectional view of a heat-treatment flow using one exemplary heat-treatment furnace of the invention.

FIG. 6 is a schematic cross-sectional view of a heat-treatment flow using another exemplary heat-treatment furnace of the invention.

FIG. 7 is a schematic cross-sectional view of a heat-treatment flow using the conventional heat-treatment furnace.