the silicon Fin part 11 and to increase a Fin width (a size of horizontal direction in Figs. 3A to 3D) of the silicon Fin part 11. This is advantageous in manufacturing the Fin type FET. Further, it can bring an increase in drive current and the characteristic of the transistor can be improved. Such a Fin type FET is called a TriFET. In this case, it is required to implant the impurity into upper side walls of the silicon Fin part 11, that is an upper flat portion of the silicon Fin part 11, in the same concentration level as the side walls lower than the upper flat portion.

However, in the above method proposed by the present inventors, the impurity implantation to the upper flat portion of the silicon Fin part is never considered. For this reason, it is impossible to effectively utilize the upper portion of the silicon Fin part and therefore the Fin type FET has degraded drive current.

Summary of Invention

EmbodimentsAn object of the present invention seekis to improve a doping method of an impurity atom to side wall portions and an upper flat portion of a cubic concavity and convexity part of a three-dimensional device.

An embodimentspecific object of the present invention seeksis to provide a method for performing impurity diffusion to a three-dimension device, for example, an upper flat portion of a silicon Fin part, in the same concentration as side wall portions of the silicon Fin part.

In a semiconductor device manufacturing method according to the present invention, a cubic concavity and convexity part is formed with an etching process or the like onto a semiconductor substrate which is a base substrate of the semiconductor device. A thin film including an impurity atom which can become a carrier impurity atom serving as a donor or an acceptor in the semiconductor substrate is formed, as a deposited film, to the cubic

becomes a substantial dose amount of 17.6% defined by cosine 80°/cosine 10° relative to the upper surface (upper flat portion) of the cubic concavity and convexity part, the thickness of the deposited film deposited on the upper flat portion of the cubic concavity and convexity part is set to enough thickness concomitant with the above mentioned value. Generally, in the film deposition with plasma, since the coverage of the deposited film to the upper flat portion and the side walls of the cubic concavity and convexity part can be controlled, it is natural that the deposited film is formed to the upper flat portion with a thick thickness while the deposited film is formed to the side walls with a thin thickness and therefore the film formation is easy.

Aspects of the present invention are enumerated as follows.

(First Aspect)

A manufacturing method of a semiconductor device according to a first aspect of this invention comprises forming a cubic concavity and convexity part on the surface of a semiconductor substrate which is a base substrate of the semiconductor device. The cubic concavity and convexity part have a plurality of convexity parts and a plurality of concavity parts presented between the plurality of convexity parts. The cubic concavity and convexity part has side wall portions and an endupper flat portion. The manufacturing method further comprises depositing on the surface of the convexity partssemiconductor substrate an impurity thin film including an impurity atom arranged towhich becomes a donor or an acceptor in the semiconductor substrate so that a film thickness of the impurity thin film formed on the surface of the endupper flat portion becomes large relative to a film thickness of the impurity thin film formed on the

surface of the side wall portions. The manufacturing method still further comprises performing with an ion beam, a first diagonal ion implantation from a diagonal upper side direction relative to one side wall portion of the convexity part to the impurity thin film deposited on the one side wall portion and the end flat portion of the~~cubic concavity and~~ convexity part and subsequently a second diagonal ion implantation from a~~n opposite~~ diagonal upper direction relative to another side portion of the convexity part to the impurity thin film deposited on the other side wall portion and the end flat portion of the~~cubic concavity and~~ convexity part so as to~~and~~ recoil~~ing~~ the impurity atom from the inside of the impurity thin film to the inside of the side

wall portions and the inside of the endupper flat portion of the ~~cubic concavity and~~ convexity part by performing the first and second diagonal ion implantations. It is important that an impurity amount implanted to the side wall portion is substantially a half of an impurity amount implanted to the upper flat surface in a single ion implantation. By the first and second diagonal ion implantations from diagonal upper left and right directions, the impurity is implanted into the side wall portion and the upper flat portion with the same amount. The first diagonal ion implantation is performed orthogonal to the second diagonal ion implantation. The impurity atom in said impurity thin film is recoiled from the inside of said impurity thin film to the inside of said semiconductor substrate by a knock on effect that is caused, at a surface part of the convexity part, by collision of the implantation ion to the impurity atom in said impurity thin film in a direction substantially orthogonal to the surface part of the convexity part, a ratio of impurity implantations to the side wall portion and the end flat portion is adjusted by adjusting a ratio of a deposition thickness of the impurity thin film deposited to the side wall portion and a deposition thickness of the impurity thin film deposited to the end flat portion and by adjusting an ion implantation angle of said first and second diagonal ion implantations, and wherein implantation ions in the ion beam of the first and second diagonal ion implantations is any one of Si, As, Ge, In and Sb so that a mass of the implantation ions is heavier in weight than that of the impurity atom in said impurity thin film in order to give energy to more atoms in said impurity thin film and a number of purpose impurity atoms greater than the implantation ions can be implanted within the semiconductor device base substrate and that an energy of the implantation ions can be set higher than an energy given to the purpose impurity atoms.

(Second Aspect)

In the manufacturing method according to the first aspect, a ratio of impurity implantations to the side wall portion and the upper flat portion is adjusted by adjusting a ratio of a deposition thickness of the impurity thin film deposited to the side wall portion and a deposition thickness of the impurity thin film deposited to the upper flat portion.

(Third Aspect)

In the manufacturing method according to the first aspect, a ratio of impurity implantations to the side wall portion and the upper flat portion is adjusted by adjusting an ion implantation angle of the first and second diagonal ion implantations.

(Fourth Aspect)

In the manufacturing method according to the first aspect, a ratio of impurity implantations to the side wall portion and the upper flat portion is adjusted by adjusting a ratio of a deposition thickness of the impurity thin film deposited to the side wall portion and a deposition thickness of the impurity thin film deposited to the upper flat portion and by adjusting an ion implantation angle of the first and second diagonal ion implantations.

(Fifth Aspect)

In the manufacturing method according to the first aspect, an impurity is implanted into the side wall portion and the upper flat portion at a ratio of