Formation and Thermal Stability Characteristics of Ni Silicide on Boron Cluster ($B_{18}H_{22}$) Implanted Source/Drain

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Abstract

The formation and thermal stability characteristics of Ni silicide formed on boron cluster ($B_{18}H_{22}$) implanted substrate were examined in comparison with those formed on conventional boron and BF_2 implanted substrates. The Ni silicide formed on boron cluster implanted substrate showed similar characteristics as those formed on boron and BF_2 implanted source/drain. Its sheet resistance, however, increased compared with boron and BF_2 cases after high temperature post-silicidation annealing.

1. Introduction

SALICIDE (Self Aligned Silicide) technology has been used for high-performance integrated circuit to reduce contact resistance of gate, source and drain. [1] At present, it is believed that Ni silicide will replace current $CoSi_2$ for nano-scale MOSFET (Metal Oxide Semiconductor Field Effect Transistor) because Ni silicide has several advantages over $CoSi_2$, such as small silicon consumption during the silicidation, little line width dependence of sheet resistance of silicide [2].

Also, in order to attain continued reduction of minimum feature size of MOSFET, formation of an ultra-shallow junction is highly required to suppress the short channel effects (SCE). [3] Recently, boron cluster ion implantation has been proposed for ultra shallow junction in source/drain extension (SDE) region for nano-scale PMOSFETs. [4-6] However, there was little study on the formation of Ni silicide on the boron cluster implanted source/drain region.

In this paper, properties of Ni silicide on boron cluster implanted source/drain will be analyzed. Ni silicide is also formed on conventional dopants such as B and BF_2.

2. Experimental

$B_{18}H_{22}$, BF_2, and B^+ were implanted on Si wafer. Ion implantation conditions are noted in Table 1 and fabrication flow is summarized in Fig. 1. Implanted dopants are activated using a spike RTA at 1070°C for 10 sec. Then, Ni was deposited using the RF magnetron sputter at the base pressure of less than 5×10^{-7} torr after dipping the specimen in a diluted HF solution to remove the native oxide. The deposited thickness of Ni is 10nm.

Table 1. Ion implantation conditions of dopant used for experiment

	Dose [$/cm^2$]	Energy [keV]
$B_{18}H_{22}$	3 x10^{15}	20
BF_2	3 x10^{15}	3
B^+	3 x10^{15}	2.5

To form the Ni monosilicide, RTP (Rapid Thermal Processing) was applied at 400~700°C for 30 sec in vacuum ambient. Next, un-reacted metal was selectively etched off in sulfuric solution (H_2SO_4 : H_2O_2 = 4 : 1) for 15 min. High temperature post-silicidation furnace annealing at 550~650°C for 30 min was carried out in N_2 ambient to evaluate thermal stability of the Ni silicide. Finally, Sheet resistance was measured using FPP (Four Point Probe) and uniformity of Ni silicide/Si interface and thicknesses of Ni silicide were analyzed by field emission scanning electron microscope (FE-SEM, S-4700). Phase formation of Ni silicide was analyzed by x-ray diffraction (XRD).

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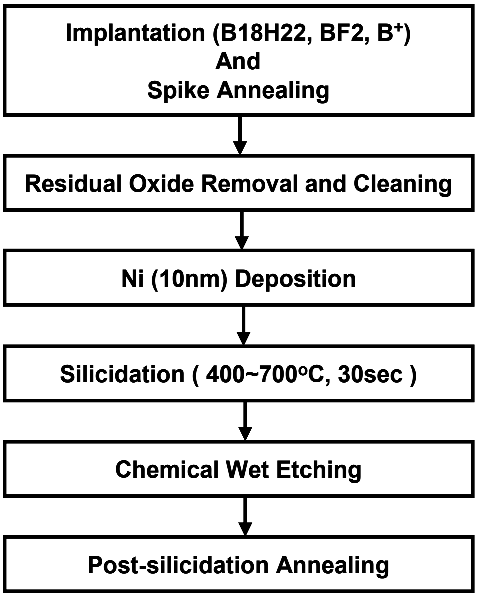


Fig. 1. Process flow for experiments.

3. Result and discussion

Fig. 2 shows sheet resistance of Ni silicide formed on different dopnats as a function of RTP temperature. The sheet resistances of boron substrate shows the widest uniform RTP window and $B_{18}H_{22}$ case shows a little larger sheet resistance. One notable point is that there is a sharp increase of sheet resistances for both BF_2 and $B_{18}H_{22}$ from 650 °C.

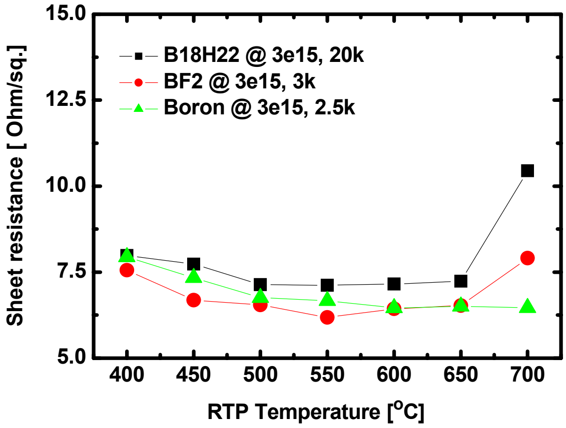
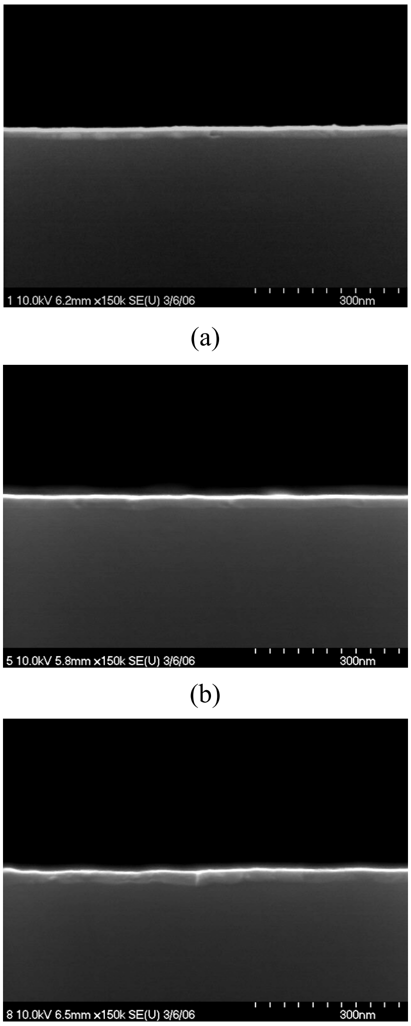


Fig. 2. Sheet resistance as a function of RTP temperaure. RTP time is 30 sec.

Fig. 3 shows the cross-sectional FESEM images of silicides that were formed at 550 °C for 30 sce. It shows that the Ni silicide was formed uniformly and with a thickness of less than 25 nm for all structures. Although thickness is somewhat similar to those with other dopants, BF_2 case shows a little larger thickness than the others, which is in consistent with the low sheet resistance as in Fig. 2.



(a)

(b)

(c)

Fig. 3. Cross sectional SEM images of Ni silicide at 550 °C RTP. (a) $B_{18}H_{22}$, (b) BF_2 and (c) Boron.

Fig. 4 shows sheet resistances after high temperature post-silicidation annealing in an N_2 ambient. Investigation of thermal stability of Ni silicide is important because there are several high temperature processes after formation of Ni silicide in ULSI CMOS technology. The sheet resistance is less than 15 ohm/sq. up to 600 °C. However, sheet resistance increased sharply at the temperature higher than 600 °C except B^+. Generally, it is well known that increase of sheet resistance strongly depends on phase transformation and agglomeration of Ni silicide after post-silicidation annealing. Phase transformation was observed through the XRD spectra.

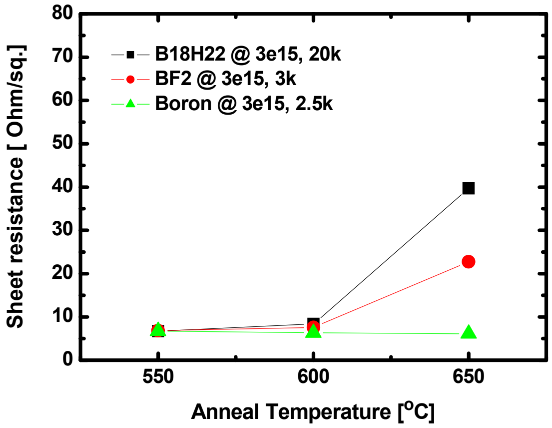


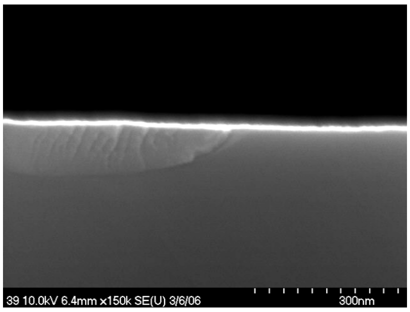
Fig. 4. Sheet resistance after post-silicidation annealing

Fig. 5 shows the cross sectional FE-SEM images with a annealing temperature of 650 ^oC. Fig. 5(a) shows Ni silicide on boron cluster implanted substrate. As can see in figure, there is severe agglomeration. In case of BF2 and boron, there were also silicide agglomeration although it is less severe than $B_{18}H_{22}$ case.. In case of 600 ^oC annealing, there was little difference between the samples. Therefore, it can be said that the agglomeration is a main cause of sheet resistance increase.

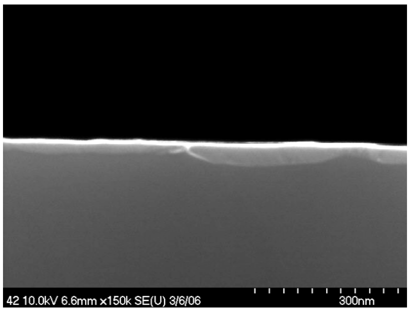
Fig. 6 shows XRD spectra of Ni silicide with a post-silicidation annealing at 650 ^oC to confirm the phase transformation. The Ni silicides formed on BF_2 and $B_{18}H_{22}$ implanted substrates show phase transformation from NiSi to high resistive $NiSi_2$. However, there is no transformation in case of B^+. Therefore, it can be said that phase transformation to high resistive $NiSi_2$ and agglomeration of silicide result in increase of sheet resistance.

4. Conclusion

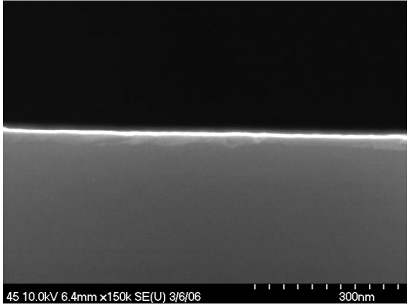
Ni silicide formed on boron cluster ($B_{18}H_{22}$) implanted substrate was studied in comparison with those formed on conventional boron and BF_2 implanted substrates. $B_{18}H_{22}$ case showed similar sheet resistance trend with boron and BF_2 cases. Ni silicide less than 25 nm can be obtained in all dopants structures at 550 ^oC RTP. Although $B_{18}H_{22}$ case showed a little larger sheet resistance and silicide agglomeration than boron and BF_2 cases, stable Ni silicide can be formed on $B_{18}H_{22}$ case if the RTP annealing and silicidation condition are optimized.



(a)$B_{18}H_{22}$



(b)BF2



(c)Boron

Fig. 5. Cross sectional SEM images of Ni silicide after post-silicidation annealing.

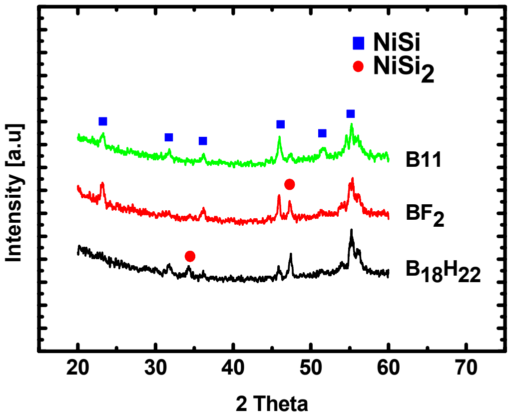


Fig. 6. XRD spectra after post-silicidation annealing (650°C, 30min)

Acknowledgments

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