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Low Temperature Formation of Highly Thermal Immune Ni Germanosilicide Using NiPt Alloy with Co Over-layer in $Si_{1-x}Ge_x$ according to Different Ge Fractions (x)

Jang-Gn Yun[1], Soon-Young Oh[1], Bin-Feng Huang[1], Yong-Jin Kim[1], Hee-Hwan Ji[1], Yong-Goo Kim[1], Yeong-Cheol Kim[2], Seong-Hyung Park[2], Heui-Seung Lee[2], Dae-Byung Kim[2], Ui-Sik Kim[2], Han-Seob Cha[2], Sang-Bum Hu[2], Jeong-Gun Lee[2], and Hi-Deok Lee[1]

[1]Dept. of Electronics Engineering, Chungnam National University, Yusong-gu, Daejeon 305-764, R.O.Korea
Phone: +82-42-821-6868 E-mail: hdlee@cnu.ac.kr
[2]Dept. of Materials Engineering, Korea University of Technology and Education, P.O.Box 55, Chonan 330-708, R.O.Korea
[2]System IC R&D Division, Hynix Semiconductor Inc., Hungduk-gu, Chongju 361-725, R.O.Korea

1. Introduction

SiGe technology is becoming an attractive alternative of conventional Si based process technology as device dimension scaling down to nano-scale regime because of its superior electrical properties than Si. For the successful incorporation of SiGe to ULSI technology, developing a high quality Germanosilicide is inevitable with a wide range of Ge fraction especially for enhancing hole mobility.

Among metal silicides, Ni silicide is regarded as one of potential candidates for next generation deep-submicron CMOS technology [1]. However, the thermal stability problem is still being issued for its application to high temperature needed devices during backend processes such as logic, DRAM and SOC. To make matters worse, in case of Ni Germanosilicide, more severe degradation than NiSi has been reported after the post-silicidation annealing due to the Ge segregation [2]. And, the degradation becomes more serious as the Ge fraction in $Si_{1-x}Ge_x$ increases.

By employing NiPt alloy instead of Ni, the thermal stability is improved in case of both Si and $Si_{1-x}Ge_x$ contacts [3, 4]. And, the formation temperature of silicide is changed by adding small amount of metals such as Co, Pt, or Au; the formation temperature of NiSi or $CoSi_2$ is lowered by the combination use of Ni and Co in forms of multi-structures or alloy and so on [5, 6].

In this study, the effects of Co addition on the formation of Ni Germanosilicide using NiPt and the Ge ratio on the thermal stability were investigated.

2. Results and discussion

The key process flow is in Fig. 1. NiPt/TiN (150/250 Å) or NiPt/Co/TiN (85/15/250 Å) tri-layer were sequentially sputter-deposited. And, the $Si_{1-x}Ge_x$ with different fractions of Ge was used for this study and the x found to be 0.12, 0.15 and 0.18 as depicted in Fig. 2. As shown in Fig. 3, the sheet resistance using the conventional pure-Ni increases dramatically after the post-silicidation annealing at 600 ℃ for 30 min and the degradation is a very serious problem for application of the pure-Ni to $Si_{1-x}Ge_x$ contact.

Figure 4 shows the sheet resistance with- and without Co over-layer before- and after the post-silicidation annealing at 600 ℃ for 30 min as a function of RTP temperature. In case of NiPt/TiN structure, the formation temperature of low resistivity Ni Germanosilicide is above 700 ℃. However, low formation temperature with wide RTP window of 500 ~ 850 ℃ can be achieved using the Co over-layer (that is, in case of NiPt/Co/TiN tri-layer). Moreover, low sheet resistances were maintained even after the post-silicidation annealing at 600 ℃ for 30 min as shown in Fig. 4 (b). Compared with the case of without Co over-layer, the Ni Germanosilicide with Co over-layer was withstood against the high temperature post-silicidation annealing as FESEM images illustrated in Fig. 5 (a)-(e). And, the films indicated more agglomeration as the Ge fraction increases in both structures. Fig. 6 shows the sheet resistance difference according to different Ge fractions in case of both with- and without Co over-layer. The results clearly show that the Ni Germanosilicide is strongly dependent on the Ge ratio in $Si_{1-x}Ge_x$ and the sheet resistance increased as Ge fraction increasing. Much larger particle size was observed from the AFM analysis as the Ge fraction increases as shown in Fig. 7 (a)-(c). However, the sheet resistance differences according to different Ge ratios reduced a lot using the Co over-layer.

From the XPS surface binding energy analysis of Ge, strong Ge intensities were found in case the NiPt/TiN structure and much higher intensities were observed as the Ge fraction increases in $Si_{1-x}Ge_x$. Therefore, it can be concluded that the thermal stability of Ni Germanosilicide is improved greatly using the Co over-layer by suppressing the Ge segregation on the surface as well as the increase of the surface energy (σ) in $\Delta G_{th} = \Delta\sigma^3 / \Delta G^2$ by the Pt incorporation within films as shown in Fig. 9 (a)-(c).

3. Conclusions

As increasing the Ge fraction in $Si_{1-x}Ge_x$, the thermal stability decreases due to the Ge segregation. By reducing the Ge segregation on the surface of Ni Germanosilicide using the Co over-layer, highly thermal robust Ni Germanosilicide with low formation temperatures can be achieved. A novel Ni Germanosilicide technology using the Co over-layer and the Pt incorporation is developed promising for the future SiGe-based ULSI technology.

Acknowledgements

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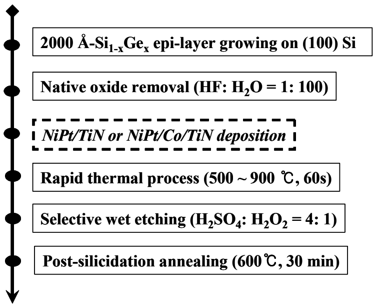

Fig. 1 The process flow.

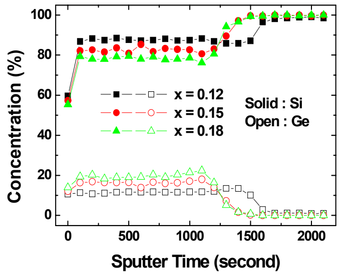

Fig. 2 XPS depth profiles of $Si_{1-x}Ge_x$ used for experiments.

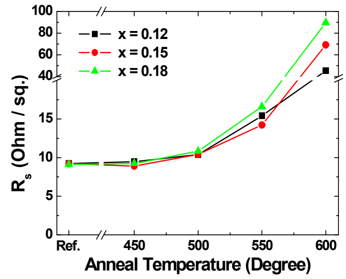

Fig. 3 Sheet resistance in case the pure-Ni according to the annealing temperature.

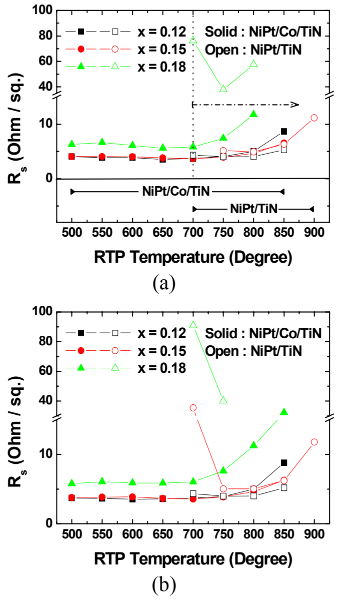

Fig. 4 Sheet resistance with- and without Co over-layer (a) before- and (b) after the post-silicidation annealing at 600 ℃ for 30 min as a function of RTP temperature.

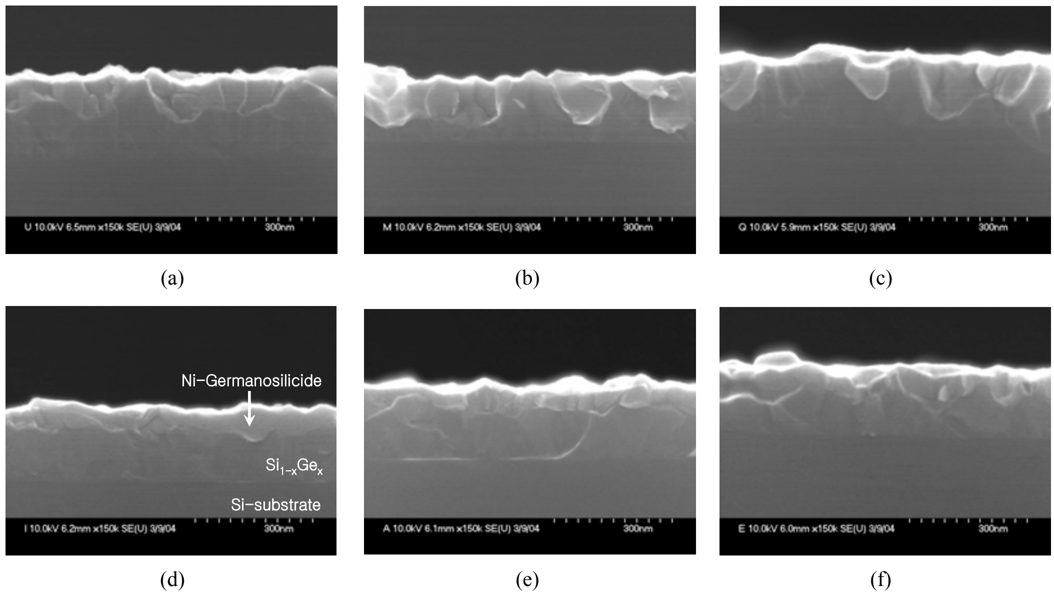

Fig. 5 FE-SEM images of Ni Germanosilicide on the $Si_{1-x}Ge_x$ according to different Ge fractions (a)-(c) without- and (d)-(e) with Co over-layer after the post-silicidation annealing at 600 ℃ for 30 min. (a), (d) x = 0.12, (b), (e) x = 0.15 and (c), (f) x = 0.18.

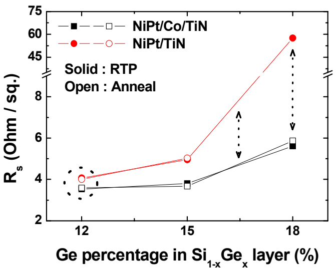

Fig. 6 sheet resistance according to Ge percentages in $Si_{1-x}Ge_x$ before and after the post-silicidation annealing at 600 ℃ for 30 min.

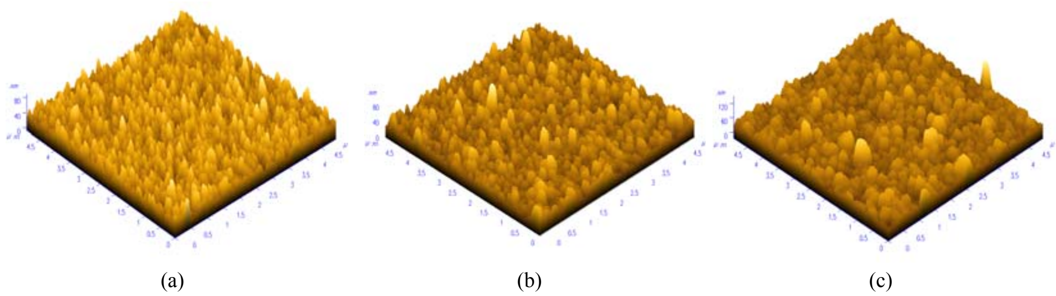

Fig. 7 AFM surface morphologies of Ni Germanosilicide on the $Si_{1-x}Ge_x$ according to different Ge fractions with Co over-layer after the post-silicidation annealing at 600 ℃ for 30 min. (a) x = 0.12, (b) x = 0.15 and (c) x = 0.18.

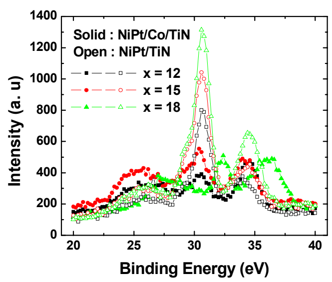

Fig. 8 XPS surface binding energies of Ge in case with- and without the Co over-layer.

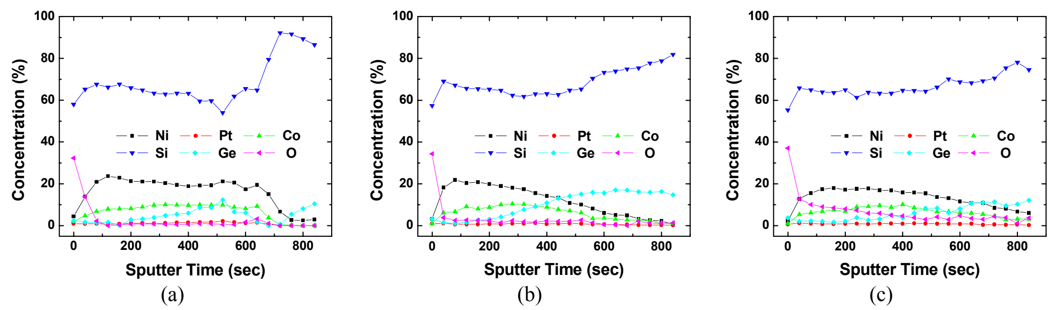

Fig. 9 XPS depth profiles of Ni Germanosilicide on the $Si_{1-x}Ge_x$ according to different Ge fractions with Co over-layer after the post-silicidation annealing at 600 ℃ for 30 min. (a) x = 0.12, (b) x = 0.15 and (c) x = 0.18.