Extended Abstracts of the 2014 International Conference on Solid State Devices and Materials, Tsukuba, 2014, pp696-697

NiPt Silicide Agglomeration Caused by Stress Relaxation along <010> Direction in NiSi Grain

Mariko Mizuo[1], Tadashi Yamaguchi[2], Xavier Pagès[3], Koen Vanormelingen[3], Martin Smits[3], Ernst Granneman[3], Masahiko Fujisawa[2] and Nobuyoshi Hattori[1]

[1] Renesas Semiconductor Manufacturing Co., Ltd.
4-1-3, Mizuhara, Itami, Hyogo 664-0005, Japan
Phone: +81-72-787-5939 E-mail: mariko.mizuo.rh@renesas.com
[2] Renesas Electronics Corporation
Hitachinaka, Ibaraki, 312-8504, Japan
[3]Levitech BV
Versterkerstraat 10 1322 AP Almere, The Netherlands

Abstract

The NiPt silicide agglomeration mechanism is clarified in terms of NiSi crystal orientation and stress for the first time. Furthermore, the influence of Pt diffusion to the NiSi/Si interface during the thermal process on agglomeration is discussed.

1. Introduction

Pt doped Ni (NiPt) silicide has been increasingly adopted in state-of-the-art CMOS because of its ability to suppress the agglomeration of silicide during thermal process. It was reported that a reduction of free energy due to the incorporation of Pt into NiSi suppresses agglomeration [1]. However, the NiPt silicide agglomeration mechanism is not yet sufficiently understood in terms of microstructures. Our previous microstructure analyses clarified that the segregated Pt at the NiSi/Si interface accelerates the formation of the NiSi grains [NiSi(010)//Si(001)], and residual stress is induced in the film [2,3].

In this paper, the NiPt silicide agglomeration mechanism is clarified using X-ray diffraction (XRD) analysis, scanning transmission electron microscopy (STEM), and high resolution Rutherford backscattering spectrometry (HRBS).

2. Experimental Procedure

Figure 1 shows the sample preparation process. NiPt silicide film on 300mm Si(001) wafers was formed in various conditions of rapid thermal process (RTP), as shown in Table I. Sheet resistance (R_s) was measured using a four point probe, and other properties of NiPt silicide after RTP2 and RTP3 were investigated using out-of plane XRD analysis, STEM, and HRBS.

- S/D implantation p-type(B)
- S/D activations (1000°C)
- NiPt deposition(25nm)
- TiN deposition (15nm)
- 1st annealing(RTP1)(260°C, 41s)
- Unreacted cap-TiN and NiPt selective etching
- 2nd annealing(RTP2)
- 3rd annealing(RTP3)(800°C, He)

Fig. 1 Sample fabrication steps.

Table I Experimental conditions.

	RTP2		
Sample	Gas	Temp. [°C]	Time
A	He	540	0.5s
B	He	635	0.5s
C	He	825	0.5s
D	He	800	1.5s
E	N_2	600	10s
F	N_2	260	10hrs

3. Results and discussion

Figure 2 shows the out-of plane XRD patterns in samples A-C. Figure 3 focuses on the NiSi (020) peaks, and shows the peak intensity ratios of NiSi(020) to NiSi(013) ($I_{NiSi020}$) and the peak shift, namely NiSi stress. These increased with an increase in the temperature of the RTP2.

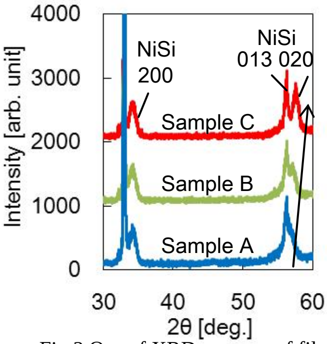

Fig.2 Out-of XRD patterns of films aligned to the Si[001]direction.

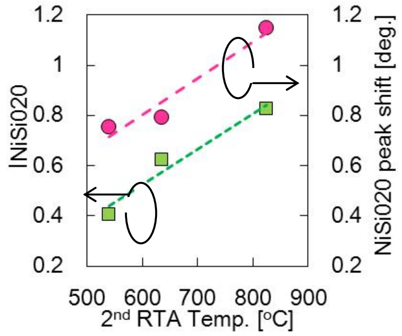

Fig.3 Temperature dependence of INiSi020 and NiSi(020) peak shift.

Figure 4 shows the depth profiles of Pt, Ni and Si obtained by HRBS. The Pt atoms at the NiSi/Si interface increase with an increase in the temperature of RTP2. These results indicate that large Pt segregation at the NiSi/Si interface causes an increase of NiSi(010)//Si(001) grains and stress, and this phenomenon is enhanced by high RTP2 temperature. In addition, high RTP temperature causes large NiSi grains, as a result, low R_s, as shown in Fig. 5.

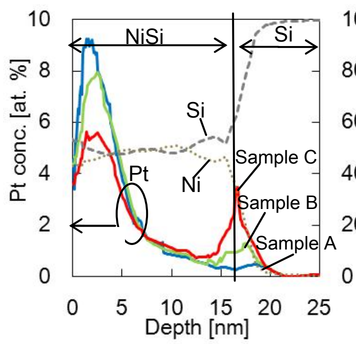

Fig.4 Depth profiles of Pt, Ni and Si from the film surfaces to the Si substrate.

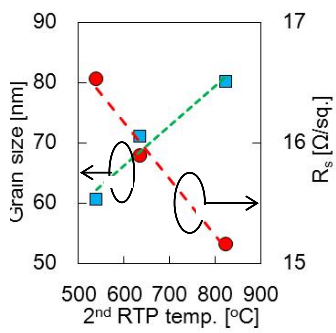

Fig.5 Temperature dependence of grain size and R_s.

Furthermore, the thermal stability of NiPt silicide in samples A-C with additional RTP3 is shown in Fig.6. R_s of sample C rapidly increases with silicide agglomeration compared with that of samples A and B. Silicide agglomeration fairly depends on RTP2 conditions.

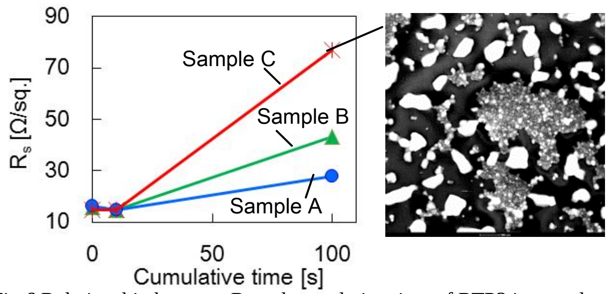

Fig.6 Relationship between R_s and cumulative time of RTP3 in samples A-C.

In order to understand the NiPt silicide agglomeration mechanism, the agglomeration process of samples D-F with various $I_{NiSi020}$, stress, grain size and R_s were evaluated, as shown in Table II. Figure 7 shows the relationship between R_s and cumulative time of RTP3. R_s in samples E and F first decreases and then increases. On the other hand, R_s in sample D consistently rises. The characteristics of the films before and after 10s of RTP3 were evaluated in order to clarify these differences in agglomeration process.

Table II Characteristics of samples D-F.

	$I_{NiSi020}$	020 peak shift[°]	Grain size [nm]	R_s[Ω/sq.] (After RTP2)
D	0.83	1.15	76	14.9
E	0.51	0.78	83	15.2
F	0.14	N.D.	137	16.3 (Inc. Ni_2Si)

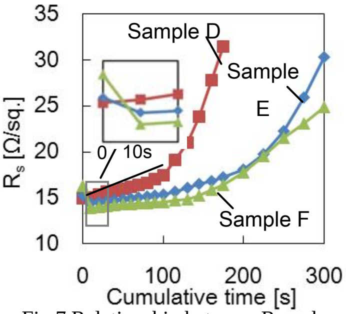

Fig.7 Relationship between R_s and cumulative time in samples D-F.

Figure 8 shows the $I_{NiSi020}$ and NiSi(020) peak shift. $I_{NiSi020}$ and NiSi(020) peak shift in samples E and F both increase after 10s of RTP3. On the other hand, NiSi(020) peak shift in sample D decreases in spite of $I_{NiSi020}$ increase. These results indicate that stress relaxation occurs with NiSi grains [NiSi(010)//Si(001)] growth in sample D.

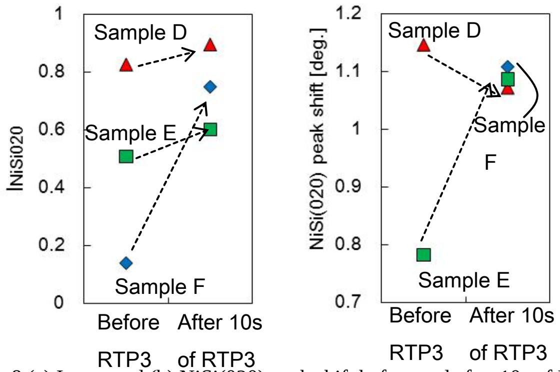

Fig.8 (a) $I_{NiSi020}$ and (b) NiSi(020) peak shift before and after 10s of RTP3.

Figure 9 shows the HRBS results before and after 10s of RTP3. In samples E and F, Pt atoms at the NiSi/Si interface increase after RTP3. In contrast, in sample D, Pt atoms at the NiSi/Si interface after RTP3 are almost the same as that before one. Furthermore, the trailing Ni spectra at the NiSi/Si interface is observed only in sample D.

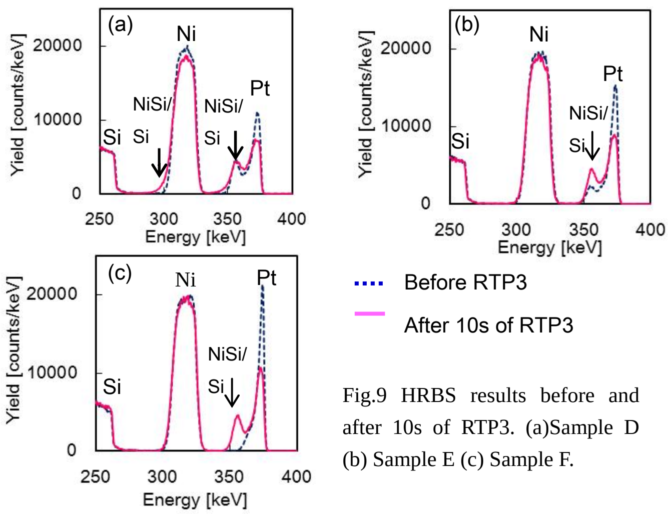

Fig.9 HRBS results before and after 10s of RTP3. (a)Sample D (b) Sample E (c) Sample F.

In addition, large NiSi grains of sample F after RTP3 are observed by STEM, as shown in Fig. 10. These results are suggested that in sample D, the NiSi/Si interface roughness degrades due to the beginning of silicide agglomeration after RTP3. On the other hand, in samples E and F, Pt diffuses into the NiSi/Si interface, and NiSi(010)//Si(001) grains grow during RTP3.

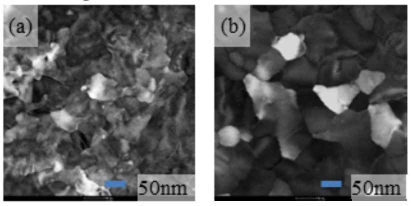

Fig.10 Plan-view STEM images of sample F. (a)Before RTP3 (b)After 10s of RTP3

The NiPt silicide agglomeration mechanism is summarized in Fig. 11. After RTP2, the NiSi grains [NiSi(010)//Si(001)] with segregated Pt at the NiSi/Si interface, and NiSi grains with other crystal orientation are both aligned to Si(001) [Fig.11(a)]. During RTP3, Pt segregates at the NiSi/Si interface, and the NiSi grains (NiSi(010)//Si(001)) recrystallize with large residual stress [Fig. 11(b)]. Finally, NiPt silicide agglomeration accompanied with stress relaxation occurs [Fig. 11(c)].

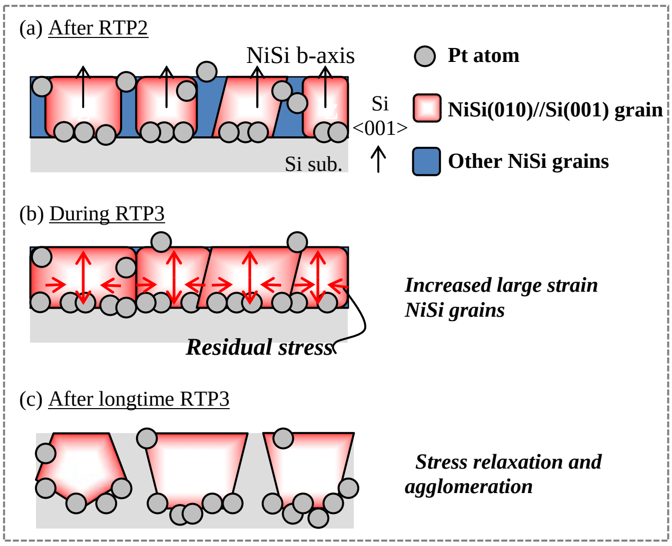

Fig.11 NiPt silicide agglomeration mechanism.

3. Conclusions

Our microstructure analysis has revealed that the NiPt silicide agglomeration mechanism is explainable in terms of stress relaxation. Large stress of the NiSi grains [NiSi(010)//Si(001)] by Pt enhances silicide agglomeration. We conclude that the stress of NiPt silicide has a significant influence on the thermal stability.

Acknowledgements

We would like to express sincere thanks to Mr. Hiroshi Kimura and Mr. Jun-ichi Tsuchimoto at Renesas for their cooperation of measurement of XRD and HRBS.

References

[1] D. Mangelinck *et al.*, Appl. Phys. Lett. **75**,1736 (1999)
[2] M. Mizuo *et al.*, Jpn. J. Appl. Phys. **52**, 096502 (2013).
[3] M. Mizuo *et al.*, Jpn. J. Appl. Phys. **53**, 04EA02 (2014)