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A Study on the Germano-Silicide Formation in the Ni/$Si_{1-x}Ge_x$ System for CMOS Device Applications

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1. Introduction

$Si_{1-X}Ge_X$ has been studied in many applications in order to resolve issues on size reductions in ULSI devices[1]. For the application of $Si_{1-X}Ge_X$ to ULSI devices, interactions with metals such as Co, Ti, or Ni should be investigated in order to test the SALICIDE process adaptability. It has been reported that the Ge segregation and the silicide film's islanding occurs in Metal/$Si_{1-X}Ge_X$ systems, which lead to the increase of gate resistance[2, 3].

In this study, the solid phase reaction of Ni/poly-$Si_{1-X}Ge_X$(X=0, 0.16, 0.25, and 0.29) using RTA is investigated. Much attention is focused on the Ni-silicide for sub-100nm technology due to its low resistance, leakage current, and pattern size independence. We discuss the influence of Ge on the electrical properties and the morphological changes of the Ni germano-silicide films.

2. Experiments

The poly-$Si_{1-X}Ge_X$ films were grown by chemical vapor deposition(CVD) on Si(100) substrates following the deposition of a 1000Å SiO_2 layer. The content of Ge was controlled at 16%, 25%, and 29%. Ni(25 nm) and TiN(10 nm) films were deposited on 200nm poly-$Si_{1-X}Ge_X$(X=0, 0.16, 0.25, and 0.29) films by sputtering. In order to identify the effect of Ge on the Nickel silicide formation process, the samples were annealed by RTA from 500℃ to 980℃ for 30sec under N_2 flow. The sheet resistance(Rs) and structural properties were examined by four-point probe method, XRD and a raman spectroscopy. Morphologies were examined using a transmission electron microscope(TEM). Also, TEM-EDS analyses were performed for chemical analyses.

3. Results and Discussion

As shown in Fig. 1 sheet resistance values of Ni/$Si_{1-X}Ge_X$ (X=0.16, 0.25, and 0.29) increases to its highest values about 10^6 Ω/□ at 620℃, which indicates a phase transition or a morphology change of the silicide films. XRD spectra in Figs. 2 (a), (b) show that NiSi phase is completely transformed to $NiSi_2$ over in the Ni/poly-Si system. However in Ni/poly-$Si_{1-X}Ge_X$ systems the nickel gernamo-silicide Ni(Si-Ge) phase is observed until 820℃(see Figs. 2(c), (d)).

Between two germano-silicide grains, a Ge rich $Si_{0.44}Ge_{0.56}$ alloy grain is observed to be formed by TEM and EDS analyses at 580℃(see Fig. 3). Fig. 4 represents the Raman spectra as a function of annealing temperature for the Ni/$Si_{0.75}Ge_{0.25}$ systems. The appearance of the Si-Si mode at 620℃ and the Ge-Ge mode over 540℃ in Raman spectra indicates the agglomeration or inversion of the Ni(Si-Ge) layer and the formation of Ge-rich Si-Ge alloy grains near free surface respectively.

Fig. 5 show the XTEM micrographs and EDS spectra of Ni/$Si_{1-X}Ge_X$ after an RTA at 660℃(X=0:(b), X=0.25:(a), (c), (d)). An abrupt inversion of germano-silicide layer with poly-$Si_{1-X}Ge_X$ is observed. As shown in Fig. 6(a), after annealing at 740℃, the growth of the inverted grains proceeds to the lateral direction until they reach the free surface. At 900℃, the overgrowth of poly-$Si_{1-X}Ge_X$ and silicide grains is observed(see Fig. 6(b)).

4. Conclusions

The silicide formation and the stability of the Ni/ $Si_{1-X}Ge_X$ system have been studied. When Ge is incorporated, germano-silicide on poly-$Si_{1-X}Ge_X$ is unstable due to the formation and growth of Ge rich Si-Ge alloy grains between germano-silicide grains near free surface. This results in a layer inversion of Ni(Si-Ge) and $Si_{1-X}Ge_X$ layers, and consequent increase in Rs values about 10^6 Ω/□ over 620℃. Upon higher temperature annealing, the inverted grains grow and finally reach the free surface. Due to the incorporation of Ge, the complete transition to disilicide occurs at the higher temperatures in the Ni/$Si_{1-X}Ge_X$ systems. Prior to the phase transition, inversion of germano-silicide layers and $Si_{1-X}Ge_X$ layers occurs, which results in sharp increase of sheet resistance values at above 620℃.

References

[1] Neal kistler, Jason Woo IEDM'93 (727).

[2]B.I.Boyanov, P.T.Goeller, D.E.Sayers, and R.J.nermanich, J.Appl.phys. 84 (1998) 4285.

[3]D.B.Aldrich, Holly L. Heck, Y.L.Chen, D.E.Sayers, and R.J. Nemanich, J. Apply. Phys.78 (8), (1995) 4958.

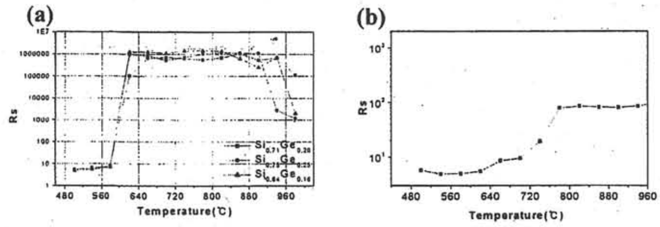
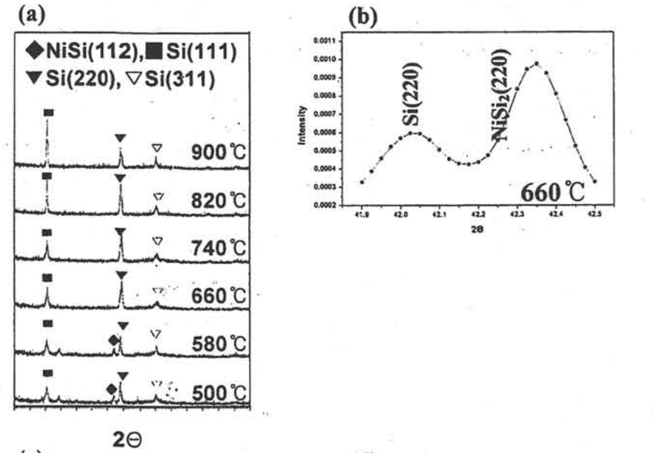
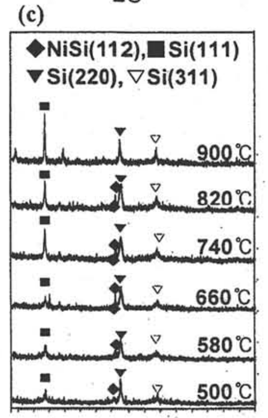


Fig. 1 Sheet resistance as a function of RTA temperature in N_2 ambient for solid state reaction of Ni with (a) $Si_{1-X}Ge_X$(X=0.16, 0.25, and 0.29) and (b) X=0.





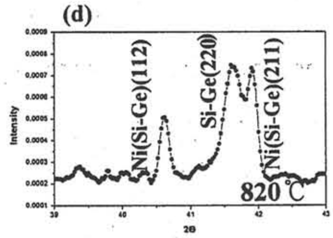
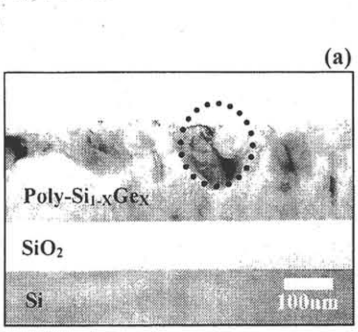


Fig. 2 XRD spectra of $Ni/Si_{1-X}Ge_X$ system after RTA (a), (b) X=0 and (c), (d) X=0.25.



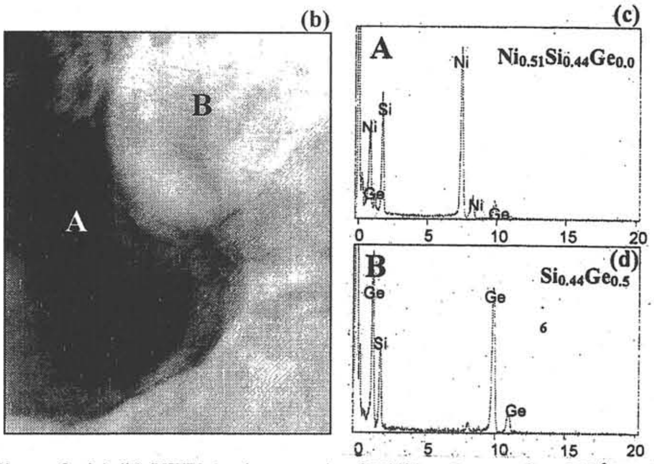


Figure 3. (a),(b) XTEM micrograph of $Ni/Si_{0.75}Ge_{0.25}$ after 580℃ RTA, (c), (d) corresponding EDS spectra.

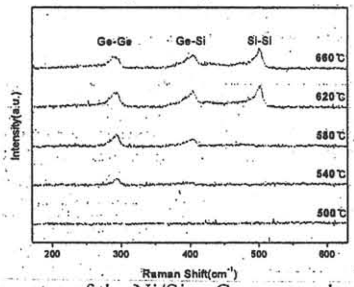


Fig. 4 Raman spectra of the $Ni/Si_{0.75}Ge_{0.25}$ samples after an RTA.

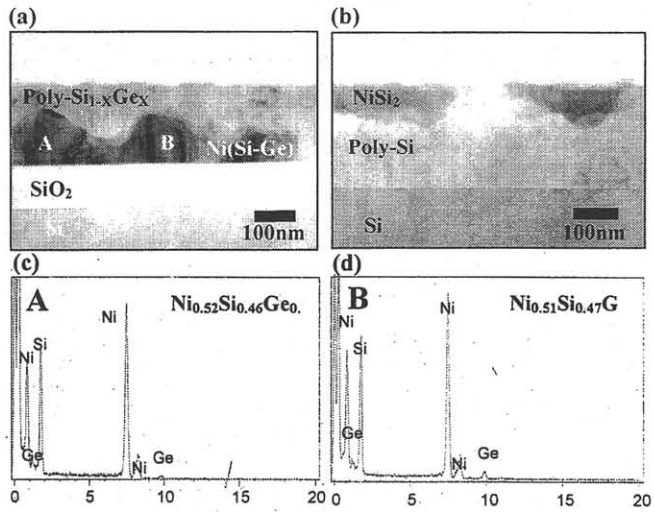


Fig. 5 (a) XTEM micrograph of $Ni/Si_{0.75}Ge_{0.25}$, (b) Ni/poly-Si after 660℃ RTA, and (c), (d) corresponding EDS spectra.

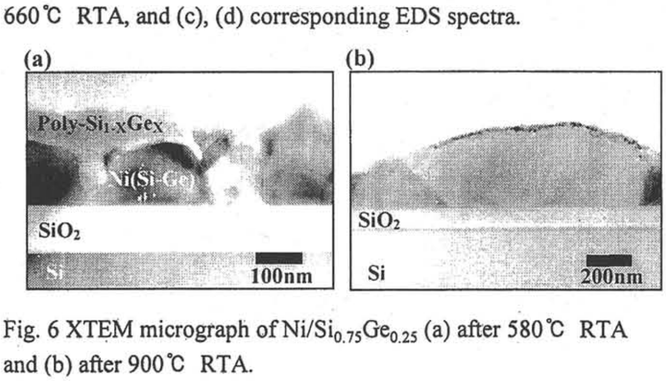


Fig. 6 XTEM micrograph of $Ni/Si_{0.75}Ge_{0.25}$ (a) after 580℃ RTA and (b) after 900℃ RTA.