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The Formation of High Temperature Stable Co-Silicide from $Co_{1-x}Ta_x$/Si Systems

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1. Introduction

Co- SALICIDE process has been widely used in deep submicron CMOS device fabrications owing to the low resistivity and easy formation on narrow Si lines.[1, 2] The employment of the Co-salicide process, however, is limited upto 800℃, above which thermal degradation occurs due to the agglomeration of the Co-silicide films. Therefore, for the application to the merged process with logic and memory devices, the high temperature Co-salicide process is required.[3] In order to improve thermal stability of Co-silicide, we investigated Co-silicide formation using $Co_{1-x}Ta_x$/Si systems, and studied their thermal stability upon annealing.

2. Experiments

The Si(100) substrates were chemically cleaned by standard RCA clean, followed by dipping in a HF solution to remove the native oxide. $Co_{1-x}Ta_x$ films were co-deposited by DC magnetron sputtering using Co and Ta targets. In order to prevent oxidation during silicidation reaction, Ti films were deposited on top of $Co_{1-x}Ta_x$ films as a capping layer. Samples were annealed by RTA at various temperatures in N_2 ambients, after which, unreacted metals were selectively etched by a chemical solution (H_2SO_4:H_2O_2=6:1). After chemical etching, 2nd RTA was performed at 850℃ for 30s in N_2 ambients. In order to test the thermal stability of the $Co_{1-x}Ta_x$/Si systems, samples were annealed in the furnace at 950℃ for 30, 60 and 120min in Ar ambients. The Ta contents were analyzed by RBS. Microstructures and electrical properties were analyzed by XRD, AES, TEM and four-point probe.

3. Results and Discussion

The Ta contents in Co/Ta alloy films were 8 atomic%, as determined from RBS analyses.(Fig. 1) Fig. 2 shows the changes of sheet resistance values of the Co/Si and the $Co_{0.92}Ta_{0.08}$/Si systems as a function of 1st RTA temperature. Compared with Co/Si systems, the transformation temperature from CoSi to $CoSi_2$ increased in the $Co_{0.92}Ta_{0.08}$/Si systems. Fig. 3(a) show that as the RTA temperature increases, the $CoSi_2$(220) and (111) peaks appear in the Co/Si systems. Compared with Co/Si systems, the $CoSi_2$(200) peak is observed in the $Co_{0.92}Ta_{0.08}$/Si system (Fig. 3(b)), which indicates the presence of strong (200) preferred orientation in the Co-silicide films from $Co_{0.92}Ta_{0.08}$/Si systems.

Fig. 4 shows AES depth profiles of the $Co_{0.92}Ta_{0.08}$/Si systems after RTA process at 740℃, followed by the 2nd RTA process at 850℃. Co-silicide is formed on Si substrate, and Ta compound is observed to be formed at the top surface. Fig. 5 is TEM micrograph of the $Co_{0.92}Ta_{0.08}$/Si systems after the 2nd RTA process. Ta rich phases are observed on the surface of $CoSi_2$ films.

Fig. 6 shows the sheet resistance of the Co-silicide films as a function of annealing time for the Co/Si and the $Co_{0.92}Ta_{0.08}$/Si systems. As annealing time increases, the sheet resistance of Co-silicide from Co/Si systems increases significantly, while the Co-silicide from $Co_{0.92}Ta_{0.08}$/Si systems maintain at low sheet resistance values. In Fig. 7(a), $TaSi_2$ phases are observed at the grain boundaries and at the surface of $CoSi_2$ films by HRTEM and EDS analyses (Fig. 7, 8) These results indicate that the agglomeration of $CoSi_2$ films is reduced by the formation of $TaSi_2$ at the grain boundaries of $CoSi_2$ films.

4. Conclusions

We obtained thermally stable $CoSi_2$ films on Si(100) substrate from $Co_{1-x}Ta_x$/Si systems. The improvement of thermal stability of Co-silicide formed from alloyed Co/Ta thin films is due to the formation of the $TaSi_2$ phase at the grain boundaries of $CoSi_2$ films

References

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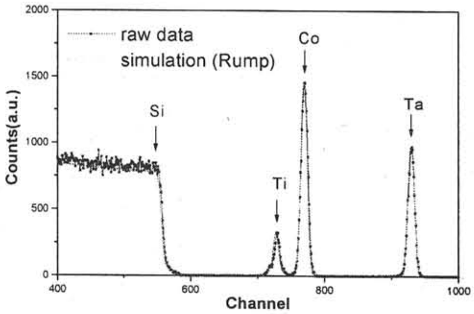

Fig. 1 RBS spectra from as-deposited Ti/$Co_{0.92}Ta_{0.08}$/Si systems.

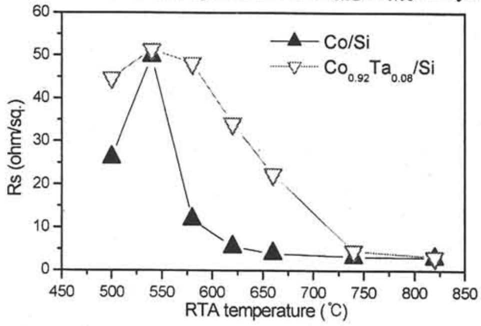

Fig. 2 Sheet resistance values of Co-silicide films as a function of RTA temperature for 30s in N_2 ambients for Co/Si systems and $Co_{0.92}Ta_{0.08}$/Si systems.

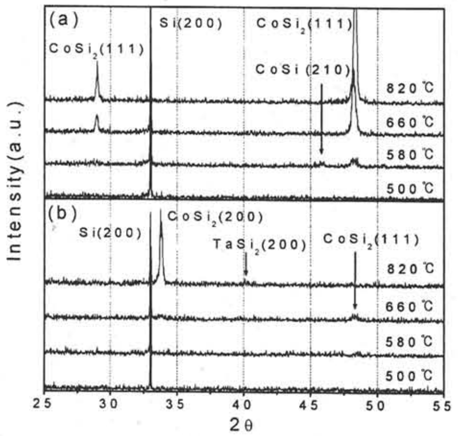

Fig. 3 XRD spectra of (a) Co/Si systems and (b) $Co_{0.92}Ta_{0.08}$/Si system after 1[st] RTA for 30s in N_2 ambients.

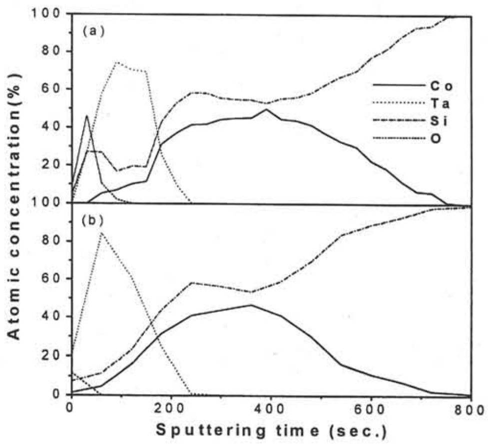

Fig. 4 AES depth profile of $Co_{0.92}Ta_{0.08}$/Si systems (a) 1[st] RTA at 740℃ and (b) after 2[nd] RTA at 850℃.

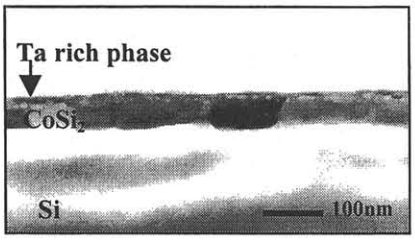

Fig. 5 Cross-sectional TEM micrographs of $Co_{0.92}Ta_{0.08}$/Si systems after 2[nd] RTA at 850℃.

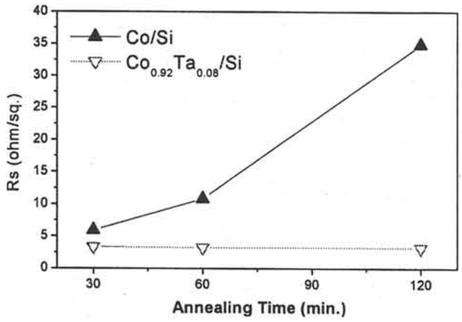

Fig. 6 Sheet resistance values of Co-silicide films as a function of annealing time at 950℃ in Ar ambients with Co/Si systems and $Co_{0.92}Ta_{0.08}$/Si systems.

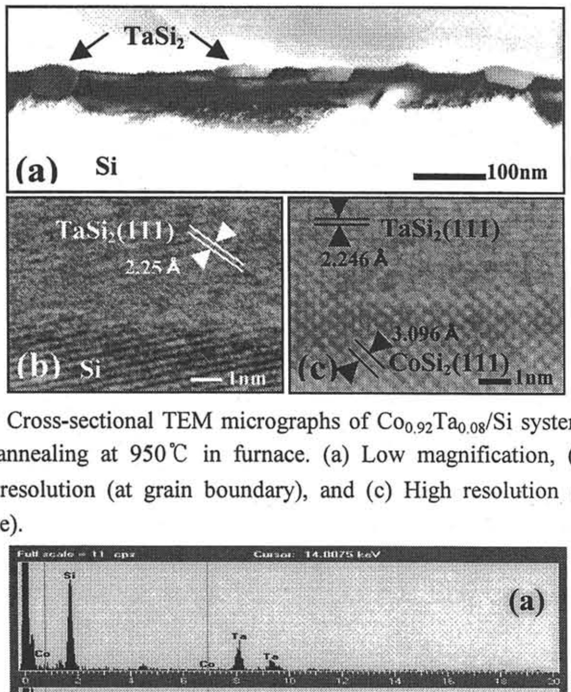

Fig. 7 Cross-sectional TEM micrographs of $Co_{0.92}Ta_{0.08}$/Si systems after annealing at 950℃ in furnace. (a) Low magnification, (b) High resolution (at grain boundary), and (c) High resolution (at surface).

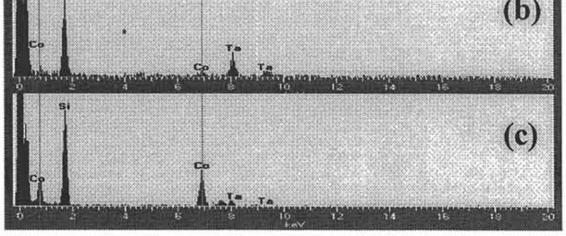

Fig. 8 EDS spectra for $Co_{0.92}Ta_{0.08}$/Si systems after annealing at 950℃ in furnace. (a) $TaSi_2$ at grain boundaries, (b) $TaSi_2$ at surface of $CoSi_2$ films, and (c) $CoSi_2$ films.