Influence of the annealing schemes and silicide thickness on the stability of Ni(Pt)Si thin film formed on 300 mm Si(100) wafers

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Nickel silicides, due to their low resistivity and low formation temperature, are today used in the microelectronics industry to ensure electrical continuity between tungsten contacts and transistors for advanced technology nodes, below 65 nm [1]. Nevertheless, the emergence of new FDSOI technologies (for Fully Depleted Silicon On Isolator) induces a drastic reduction of Ni(Pt)Si final thickness, and then, a higher sensitivity to agglomeration [2,3]. To prevent such degradations in the case of 3D integrations, recent studies reveal that the annealing schemes might influence the thermal stability of final Ni(Pt)Si layer, in particular partial anneal seems to present real advantages in terms of thermal stability [3,4]. In addition, based on the work of T. Luo at al. [5]; Si diffusion at Ni(Pt)Si/ Si interface appears to be the most influent factor in agglomeration phenomena, and final species distribution might indicate the progress in agglomeration stages.

We propose in this paper a systematic study of the influence of annealing schemes (partial, total and unique anneal) on Ni(Pt)Si films thermal stability for different final thicknesses (14, 20 and 24 nm, as described in Fig. 1). To explore the film agglomeration evolution, all samples are submitted to additional anneals at a temperature comprised between 550 and 800 °C for 30 s (Fig. 1). In this way, several ex-situ characterization techniques (4-point R_s, tilted-SEM, TEM-EDX, ToF-SIMS) have been used to identify morphological and chemical evolutions inside silicide layer, and also at interfaces (silicide top surface and Ni(Pt)Si/Si interface mainly).

Rs and tilted SEM characterizations for all studied samples are shown in Fig. 2. In details, for a final thickness of 14 nm, morphological degradation is observed at 600 °C for total and unique anneals contrary to partial anneal (Figs. 2a,d). This delay in agglomeration phenomenon linked to partial reaction is not so clear for 20 and 24 nm. For thicker films, all anneal schemes appear to be almost equivalent (Figs. 2b,c,e,f). Nevertheless, the agglomeration temperature is shifted to the high temperatures for thicker silicide films (here 700 °C), as expected. And a slight delay in agglomeration stages is then observed for unique anneal. One might observe a clear threshold in thermal stability between 14 and 20 nm like “ a frontier”, as already proposed by F. Geenen et al. [2]. TEM cross-sections obtained after the formation of 14 nm-Ni(Pt)Si by partial, total and unique anneal and an additional anneal at 550 °C are shown in Fig. 3. Such observations allow to clearly identify the starting point of agglomeration, usually called grain boundary grooving, in the case of a total anneal at 550 °C (Fig. 3b). In addition, EDX profiles obtained perpendicularly to the Ni(Pt)Si layers for all samples are displayed in Fig. 4. We focused here on Pt redistribution at the top surface, inside silicide layer, and at the interface between Ni(Pt)Si film and Si substrate. Significant differences in Pt redistribution are observed for 20 nm-Ni(Pt)Si layers (Fig. 4b). Higher Pt concentrations are detected for partial, and total anneals at Ni(Pt)Si/Si interface compared to unique anneal treatment. This could be an indication of higher Pt diffusion through silicide grain boundaries during the first stages of agglomeration in this case relating to a change in grain size or grain boundaries orientations. Moreover, we could highlight that the Pt atomic concentration increases at the top surface of silicide films increase consistently to the silicide thickness (as an example for unique anneal, from 8 to 12 at.%, Figs. 4a, b and c). Thus, the delay in agglomeration phenomenon for Ni(Pt)Si films could be not only related to silicide film thickness, but also to higher concentration of Pt at the interfaces which moderates the Si diffusion.

In the final paper, additional characterization and deep discussions on the influence of anneal schemes and silicide film thickness will be exposed to identify the role of minor species distribution on Ni(Pt)Si thermal stability.

References

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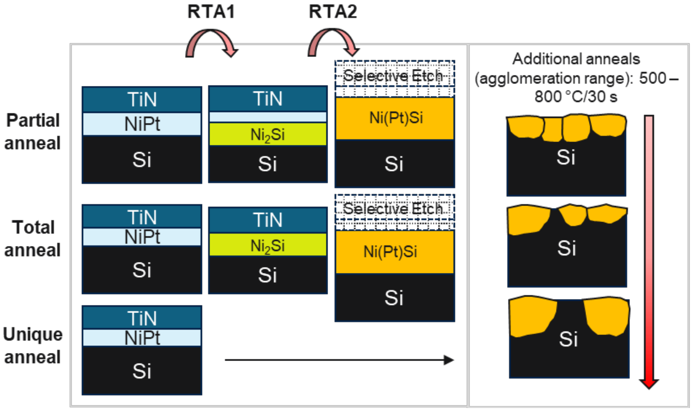

Fig. 1: Process flow used, based on the salicide process, to form different thickness of Ni(Pt)Si layers.

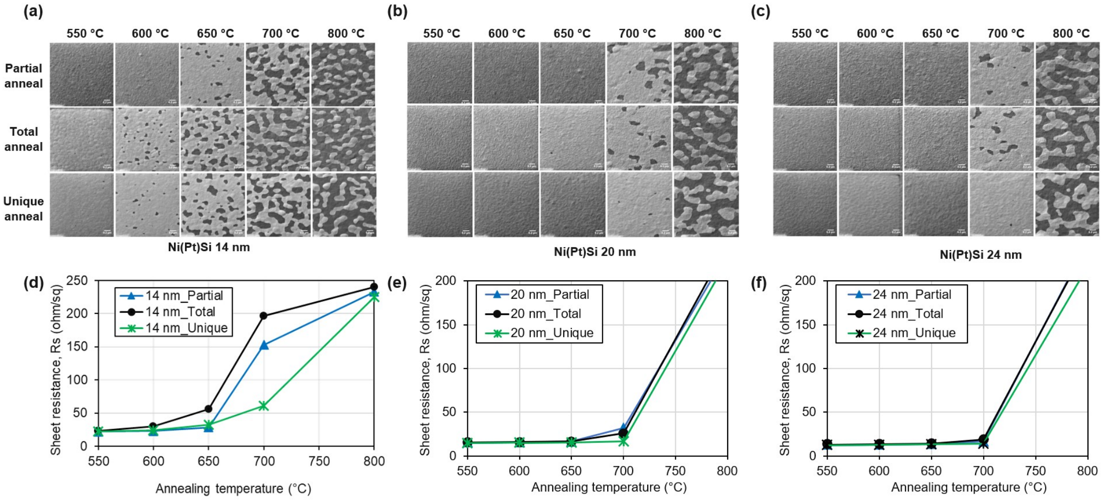

Fig. 2: Top-view tilted-SEM images of Ni(Pt)Si films presenting different final thicknesses equal to (a) 14, (b) 20, and (c) 24 nm formed by total, partial and unique anneal. Tilted-SEM images are correlated with R_s resistance measurements displayed in d, e, and f respectively for each Ni(Pt)Si thickness.

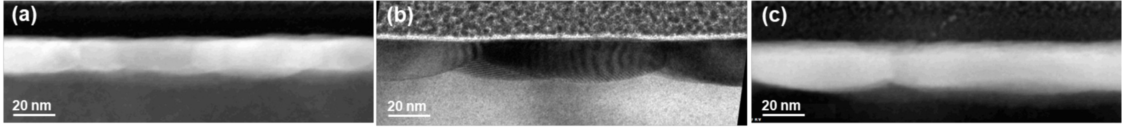

Fig. 3: Cross-section TEM images of 14 nm Ni(Pt)Si films formed by (a) partial, (b) total, and (c) unique anneal after an additional anneal at 550 °C for 30 s. Grain boundaries grooving is clearly observed for total anneal indicating the early stages of agglomeration.

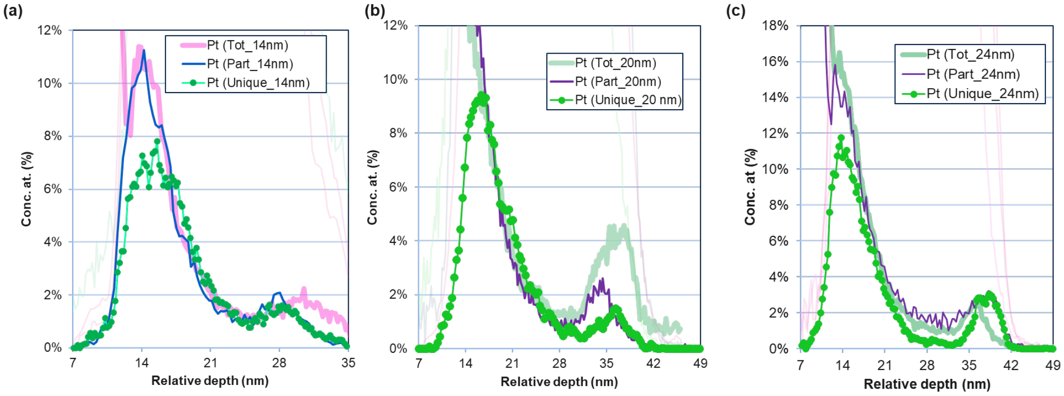

Fig. 4: TEM-EDX line scans describing the Pt redistribution within the (a) 14, (b) 20, and (c) 24 nm Ni(Pt)Si layers formed by partial, total and unique anneal, and an additional anneal at 550 °C for 30 s. Pt accumulations are then observed at top surface of Ni(Pt)Si film and Ni(Pt)Si/Si interface.