Nickel silicide phase change transformation upon nanosecond laser annealing

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In recent devices, nickel silicide is widely used due to its low resistivity and silicon consumption [1]. A classical process flow used for nickel silicide fabrication consists in a first anneal to form the Ni_2Si phase, a selective etch to remove unreacted metal, and a second anneal to obtain the low resistivity NiSi phase [1]. However, the high diffusivity and the low temperature stability of the phase of interest is a problem [2]. Research has been performed on the second anneal to overcome these problems. "Plateau" anneal [3], spike anneal [4] and then millisecond anneal have been investigated with significant gains in agglomeration robustness [5–7]. Nanosecond anneal is a logical alternative but still largely unexplored when the energy is kept below the melting threshold [8].
Sample preparation is described in **Figure 1.** On a p-doped bulk silicon substrate, a partial silicidation followed by a selective etch is performed. Then, nanosecond (ns) anneals at different energy densities are applied. The sheet resistance (Rs) value as a function of nanosecond laser energy density is shown, for 10 laser shots in ***Figure 2***. The curve shows four distinct regimes. R_S exhibits a high resistance plateau, followed by an intermediate one, then a low resistance plateau. The last regime starts with an abrupt R_S increase due to the onset of silicide melting.
To better understand this phase transformation curve, in-plane and out-of-plane X-ray diffraction (XRD) measurements were performed (***Figure 3***). In the diagrams corresponding to the initial plateau and the melt region at around 1 J/cm², small peaks of Ni_3Si_2 (identified by circles in the figure) are detected. In the intermediate plateau, the main phase observed is Ni_3Si_2. In the low resistivity plateau, the NiSi phase is identified (triangles) with residual peaks of Ni_3Si_2 but with a different preferential orientation compared to that in the intermediate plateau. In melt region at high ED no other peaks than the one due to the substrate is obtained. The formed silicide(s) may be amorphous or made of too small nanocrystallites to be detected.

The possibility of obtaining a low resistivity NiSi phase by nanosecond laser anneal was thus demonstrated. The phase sequence obtained with ns anneal was atypical. In fact, the expected Ni_2Si phase was not seen in XRD for the initial plateau. Furthermore, an intermediate phase between the first Ni silicide phase and the NiSi phase was shown to be Ni_3Si_2. Finally, the melt regime showed a huge variation in resistivity, which was not correlated with the evolution of the diffraction peaks, since no peaks other than those due to the substrate were detected in XRD diagrams at high energy density.

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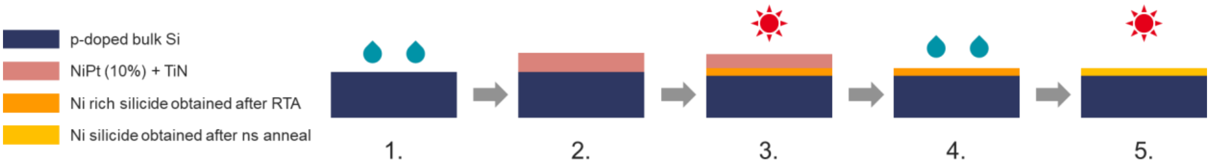

Figure 1: Details of the sample preparation flow. 1. Wet surface preparation. 2. 16 nm NiPt (10%) deposition. 3. Rapid thermal annealing (RTA) for partial silicidation. 4. Selective etch to remove unreacted metal. 5. Nanosecond laser anneal to complete phase transformation.

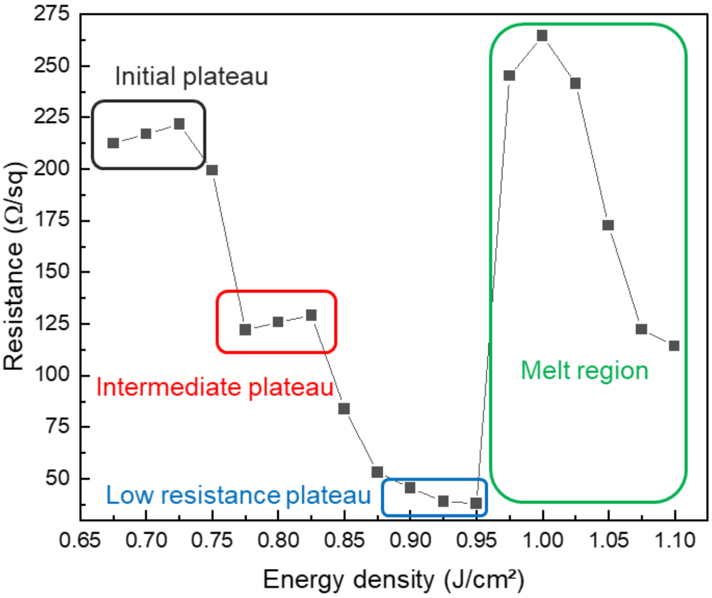

Figure 2: Sheet resistance (Rs) as a function of nanosecond laser energy density for 10 laser shots.

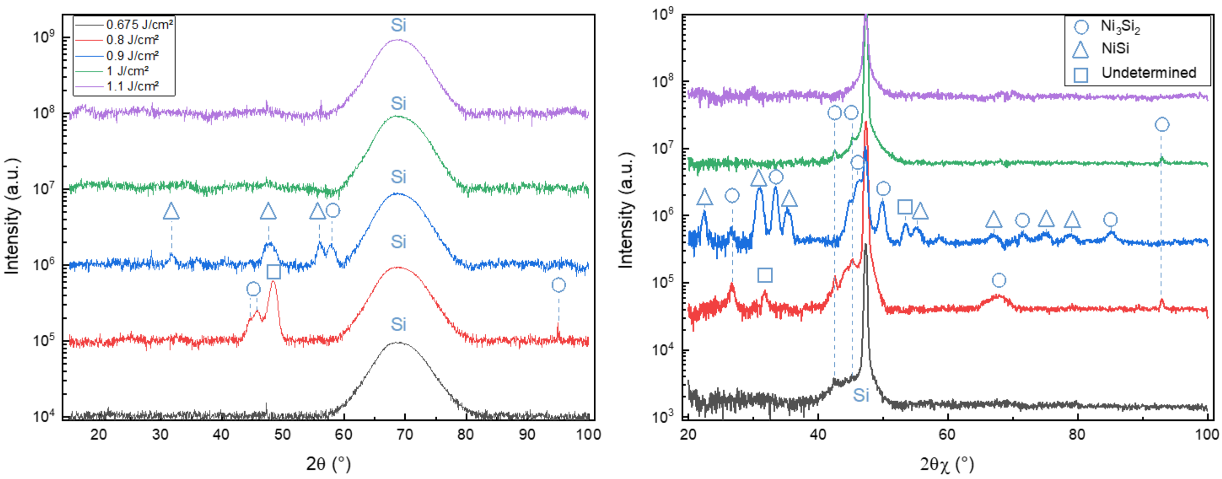

Figure 3: Out-of-plane (left) an in-plane (right) X-ray diffraction diagrams for different nanosecond laser energy densities.