ROBL-CRG	**Experiment title:** **Phase formation processes in nanoscale Nickel-alloy layers during heat treatment on Si:C substrates**	**Experiment number:** **20_02_639**
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REPORT

The formation of nickel silicides has been studied by X-ray diffraction (XRD) experiments using synchrotron radiation with an energy of 8.048 keV. A gracing incidence setup was chosen with a fixed incidence angle of 0.5° to perform the large angle detector scans. For thermal treatment, an annealing chamber was used to investigate the phase formation and transition processes under quasi-statically conditions at elevated temperatures in the range of RT to 700°C.

The investigated samples consisted of blanket, carbon doped silicon (Si:C) on insulator (SOI) wafer pieces. Two different sets of samples were investigated. The thickness of the deposited nickel layer was chosen to be 10 nm for one set of samples and 35 nm for the other set. The deposited metal layer were pure Ni, Ni with 5at.% of element A1 and Ni with 5at.% A1 plus 5at.% element A2. The alloying elements A1&A2 were used to alter the thermal stability of the resulting monosilicide as well as to influence their texture [1].

Results

All samples with a 10 nm thick metal layer exhibit diffraction peaks of Ni from RT up to around 150-175°C. However, the formation of the metal-rich Ni_2Si changes with alloying of the Ni. For pure Ni the formation of Ni_2Si starts as low as 100°C, whereas 5at.% of A1 shifts this temperature to 175°C. When adding additionally 5at.% A2, no diffraction maxima of Ni_2Si or any other Ni silicide phase could be found between 175°C and 275°C. At 275°C, NiSi is present in the NiA1A2 sample as it is the case for pure Ni, the formation of NiSi starts at 275°C and 250°C, respectively. The NiA1 samples exhibits Ni_2Si, which is stable only up to 200°C, and NiSi simultaneously. The alloying elements narrow the stability range of Ni_2Si from 150K to 25K to none with increasing content. A1 seems to widen the stability range of NiSi to lower temperatures significantly. The NiA1 sample shows only at 400°C a diffraction maximum at a *d*-value of 3.1315Å which could be attributed to Ni_3Si (JCPDS: 32-700 [2]). No $NiSi_2$ formation could be observed up to 700°C for all samples, opposed to previous investigations on pure Si substrates [3-5].

The samples with 35 nm show diffraction peaks of Ni from RT up to around 225°C for pure Ni, and 250°C for the alloyed samples. In the pure Ni sample, the formation of Ni_2Si started between 150°C-175°C and it is stable up to 350°C. The formation of Ni_2Si started at 200°C in the alloyed samples, in which this phase is stable up to 400°C. All samples exhibit diffraction peaks of NiSi from 275°C up to 700°C. No indication of other metal-rich Ni silicides or the high temperature phase $NiSi_2$ could be found in any of these samples. The

alloying elements shift the formation and transition temperatures of Ni_2Si to slightly higher temperatures for this set of samples. No narrowing of the stability range of this phase could be observed.

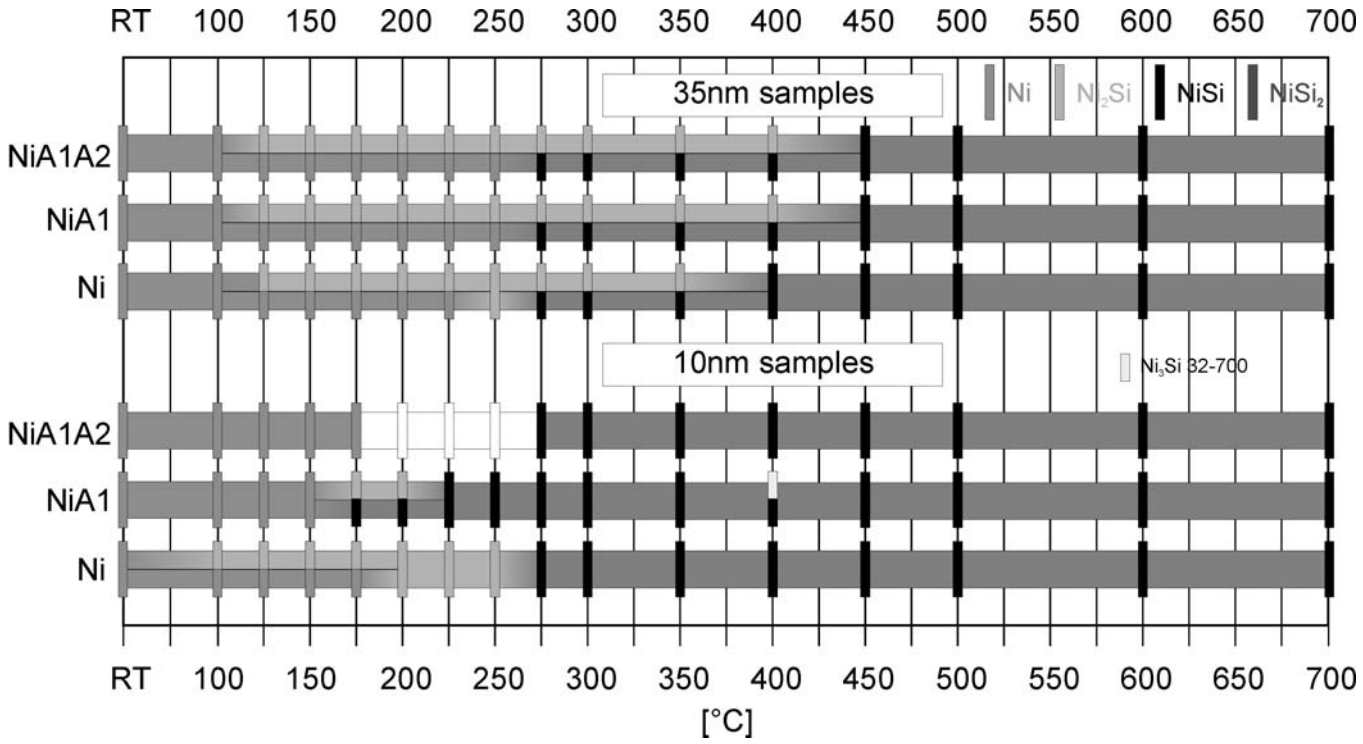

Fig. 1: *Summary of 96 SR-XRD results of unpatterned nickel samples with different alloying elements. High bars are actual measuring temperatures. The formation and transition temperatures of the various silicide phases are displayed.*

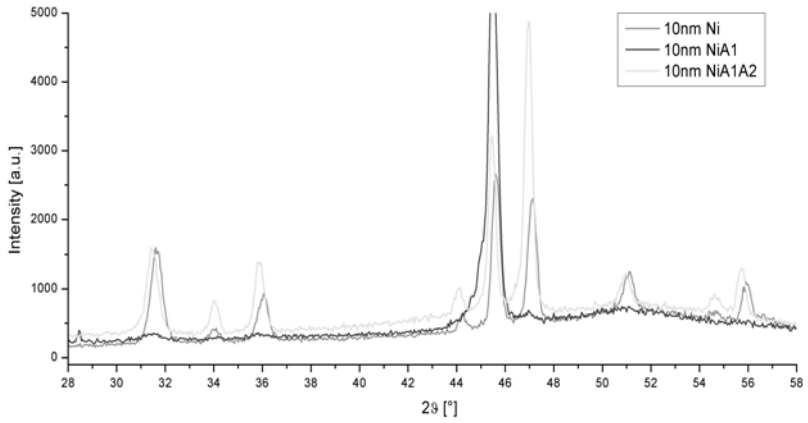

Fig. 2: *Comparison of XRD pattern of the samples with and without alloying elements after 400°C heat treatment.*

Figure 2 shows a comparison of three samples. The XRD patterns were collected at 400°C each. All diffraction maxima can be attributed to NiSi. The sample with A2 exhibits the most "powder-like" orientation distribution. The sample with A1 shows a XRD pattern with a very strong (112) peak, this does not change with higher temperatures. This could be explained by an off-axis fiber texture [1]. In addition, the incorporation of the alloying elements into the crystal structure of NiSi lead to a change of the *d*-values and thus the corresponding Bragg angles which can also be seen in figure 2.

References

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