	Experiment title: Size and stress influence on the reaction of Ni wires with Si (001)	**Experiment number**: SI-1927
Beamline: BM02	**Date of experiment**: from: 27 January 2010 to: 2 Febuary 2010	**Date of report**: 6 July 2010
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Report:

Nickel monosilicide (NiSi) is used as a contact material in advanced microelectronic devices (i.e. for transistor channel lengths smaller than 65 nm), thanks to its low resistivity [1]. It is formed via a solid state reaction between a thin metal film (between 10 and 20 nm) and single crystal silicon. At different annealing time and temperature various metal silicides form as a result of the reaction. Whereas the reaction of nickel (Ni) blanket films with silicon (Si) are fairly well understood very few basic studies have been devoted to the investigation of the reaction of narrow lines with Si. It is important for two reasons: 1) it is found in advanced technologies that Ni (or Ni alloyed with Pt) reaction with Si in small features may be difficult to control [2] and abnormal penetration occurs. 2) There is a strong need for a fundamental investigation of solid state reactions in small dimensions. Among the questions to be addressed is the respective influence of size and stress when decreasing the size. Indeed high mechanical stresses develop during silicidation [3, 4] and they certainly highly depend on the boundary conditions.

Deposits of Ni (3 and 6 nm) on Si substrates and arrays of patterned lines were produced to study the silicidation (phase sequence, phase formation kinetics and structures of phases) of ultra-thin or strained metallic films. Arrays of patterned lines are created with oxide or nitride spacers. Films of Ni (20nm) are deposited to create large actives areas of 200 and 50 nm in the trenches, between the spacers. Studies of in-situ XRD were carried out in synchrotron at the ESRF BM02 line, with an energy of 9.5 keV. The array of lines structures being in wide areas of 200x200µm², the dimensions of X-ray beam allowed exploring these small areas of our sample. To observe their silicidation and form the silicide NiSi, the samples have been heated in situ (2 ° C / min) to 500 ° C , under vaccum, with a heating stage from ESRF'Sample Environment Laboratory. A two-dimensional charged-coupled detector (CCD) capture reflection peaks of Ni silicides.

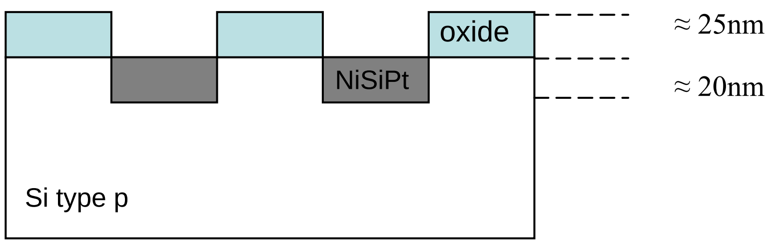

Fig. 1 Array of lines structure

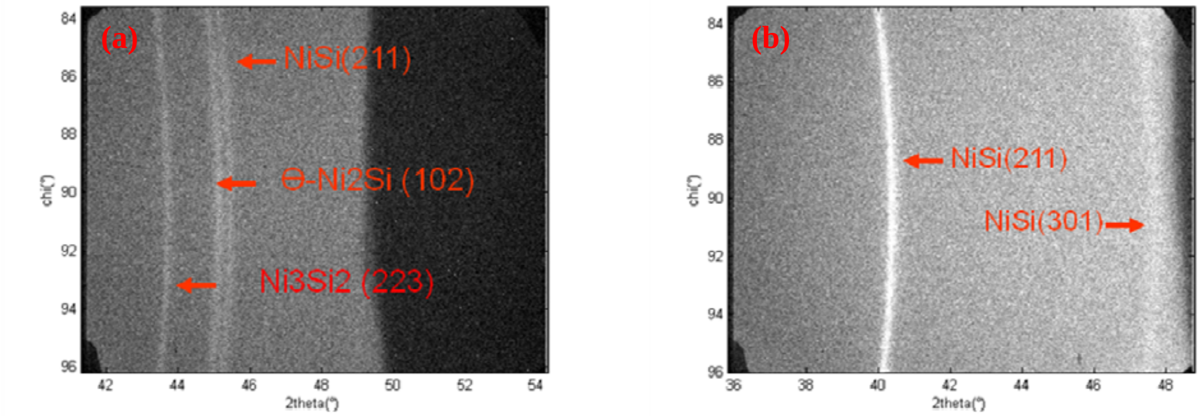

Fig. 2 Diffraction peaks of Ni silicide, from CCD, of arrays of lines sample, at 500°C, with wide active areas of 200 (a) and 50nm (b) and Ni deposit (thickness 20nm).

For array of lines with large active areas of 200 nm, several phases like Ni_2Si, Ni_3Si_2 and NiSi are formed sequentially. Also, during the rise in temperature, Ni_2Si phase disappears while θ-Ni_2Si phase appears (c.f. Fig2.a). The intensity of diffraction peaks homogenized in the direction of chi and their widths decrease in 2θ. For large active areas of 50 nm, only one phase is present, NiSi (c.f. Fig2.b) and the peaks evolve slightly with temperature.

The Fig. 3 shows the diffraction peaks of ultra-thin films of Ni annealed at 500°C, under vaccum. During the annealing process, with a Ni film of 6 and 3 nm of thickness, only NiSi and Ni_3Si_2 phases are formed. But for the deposition of 3nm a texture appears, intense peaks are located at 2θ and χ defined positions..

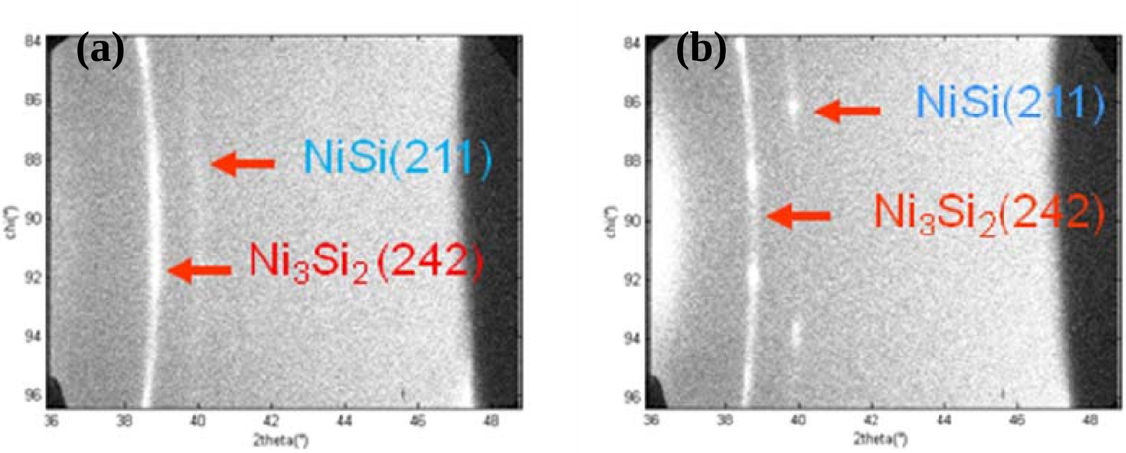

Fig. 3 Diffraction peaks of Ni silicide, from CCD, at 500°C, of sample with Ni deposits of 6 (a) and 3 nm (b) on Si substrates.

These preliminary results show clearly the impact of size on silicidation, which influence the phase texture of thin films and the impact of confinement, which influence the phase sequence. Indeed, all the sample exhibit the presence of texture from the first moments of silicidation and with very thin metallic films. During this experiment, pole figure measurements have been performed using the 2D detector. Data processing is in progress and will allow for detailed pole figures as a function of Ni initial thickness. Moreover the detailed analysis of diffraction peaks will gives us information about the phase formation kinetics and the evolution of stress during the silicidation.

References

[1] C. Lavoie, F. M. d'Heurle, C. Detavernier, C. Cabral Jr, Microelectronic Engineering **70**, 144 (2003).

[2] S. Kudo, Y. Hirose, N. Hashikawa, T. Yamaguchi, K. Kashihara, K. Maekawa, K. Asai, N. Murata, K. Asayama, E. Murakami, IEEE International Reliability Physics Symposium (IRPS), p 580-3 (2008).

[3] C. Rivero, P. Gergaud, M. Gailhanou, O. Thomas, B. Froment, H. Jaouen, V. Carron, Appl. Phys. Lett. **87**, 041904 (2005).

[4] P. Gergaud, M. Megdiche, O. Thomas and B. Chenevier, Appl. Phys. Lett. **83**, 1334 (2003).