IN SITU MONITORING OF THIN FILM REACTIONS DURING RTA: NICKEL SILICIDE FORMATION.

C. Lavoie, C. Coïa[1], R. Purtell[2], P. Desjardins[1], J. Jordan-Sweet, C. Cabral, Jr., F. M. d'Heurle, J.M.E. Harper.
IBM T.J. Watson Research Center, Yorktown Heights, New York 10598
[1] Département de génie physique, École Polytechnique de Montréal, Québec, Canada
[2] IBM Microelectronics Division, East Fishkill facility, Hopewell Junction, NY 12533

We demonstrate that multiple metal rich phases are present in the Ni-Si system when reacting a thin Ni film with an underlying Si substrate. The formation temperatures for the metal rich phases are highly dependent on dopant type and surface preparation. We also show that a serious limitation for NiSi implementation in devices is the low morphological stability of the film which degrades before the monosilicide transforms to the high resistivity $NiSi_2$ phase.

We have used a combination of *in situ* monitoring techniques during rapid thermal annealing of thin films to follow changes in phases, texture, resistivity and surface roughness as reactions occur. The characterization apparatus combines time-resolved synchrotron x-ray diffraction, elastic light scattering and resistivity measurements [1]. Using a position sensitive detector, diffraction spectra can be taken every 100 ms where x-ray peaks are sequentially observed during annealing, allowing for phase identification and determination of phase transformation temperatures. The optical scattering is simultaneously measured using HeNe laser light coupled in and out of the annealing chamber with fiber optics. The scattered light is collected at two different angles in order to probe two distinct length scales in the surface topography (0.5 and 5 μm). The resistance is measured using a square four point probe.

A typical example of the reaction of a 10 nm Ni film deposited on a n-doped polySi substrate is shown in Fig. 1 as measured *in situ* with light scattering and resistance (Fig. 1a) and simultaneous x-ray diffraction (Fig. 1b). The x-ray intensity is presented both as a gray scale (black to white from low to high intensity) and as intensity contours. The presence of the metal rich phases between 250 °C and 400 °C is clear not only in the x-ray diffraction spectra but also in the variations measured in the resistance. Slightly below 400 °C, the 5 μm light scattering signal increases significantly. This increase can be correlated with either surface pits appearing as NiSi starts to form or could also be related to the reported low temperature formation of $NiSi_2$ inverted pyramids [2]. Note that the large roughening observed with both light scattering signals above 600 °C occurs at least 100 °C below the temperature at which the high resistivity $NiSi_2$ forms. This suggests that the agglomeration of the thin NiSi film precedes the disilicide formation. The higher temperature disappearance of the $NiSi_2$ x-ray peak slightly below 1000 °C in Fig. 1b was observed with every Ni films and is related to the partial melting of the silicide and possible texturing in the layer.

The influence of dopant type on the formation of metal rich silicide phases is presented in Fig.2 where the x-ray diffraction spectra for n and p doped SOI substrates (Si on insulator) show that there can be temperature variations of more than 50°C at 350°C. In this talk we will cover advantages and disadvantages of moving from Co silicide to Ni silicide for high speed CMOS logic applications. The effects of film thickness, substrate type and dopants on the formation of the silicide phases will be presented.

[1] C. Lavoie et al., Defect and Diffusion Forum **194-199**, 1477 (2001).
[2] V. Teodorescu et al., J. Appl. Phys. **90**,167 (2001).

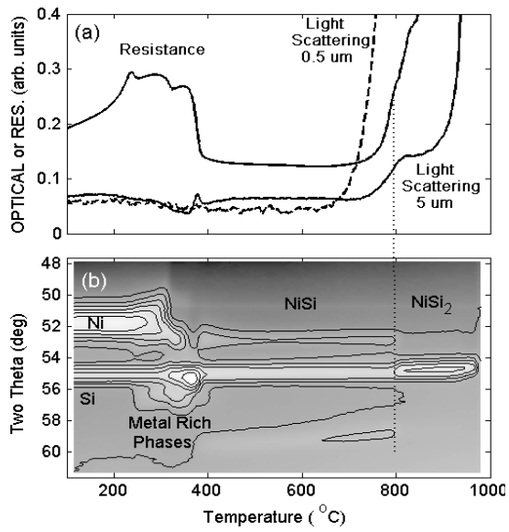

Fig. 1 (a) Resistance and light scattering from 0.5 and 5 μm length scales together with (b) x-ray diffraction measurements performed *in situ* during annealing (3 °C/s) of a 10 nm Ni film deposited on n-doped poly-Si.

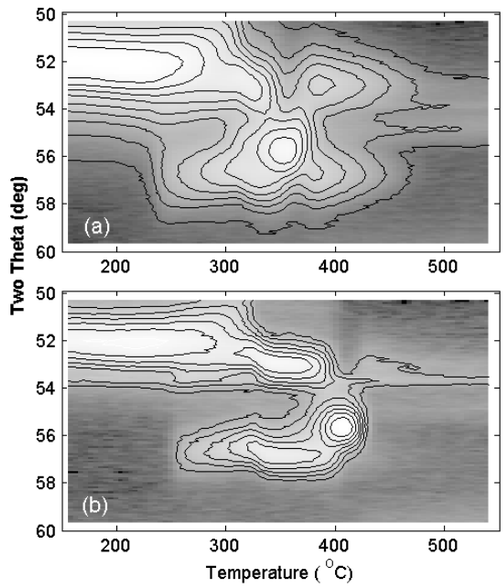

Fig.2 *In situ* x-ray measurement during annealing of a 10 nm Ni film deposited on (a) n-doped and (b) p-doped SOI substrate.