DOI: 10.1017/S1431927603444334
Microsc Microanal 9(Suppl 2), 2003

Strain Measurements at a NiSi/Si Interface Using STEM-CBED: A Quantifaction Method for Stress Relaxation During TEM Lamella Preparation

R.Pantel[1] , L. Clément [2,3], J. L. Rouvière[2] and L.F.Tz. Kwakman[3].

1) STMicroelectronics, 850 Rue Jean Monnet, F-38926 Crolles, France
2) CEA-Grenoble, DRFMC/SP2M, 17 rue des Martyrs, F-38054 Grenoble, France
3) Philips Semiconductor Crolles, 850 Rue Jean Monnet, F-38926 Crolles, France

STEM-CBED studies of a NiSi/Si(001) interface allow to determine the Si crystal relaxation inside the TEM lamella. The result is a bending (local rotation) of (001) planes. This relaxation is maximum at the interface and extends as far as 200 nm into the silicon substrate for a 260 nm thick TEM lamella. The relaxation strain field is also visible in TEM bright field imaging where oscillation intensity fringes are observed. A finite element simulation is in good agreement with the NiSi thermal contraction during cooling.

Introduction: Today, stress and strain field measurement techniques have become a 'must' in silicon technology process development to ensure dislocation-free device processing. A European project STREAM (2000-2002), dedicated to the development of such stress measurement techniques, proposed a CBED method using Si[230] zone axis pattern collections and simulations [1]. However, this project missed two difficulties: TEM lamella relaxation was neglected and high strain fields were avoided. In this communication we show that: 1) The sample relaxation must be considered as the most important phenomenon and 2) The CBED patterns of high strain field areas can be interpreted. The study is carried out on NiSi, an alternative silicide that is proposed for sub 65 nm technologies (ITRS road maps).

Experimental details : The NiSi layer (around 25 nm thick) is formed by the thermal reaction of Ni with the Si substrate at 600°C during 50 sec. During cooling tensile stress builds up inside the NiSi. The TEM samples were prepared by focused ion beam (FIB). TEM bright field and filtered CBED acquisition were carried out using a TEM FEI TECNAI F20 equipped with an energy filter Gatan GIF 200 and a 1k x 1k CCD. The STEM-CBED mode (a new function in TIA software) was used to collect line profile CBED series across the NiSi/Si(001) interface.

Results : Figure 1 presents a Si[110] zone axis TEM bright field image of a 60 nm MOS transistor integrating Nickel silicide. The sample prepared by FIB is flat with parallel faces. Its thickness as measured by CBED equals 260 nm. In Fig. 1, dark and bright fringes are observed under the silicide layer. From the CBED patterns in Fig. 2 it is concluded that this contrast is not due to thickness variations but to deformation of the Si crystal: Figures 2a to 2d present the bright disks of Si[230] zone axis (11.3° tilt) CBED patterns acquired in STEM mode at different distances of the interface, at points marked **a** ,**b**, **c** and **d** in figure 1. The HOLZ lines are sharp in Fig.2a and are split in Fig.2b to 2d. In Figure 3 a simulation of the CBED pattern using Electron Diffraction V8 software is shown [2]. The split patterns can be fitted by the superposition of two Si un-deformed crystals that have been rotated by an angle $\pm\theta$, the rotation axis being along a [1-10] direction parallel to the thin lamella faces. The bending of Si(001) planes is due to the relaxation of the stress generated by the NiSi layer during sample thinning. Figure 4 presents a drawing of the strain field coherent with a finite element simulation that considers that the stress was built inside the NiSi layer during cooling. In figure 5 the total Si(001) plane rotation 2θ versus NiSi/Si interface distance, extracted from a STEM CBED line profile, is reported. The rotation 2θ is as high as 0.16° (2.8 mrad) at a distance of 60 nm from the NiSi/Si interface.

Conclusions: The relaxation of stress inside thin TEM cross-sectioned samples has been evidenced by local CBED patterns. It mainly results in atomic plane bending along the electron beam direction. This bending is also qualitatively visible in TEM bright field images (z-bending fringes). Finite element modelling must be done to relate the bent thin sample geometry to the bulk specimen stress state.

References

[1] A. Armigliato et al. Microsc. Microanal. 6 (suppl. 2) (2000) 1076
[2] Jean-paul.morniroli@univ-lille1.fr

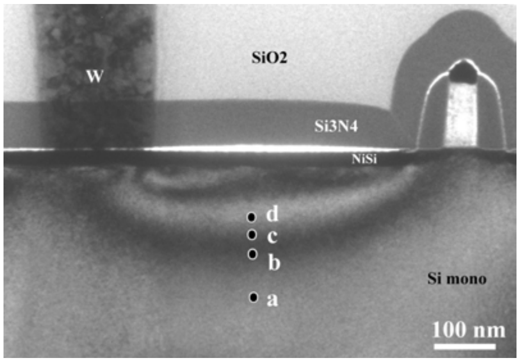
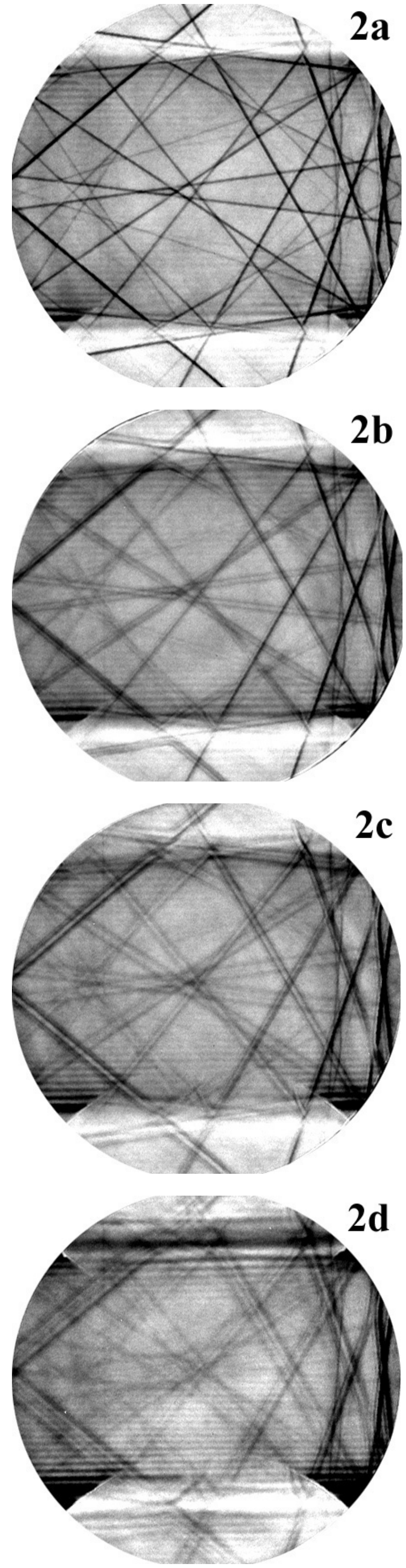


Figure 1

Fig 1 : TEM bright field Si[110] axis image of a 60 nm transistor with NiSi. At points marked **a**, **b**, **c** and **d** CBED patterns were acquired (see Fig 2).



Figures 2a, 2b, 2c, 2d

Fig 2a, 2b, 2c, 2d: CBED patterns acquired at points marked **a**, **b**, **c**, **d** in fig 1. (Si[230] zone axis, 11.3° tilt away from [110] axis).

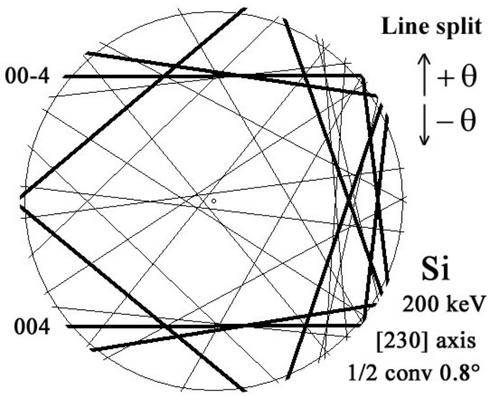


Figure 3

Fig 3: Simulated pattern using Electron Diffraction software. One Si HOLZ line system is shown, the line split (Figs. 2b, 2c ,2d) is in the vertical direction.

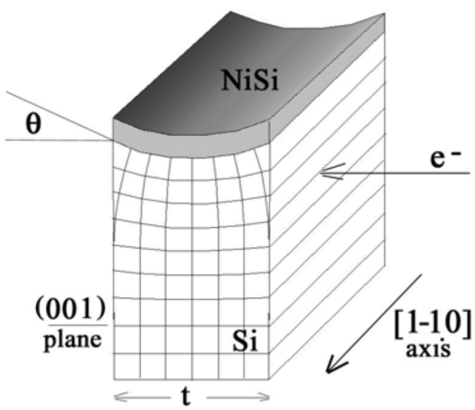


Figure 4

Fig 4: Drawing of the relaxation geometry at NiSi/Si interface. The maximum (001) plane rotation is θ at each face sides, total 2θ.

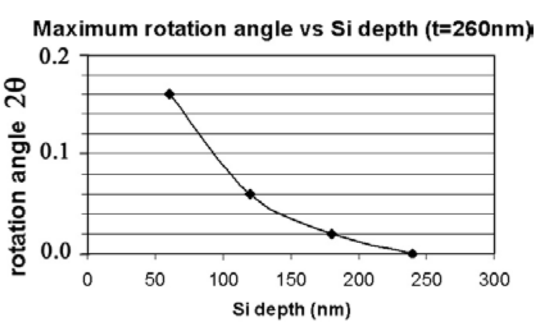


Figure 5

Fig 5: Measured (001) planes total rotation 2θ versus the distance to the NiSi interface inside a 260 nm thin lamella. The rotation axis is [1-10].

https://doi.org/10.1017/S1431927603444334 Published online by Cambridge University Press