Observation of nano-indent induced strain fields and dislocation generation in Silicon wafers using micro-Raman Spectroscopy and White Beam X-Ray Topography.

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In the semiconductor manufacturing industry, wafer handling introduces micro-cracks at the wafer edge due to the brittle nature of silicon. During heat treatment, when the temperature goes above the brittle-ductile transition point [1] these can produce larger, long-range cracks in the wafer which can cause wafer breakage during manufacture. This study used two complimentary techniques, micro-Raman spectroscopy (uRS) and synchrotron X-ray diffraction topography, to study both the micro-cracks and the associated strain fields produced by nano-indentations. Defined defects, i.e. nano-indsents, were introduced into silicon (100) samples by the use of a nano-indenter equipped with a Berkovich tip. Numerous samples were produced, including samples with a 5x5 array. Figure 1 shows a 02-2 large area transmission (LAT) topograph, showing the strain fields associated with the indents. The array was produced using horizontal applied forces of 500mN, 400mN, 300mN, 200mN and 100mN, respectively, the indents being 100µm apart. Other samples were produced with a single line of 15 indents each 1mm apart.

The samples were observed both before and after thermal treatment. During the thermal treatment the samples were heated to a temperature of 800°C ± 5°C and held constant for 20 minutes. Topographs were taken every 30 minutes. During thermal treatment the nano-indents produced slip bands in the <110> directions that are visible using X-ray topography [2]. These slip bands are most noticeable at the 500mN indents (Fig. 2).

Micro-Raman spectroscopy confirmed the presence of numerous phases of silicon; both Si-XII and Si-III are produced by the indentation process [3] and both compressive and tensile strain in the indents, prior to rapid thermal anneal treatment and the absence of these phases, other than cubic silicon Si-I, after the thermal treatment.

As previously mentioned, uRS of the indents showed both compressive strain at the edges of the indents and tensile strain at the centre of the indents. Fig. 4 shows the mapped strain fields for a typical 500mN indent.

A 6-20 back reflection topograph of the indents, X-ray penetration depths ~ 10-50µm, shows the long range strain field to be relatively isotropic in nature around the indents, fig. 4, and this is in close qualitative correlation with finite element strain simulations, fig. 5. At present the simulation results do not show the shift from compressive to tensile strain that was observed by uRS. This is due to known limitations in the simulation systems that are being addressed.

References

Fig. 1 02-2 LAT topograph of indents.

Fig. 2: 0-22 LAT topograph of an array of indents.

Fig. 3 Strain observed at the 500mN indent using uRS. Vertical red lines indicate the edges of the indent. Compressive strain is denoted by the blue arrow, tensile strain is denoted by the red arrow.

Fig. 4 6-20 back reflection topograph of nanoindents in Si

Fig. 5 Strain simulation results for the 200mN indent

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