X-RAY DIFFRACTION IMAGING FOR PREDICTIVE METROLOGY OF CRACK PROPAGATION IN LARGE DIAMETER SILICON WAFERS

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Catastrophic wafer breakage during high temperature processing of silicon results in multi-million dollar losses annually on a single semiconductor fabrication line. While there is evidence that such failure arises from cracks initiated by misaligned robotic handling tools, making reliable predictions about such stochastic processes is a major challenge. We have used X-ray Diffraction Imaging (Topography) [1] in both the laboratory and at the ANKA (Germany) and Diamond (UK) synchrotron radiation sources to record the images of cracks, similar to those produced by repeated collision of misaligned tools, generated by indentation at the bevel edge of 8 inch wafers. Using a semi-kinematical model of image formation, we have been able to identify those cracks which are likely to propagate and we define a single critical parameter κ for their identification which can be directly determined from the X-ray images. The predictions from the measured κ values have been shown to agree very well with experimental measurements of the probability of breakage of these wafers during rapid thermal annealing, using finite element modelling to determine the high temperature thermal stresses.

Cracks which propagate on {110} planes do not show asterism in the X-ray images and generally have κ values greater than the critical value κc. The presence of asterism (A in Fig 1) is a measure of non-planar cracking, side-branching and material breakout and the variation of contrast with detector geometry shows that it arises mainly, but not exclusively, from lattice tilts. Spatially resolved, high resolution diffraction reciprocal space maps confirm that the deformation across the crack is predominantly one of lattice tilt. On change of orientation, many cracks show regions of strong diffraction contrast (B in Fig 1). These local strained regions correspond precisely with regions of strain in polarised infrared images. We present time-resolved in-situ X-ray diffraction topography images showing an example of a 90° change of crack propagation direction occurring at one of these stress localities.

Fig 1 X-ray Diffraction Image of a crack of length 13.7 mm with mid-range κ value, taken at the Diamond Light Source. 220 diffraction vector is vertical. The indent location is at the far left of the image