AN 409
Detection of Threading Dislocations in Strained Si Using AFM

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Discussion

Strained Si is being evaluated as a channel material in CMOS devices for its higher carrier mobility. The manufacturing of the strained Si layer is achieved by epitaxially depositing a thin (5 to 50 nm) silicon layer on top of a strain-relaxed $Si_{1-x}Ge_x$ buffer layer. Usually, threading dislocations are present on the surfaces of the strain-relaxed $Si_{1-x}Ge_x$ buffer layers and propagate through the epitaxially grown thin Si layer (strained Si) to the surface.

Because the presence of threading dislocations can seriously degrade device performance, minimizing the density of threading dislocations has been one of the key manufacturing challenges of strained Si. Etch Pit Density (EPD) and Plan-view Transmission Electron Microscopy (PVTEM) are the most common metrology techniques for monitoring the threading dislocation density. However, both techniques are destructive because the wafer is destroyed due to sample preparation steps. Furthermore, the etching solution used in the EPD technique is hazardous and the PVTEM is limited by the field of view. In comparison, Atomic Force Microscopy (AFM) is a better metrology technique for monitoring the threading dislocation density directly on the whole 8" or 12" wafer at atmospheric conditions without any sample preparation steps (i.e. AFM is non-destructive and does not require hazardous etching solutions). In addition, AFM can operate at a larger field of view than PVTEM. The AFM detection limit for threading dislocation density is approximately 2.5 X 10^5cm^{-2} for a 20um X 20um scan size and 4 X 10^4cm^{-2} for a 50um X 50um scan size.

Samples A and B are two examples of strained Si grown on a strain-relaxed $Si_{1-x}Ge_x$ layer, which has been planarized using chemical mechanical polishing (CMP). Figures 1(a-c) show three different sizes of AFM images from the strained Si surface of sample A. These images were acquired at the location about 1cm from the wafer edge. Many threading dislocations are observed in Figure 1(a) and also shown in the 20um X 20um zoom-in view of Figure 1(b). One of the threading dislocations is imaged with a higher magnification of the 5um X 5um image size and presented in the 3-D perspective view as shown in Figure 1(c). The observation of higher threading dislocation density at this location is consistent with previous reports that the threading dislocation density is higher near the wafer edge.

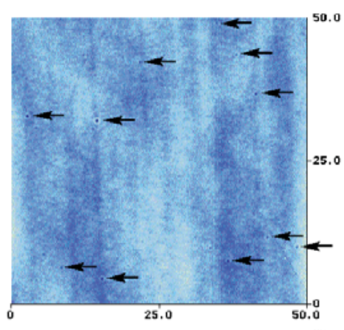

Figure 1(a): AFM image of strained Si Surface from sample A. Arrows indicate numerous threading dislocations that were detected near the wafer's edge.

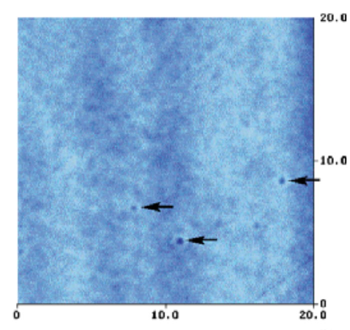

Figure 1(b): Threading dislocations zoom-in from Figure 1(a).

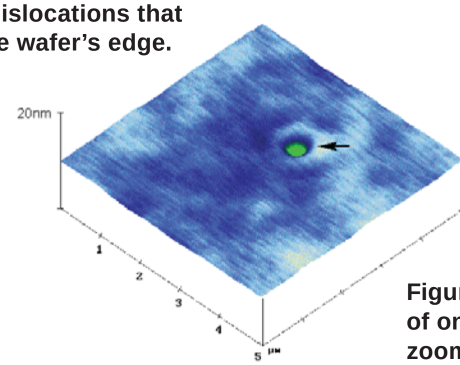

Figure 1(c): 3-D perspective view of one threading dislocation zoom-in from Figure (b).

Figures 2(a-c) also show three AFM images acquired from the strained Si surface of the other CMP'ed sample B. These images were acquired at a location away from the wafer edge. There are six threading dislocations observed in Figure 2(a) and three of them are zoom-in viewed in the 20um X 20um image of Figure 2(b). Figure 2(c) is the 3-D perspective view of one threading dislocation within a 5um X 5um area selected from Figure 2(b). This latter figure also shows that sample B has a significantly rougher surface surrounding the dislocation compared to surface surrounding the dislocation on sample A (Figure 1(c)).

In this brief note, AFM is shown to be a viable technique for detecting and monitoring the threading dislocations in strained Si.

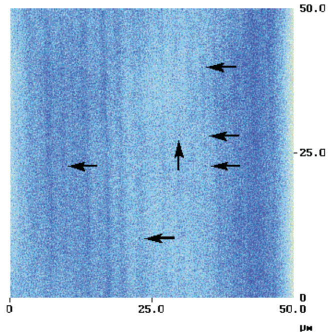

Figure 2(a): AFM image of strained Si Surface from sample B. Arrows indicate six threading dislocations that were detected away from the wafer's edge.

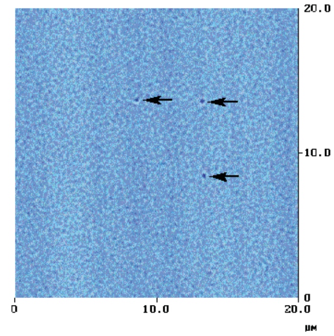

Figure 2(b): Three threading dislocations zoom-in from Figure 2(a).

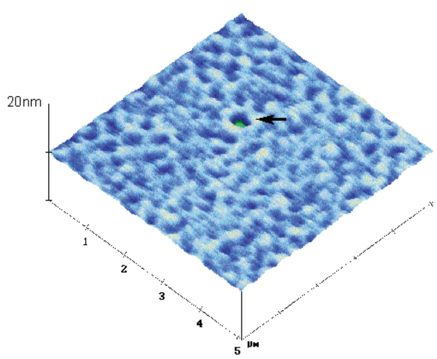

Figure 2(c): 3-D perspective view of one threading dislocation zoom-in from Figure 2(b).

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