Impact of Strained-Si/SiGe Heterostructure Dislocations on Electrical Activity of Defects

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The correlation between the presence of defects in strained Si/SiGe heterostructures grown on Si substrates and their electrical impact has been studied by a wide range of dedicated electrical and structural methods.

The primary goal has been the separation of threading (D_t) and misfit (MD) dislocations' impact on device electrical activity, taking into account that at room temperature, EBIC imaging of clean dislocations does not occur. Thus, we have bias-dependent MOS/EBIC, quantitative linescans, low-temperature image contrast, quantitative correlation of EBIC contrast with spatial distribution of dislocation etch pits and their sizes/depths (from AFM), novel intentional Contamination Enhanced Defect Delineation (CEDD) to observe defects whose electrical activity has previously been invisible in EBIC images, and correlate EBIC components with charge carrier generation/recombination lifetimes.

Separation of the EBIC signal components related to threading and misfit dislocations is considered for two cases: (a) standard diode EBIC provides a strong signal of MDs. Low-temperature MOS/EBIC with an accumulation mode at the oxide/semiconductor interface is applied (Fig. 1). The space charge region is collapsed (or diminished), which enlarges the distance to MDs, increasing the relative impact of D_t.
(b) Signals from D_t and MDs are mixed. The correlation of quantitative EBIC contrast with the spatial distribution of threading dislocations is applied that allows for the separation of the D_t and MD components of EBIC signal (Fig. 2). Local etch pit densities in many small regions are counted, not only the overall etch pit density. The etch pit distribution is described not only by its average area density, but also by its spatial distribution over the sample, and by the shape of the frequency distribution described by a histogram. It allows for distinguishing different distributions of dislocations in cases when the average density of etch pits is the same.

Intentional CEDD increases the EBIC signal (even at higher temperatures) and the etch pits visibility (especially after short preferential etching for only thin upper layer removal). Together with low-temperature studies of samples, it assists in anticipating the dislocation behavior after unintentional contamination in IC manufacturing processes.

Sizes and depths of dislocation etch pits revealed by Atomic Force Microscopy (AFM) are also related to the contamination of defects and they influence EBIC-revealed electrical activity that leads to the correlation of both, which is to be presented.

Correspondence between EBIC components and carrier generation/recombination lifetimes can be used to relate the electrical activity directly to parameters crucial for performance of devices and their applications in integrated circuits.

[1] Z. J. Radzimski, T. W. Zhou, A. Buczkowski, G. A. Rozgonyi, D. Finn, L. G. Hellwig, and J. A. Ross, Appl. Phys. Lett. **60**, 1096 (1992).

[2] K.R. Bray, W. Zhao, L. Kordas, R. Wise, McD. Robinson and G. A. Rozgonyi, ECS Proc., Fall, 2003.

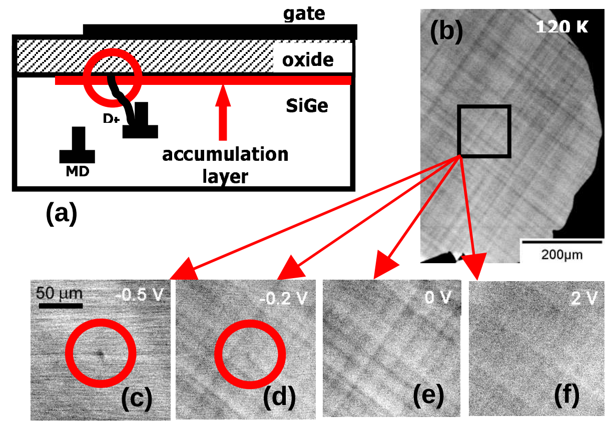

Figure 1: MOS/EBIC method: (a) scheme of the structure at accumulation mode, with shown threading (D_t) and misfit (MD) dislocations and the point where a D_t reaches the accumulation layer; (b) taken at 120 K EBIC image of structure: 20 nm strained $Si/Si_{0.86}Ge_{0.14}$/graded SiGe/Si; (c)-(f) EBIC images at various modes at oxide/semiconductor interface due to different applied biases: (c) D_t visible in accumulation mode, (d) MDs visible with very weak but observable signal from D_t at depletion mode, (e) only MDs visible, (f) only MDs visible, but weaker than in (e).

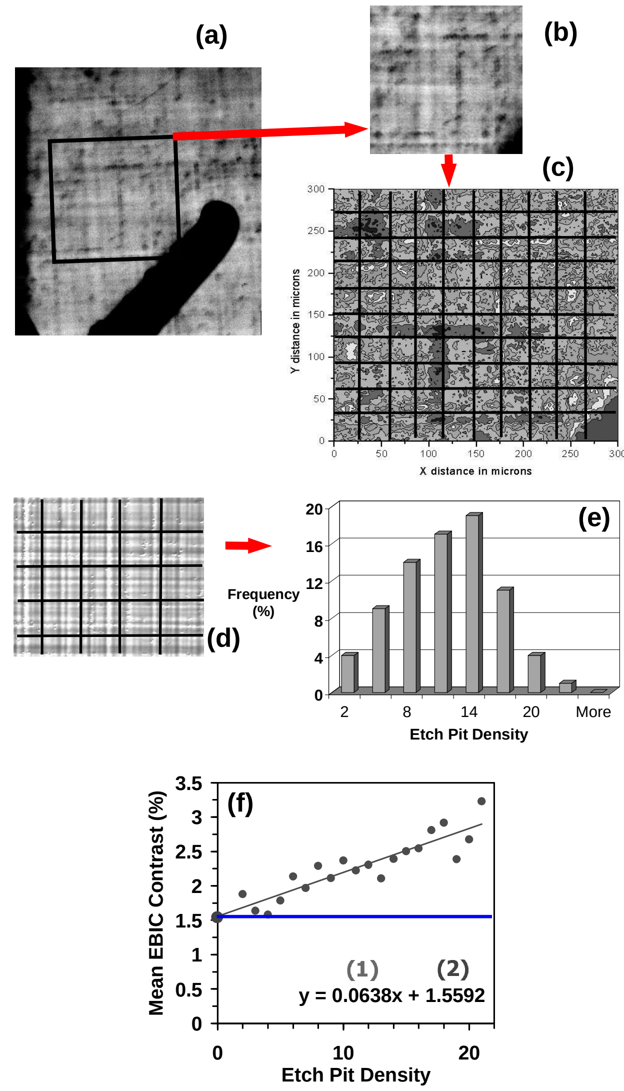

Figure 2: Correlation between quantitative EBIC contrast at 105 K and spatial distribution of dislocation etch pits for determining D_t- and MD-related EBIC components in $Si_{0.59}Ge_{0.41}$: (a)-(b) EBIC images, (c) corresponding quantitative EBIC contrast with a grid of small 30×30 μm regions, (d) Nomarski Microscope image of a part of the same area after preferential etching, (e) histogram of etch pit densities in small regions, (f) correlation between EBIC contrast and etch pit densities, with (1) D_t- and (2) MD-related EBIC contrast components.