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Nanoscale Strain Mapping in Embedded SiGe Devices by Dual Lens Dark Field Electron Holography and Precession Electron Diffraction

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For the past decade, stressors have been incorporated into the source and drain regions of the silicon semiconductor device to change the lattice constant of the current-carrying region in the channel, thereby altering the band structure of the semiconductor to enhance device performance. In semiconductor industry, it is critical to measure strain distributions at the nanometer scale. In recent years, dual lens dark field electron holography and precession electron diffraction are developed to obtain strain distribution at ~1 nm spatial resolution [1-7]. We use these two techniques to measure strain distribution of box shaped embedded SiGe devices and we compare our result with Eshelby inclusion simulations [8].

Fig.1 is the strain map obtained by dual lens dark field electron holography. The spatial resolution is about 2 nm with 1 nm fringe spacing. Dark field STEM image shows the box shaped embedded SiGe. The <220> strain map shows compressive strain in the channel region with large lattice constant in the embedded SiGe region. The <004> strain map shows slightly tensile strain in the Si region, with large lattice constant in SiGe region. Fig.2 is the strain map obtained by precession electron diffraction (PED). The probe size is about 2 nm. Fig.2(a) is the strain map along <220> direction and Fig.2(b) is the strain along <004> direction. Fig.2(c) is the shear strain map and Fig.2(d) is the crystalline rotation map. The strain map by PED is very similar to the one obtained by dark field electron holography. The shear strain shows high value at the bottom corner of SiGe and SiGe/Si boundary near the surface. The rotation map shows maximum 0.6^{o} crystal rotation at the top surface.

Fig.3 is the result of Eshelby inclusion simulation. Fig.3(a) is the simulation for the strain along <220> and Fig.3(b) is the simulation for the strain along <004> direction. The simulation results match well with measurement from dual lens dark field electron holography and electron precession diffraction measurement.

The precession electron diffraction provides better S/N ratio maps than the one by dual lens dark field electron holography. However, the acquisition time and storage space for PED is $\sim 10^3$ and $\sim 10^4$ of dark field electron holography, respectively.

In conclusion, using dual lens dark field electron holography and precession electron diffraction, we provided strain maps at high spatial resolution and demonstrated that to be valuable methods for semiconductor research and development.

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References:

[1] M. Hytch, F. Houdellier, F. Hue, E. Snoeck, *Nature* **453** (2008), p. 1086.
[2] Y.Y. Wang et al., *Ultramicroscopy* **101** (2004), p. 63; US patent: US 7,015,469 B2 (2006).
[3] Y.Y. Wang et al., *Ultramicroscopy* **124** (2013), p. 117.
[4] Y.Y. Wang et al., *Applied Physics Letters* **103** (2013), p. 052104.
[5] Y.Y. Wang, A. Domenicucci, and J. Bruley, *Microscopy Today*, May (2014), p. 2.
[6] J. Rouviere et al., *Applied Physics Letters* **103** (2013), p. 241913.
[7] Y.Y. Wang et al., *Applied Physics Letters* **106** (2015), p. 042104.
[8] J.H. Davies, *J. Appl. Mech.* **70** (2003), p. 655.

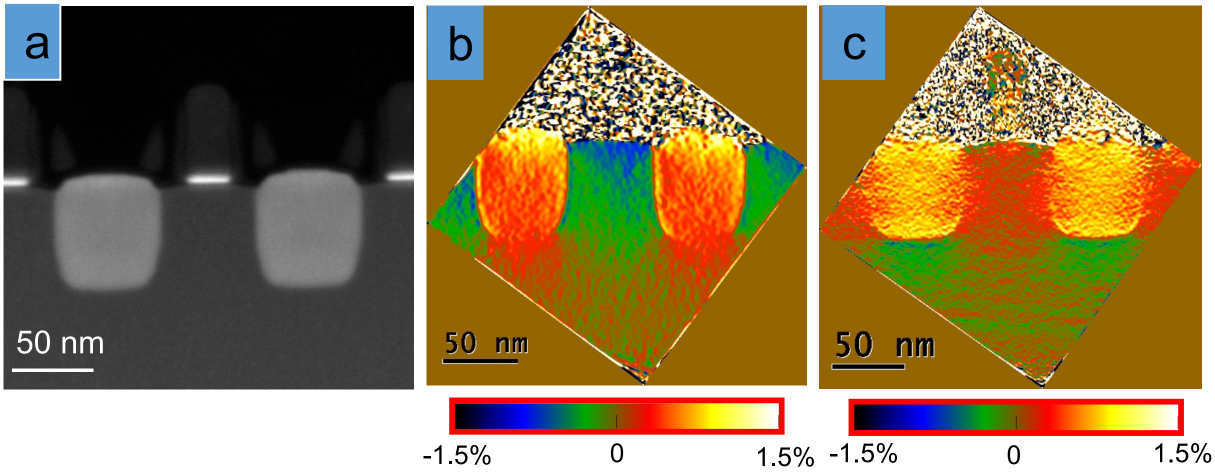

Figure 1. (a) STEM image; (b) <220> strain map by dark field holography; (c) <004> strain map.

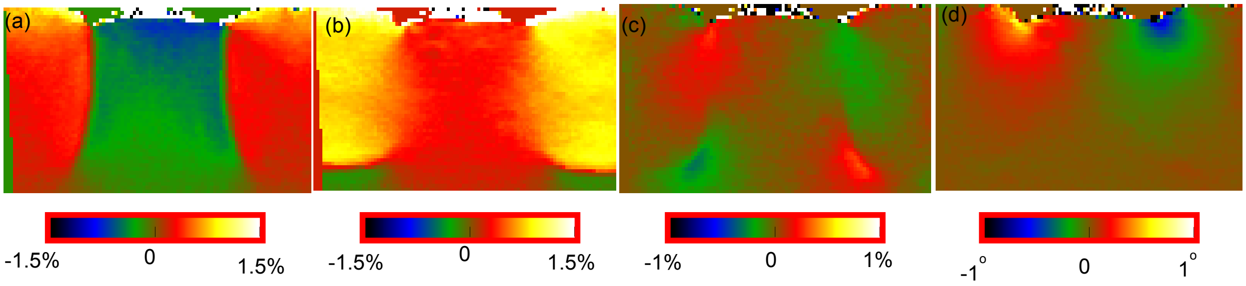

Figure 2. Strain map by PED (a) <220> map, (b) <004> map, (c) shear strain, (d) rotation map.

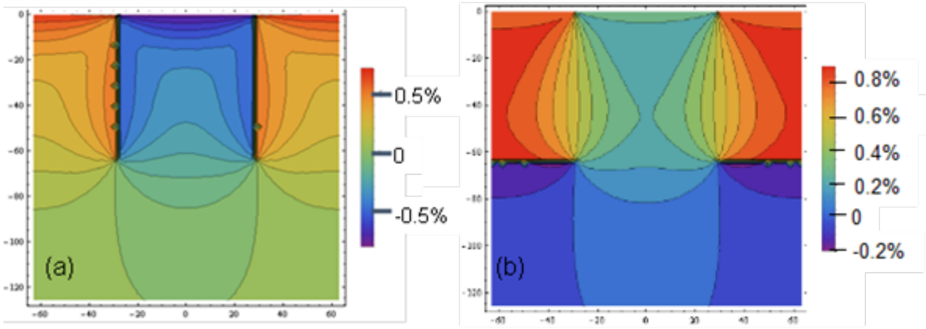

Figure 3. Eshelby inclusion model: (a) <220> strain map; (b) <004> strain map.

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