Studies of Strain Field near Interface of SiGe/Si Device-like Nano-structures by X-ray Bragg-surface Diffractions (BSD)

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The strain field produced by the mismatch of two different materials is an important problem and has been investigated for several years. The strain field near the interface of a device like MOS-FET may enhance the electron mobility by slightly changing the lattice periodicity. It could directly cause the band structure of semiconductor to shift, so that the band gap also varies. The Bragg-surface diffraction (BSD) method has been used for measuring strain field of a substrate near the interface without any destruction to the samples. The result of the BSD measurement could present the distribution of lattice-constant variation versus the depth by combining the calculation of X-ray dynamical theory.

The sample system is provided by TSMC. Nano-pad-structures of SiGe were grown on the Si(001) substrate. The pads were arranged in array and surrounded by oxide or nitride (Fig. 1). Several set of parameters (w,d) have been used in the preparation as shown in the table.

w(nm)	d(nm)	Surrounding
0.25	0.15	SiN/ Oxide
1	0.65	SiN/ Oxide
5	3.35	SiN/ Oxide
0.25	0.1	SiN/ Oxide
1	0.35	SiN/ Oxide
5	1.7	SiN/ Oxide
1	0.1	SiN/ Oxide
5	0.55	SiN/ Oxide

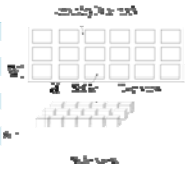

Fig. 1: Sample system of SiGe pads on Si (001).

The experiment was carried out at BL17B Wiggler beamline , NSRRC, Taiwan. First we aligned the crystal for Si(002) reflection. Then we rotated the crystal along the azimuth phi axis [002] to generate the multiple diffraction (002)/(131), in which the Si(002) and Si(131) satisfied the Bragg diffraction conditions. This is so-called three-wave Bragg-surface diffraction (Fig. 2). The Si(131) diffracted beam propagates along the interface of the SiGe/Si(001) and the Si substrate.

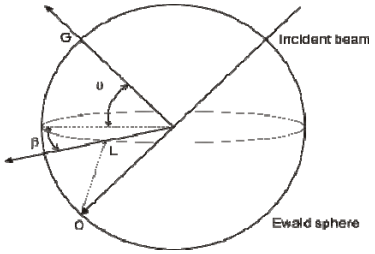

Fig. 2: Three-wave BSD geometry.

Figure 3 shows the images of the surface diffracted pattern when changing the azimuth angle, which give us the information about the distortion of the reciprocal lattice point as a function of depth. The middle one in both top and bottom series of patterns is the peak position. Away from the peak, the pattern shows many stripes normal to the interface. Those are caused by surface truncation rod (CTR). It is obvious there is much contribution to the patterns due to other periodicities or layers. These complicated patterns are hard to analyze. The iterative algorithm of phase retrieval will be used.

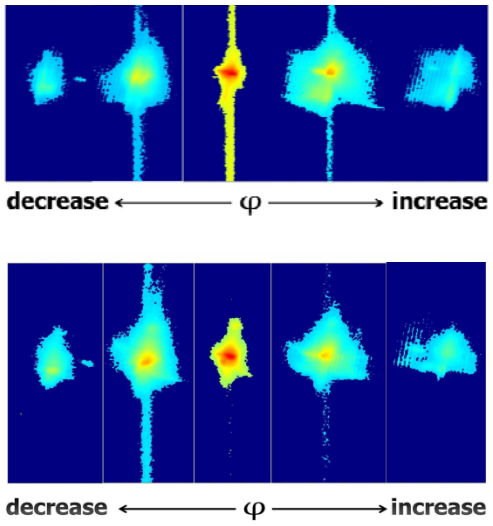

Fig. 3: Images of surface reflection recorded by a CCD detector. Top at $\varphi = 43.407^{o}$, bottom at $\varphi = -46.358$