Highly strained Si:P (HS Si:P) epitaxially grown thin films with P concentrations above 10^{21} cm^{-3} are being investigated for applications in creating tensile strain in NMOS channel regions. The films are grown using a very low temperature growth and etch process that results in the formation of a surface film with no visible defects as determined by TEM and XRD but with phosphorus concentrations well above the solid solubility limit.

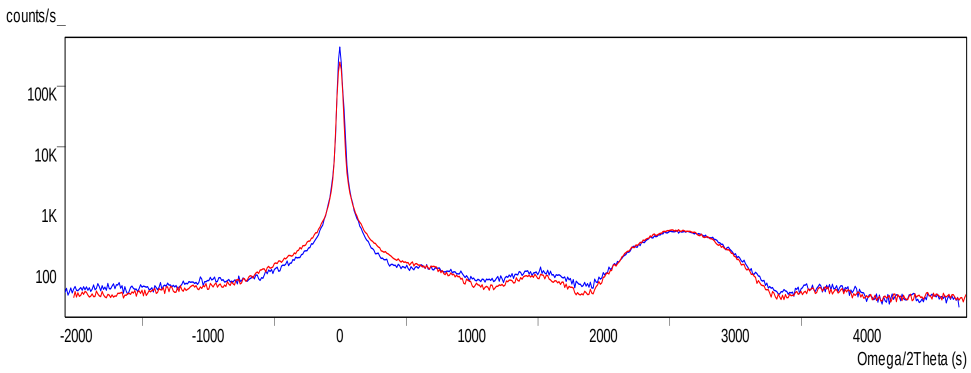

Fig. 1 Omega-2theta scan around (113) Si peak (blue trace) and simulation using the Panalytical Epitaxy software (red trace) for sample 4.4E21

Fig. 1 presents an omega-2theta scan acquired around the (113) diffraction peak from a heavily phosphorous-doped silicon sample; the doping was estimated to be 4.4×10^{21} atoms/cm^3. According to the simulations, which matches very well the shape of the acquired scan, the doped layer is 40 nm thick and has a strain of -8600 ppm with respect to the Si layer.

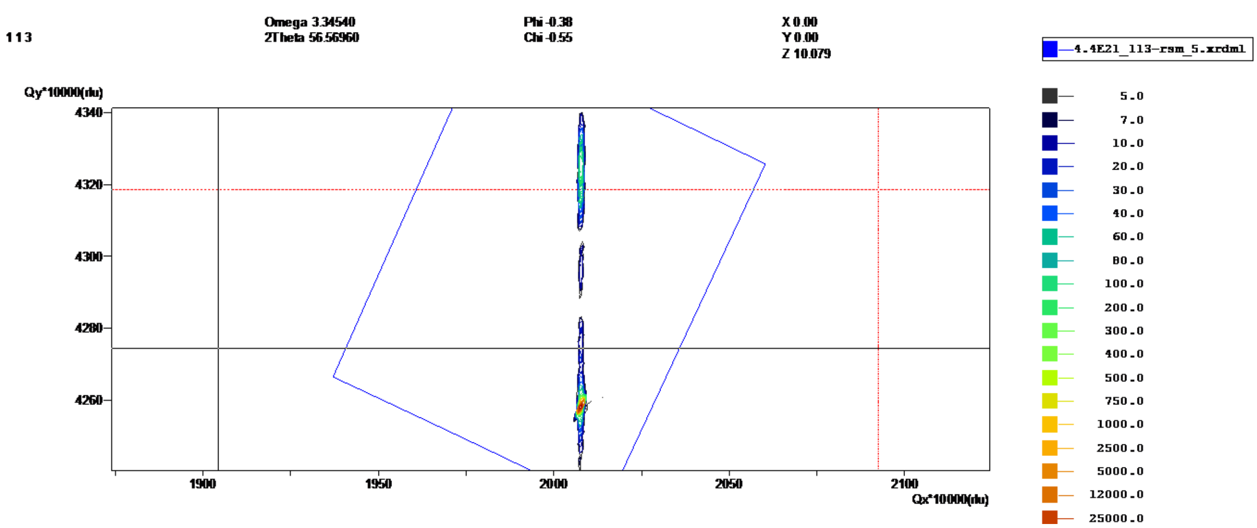

Fig. 2. RSM around (113) peak acquired from the same sample.

According to the reciprocal space map acquired around the (113) Si peak from the same sample and displayed in Fig. 2, the doped layer is 100% strained. This means that the layer in-plane lattice parameters are identical to those of Si substrate, while the out of plane lattice parameter is smaller.

40 nm thick epitaxial layers were grown with chemical doping concentrations between 0.3-4 x 10^{21} cm^{-3}. Efficient dopant activation with negligible diffusion of these HS Si:P layers have been reported using a ms time scale laser dynamic surface anneal (DSA). This work investigates the stability of the dopant activation in these HS Si:P layers during subsequent post-DSA thermal processing. Subsequent low temperature annealing between 700 and 900 °C for times up to 30 min resulted in significant electrical deactivation. TEM examination shows these films are defect free after DSA treatment but for higher concentrations, extended defect formation in the epitaxial film was observed. These extended defects appear to be in the form of dislocation loops and may be the byproduct of point defect release during deactivation. In addition phosphorus marker layer diffusion experiments suggest there are a large number of interstitials grown into the layer but this has not been confirmed.

RBS channeling measurements will help both determine if there are interstitials grown into the films and better understand how these excess point defects evolve upon annealing. A channeling experiment for such a sample along the surface normal to the crystalline planes would be identical to that of the as-received silicon sample if the P atoms are 100 % incorporated on lattice sites. Taking into account the high resolution XRD and TEM work performed so far, RBS measurements will very useful to identify point defects (interstitials).