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A review of transmission channeling experiments using focused MeV protons through thin crystals

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This presentation will review work conducted at CIBA, at the National University of Singapore on MeV ion channeling analysis using a focused beam and the Interplay between ion optics and ion channeling to develop new modes of imaging, analysis and beam alignment. MeV ion channeling is well-established in using broad, unfocused beam in conjunction with analytical techniques such RBS to study crystal quality and lattice location. A nuclear microprobe brings additional flexibility to channeling studies in that it uses a system of quadrupole lenses for focus MeV beams to small spots on the wafer surface. Spots as small as 10 to 20 nm can be achieved. The focused beam can be displaced in position or angle using different modes of magnetic or electrostatic deflection. First, the focused beam can be scanned in position over the aligned wafer surface with the beam-crystal alignment preserved, allowing any form of crystal defect, such as dislocations, stacking faults, precipitates to be detected by the resultant localized dechanneling. Use of a transmission channeling through crystals which are thinned to around 20 microns allows one to detect the dechanneled beam fraction by its higher energy loss. Second, the focused beam can be deflected in angle around a fixed position on the wafer surface, allowing the beam-crystal alignment to be altered with high precision and angular images to be collected.

In other work on proton beam deflection in a bent crystal lattice, graded epitaxial silicon-germanium layers wafers were grown on a silicon substrate. The off-normal lattice planes of the epilayer are gradually tilted, allowing beams to be steered. This process is now not limited by the cross-sectional surface area. Use of several such crystals in a volume reflection geometry allows charged particle beams which are distributed over large areas to be deflected using the multiple volume reflection effect.

We have also recently developed a process to fabricate ultra-thin silicon (001) crystal membranes of a thickness of 55 nm with a very low surface roughness. These ultra-thin membranes allow the study of early stages of ion trajectories along axial channels with very high angular resolution owing to very low multiple scattering, so that any fine structure can be revealed. They have formed the basis of our recent high-resolution channeling measurements with MeV protons where an astonishing wealth of fine angular structure is revealed, such as within {111} planes where planar channeling within the narrow planes is resolved from that in the wider planes, channeling images comprising the superposition of difference axial potential wells and a study of the superfocusing effect.

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