A.7: Non-destructive depth profiling of energetic Au ions inside p-type Si<100> substrate

Gold implanted silicon substrates are frequently utilized in the production of microelectronic devices such as detectors for infrared imaging applications, opto-electronic devices, as well as for the synthesis of implanted nano-particles inside a substrate surface. The continuous down scaling of physical size of these devices motivated us to develop methodology that can provide reliable depth profile analyses of various implanted ion species inside a substrate surface in a non-destructive manner.

The grazing incidence X-ray fluorescence (GIXRF) method offers the benefit of providing element-specific information as a function of depth without damaging the sample. The combined X-ray reflectometry (XRR) and GIXRF measurements minimize the individual uncertainties of the two approaches and provide a more precise depth distribution for an element that exists in a buried layer medium inside a substrate. The Rutherford back-scattering spectrometry (RBS) is also frequently employed to obtain qualitative and quantitative information about the implanted species in a non-destructive manner without use of a standard reference sample. However, the synchrotron based XRR-GIXRF technique has recently emerged as a superior competitor to the RBS technique, because it combines all the features of RBS along with enhanced depth resolution capabilities of the order of ~ 2Å, and exceptional sensitivity towards surface roughness effects.

In the present work, the applicability of simultaneous analysis of XRR and GIXRF data to get a reliable depth distribution profile of gold ions implanted into a silicon substrate at 80 keV energy, is reported. The XRR-GIXRF measurements on the implanted samples were carried out at the X-ray reflectometer station of BL-16 beamline of Indus-2 synchrotron facility using 15 keV X-rays. Figure A.7.1 shows a 3D schematic representation of the near surface region, where gold ions displace some of the silicon atoms, causing lattice damage. This lattice damage caused by gold ions strongly depends on the implantation energy and ion dosage values. Figures A.7.2(a) and A.7.2(b), respectively show the measured and fitted GIXRF and XRR profiles of a silicon substrate, implanted with Au ion dose values of 1×10^{16} ions/cm^2. It can be observed from Figure A.7.2(a) that the measured Au-Lα GIXRF intensity increases very slowly below the critical angle but rapidly increases as one moves beyond the critical angle boundary. This dramatic change in the Au-Lα fluorescence intensity primarily arises due to the movement of near surface X-ray standing wave (XSW) field inside the silicon substrate and its overlap with implanted region of Au atoms. The best fit XRR-GIXRF results (in case of Au ion fluence value of 1×10^{16} ions/cm^2) provided the Gaussian like distribution profile of the Au ions with a peak concentration value at the depth of ~ 54 nm. These results were found to be in close agreement with those obtained from other complementary investigations.

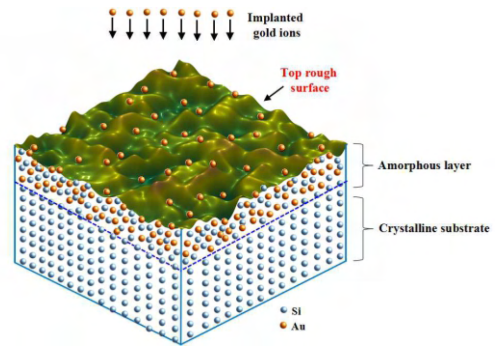

Fig. A.7.1: A 3D schematic showing the changes that occur inside the crystalline Si<100> substrate due to gold ion implantation process.

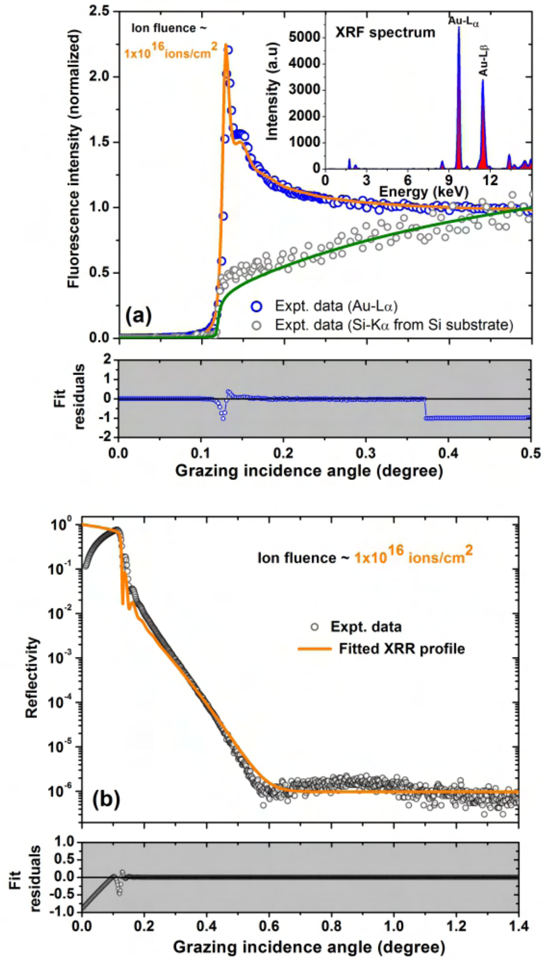

Fig. A.7.2: Measured (circles) and fitted (solid lines) profiles for simultaneous (a) GIXRF, and (b) XRR investigations along with their fit residuals.

For more details please refer to *Md. Akhlak Alam et al., Applied Surface Science, Vol. 579, p 152173 (2022).*

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