On the use of MEIS cartography for the determination of $Si_{1-x}Ge_x$ thin-film strain

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The characterization of the nanoscopic state of strain in crystalline semiconductors is important for distinct applications including, for example, the formation of extended defects, the orientation of second phase nano objects or the modification of the valence and conduction band structures and consequently the carrier mobility in semiconducting devices. In particular, strained $Si_{1-x}Ge_x$ alloys have been actively investigated during the last years because of their application in high-mobility metal-oxide-semiconductor field-effect transistors. The strain appears as a modification in atomic positions. X-ray or electron diffraction have been used to determine changes of the lattice parameter with great.

As distinct from diffraction and phase contrast techniques, H and He ion scattering techniques have been extensively employed to determine strain because changes in the channeling or blocking directions can be easily related to lattice deformations. Recently medium-energy ion scattering (MEIS) has been successfully used to determine the depth strain profile in thin Si overlayers on SiGe heterostructures [1], quantum dots [2], and nanowires [3] among other applications. Another powerful ion-beam technique namely High Resolution Rutherford Backscattering Spectrometry (HRRBS), which is comparable to MEIS, has been applied recently to get the strain profile across the HfO_2 /Si(001) [4]. Most of these methods are based on the determination of the shift in the backscattering yield minima around a given main crystallographic direction using a one-dimensional angular scan. The use of a two-dimensional yield mapping is less frequent but improves the strain measurement.

Recently, Jalabert [5] has proposed a new method to evaluate the strain state of a target material called MEIS cartography. In this method the stereographic projection of a single crystal can be measured with a standard MEIS technique for a selected atomic element and depth. Here we demonstrate that this technique can be expanded to characterize strained SiGe heterostructures with high accuracy. In this method, not only the main crystalline directions are analyzed but also the higher index ones. The advantage of this method is its elemental sensitivity with depth resolution and its capability to be used in nano-structured materials. The determination of the strain is based on the position of the many blocking lines contrary to the traditional methods where two directions are used. We also provide a method to determine the lattice deformation fitting the data best and checked it against full Monte-Carlo simulations [6].

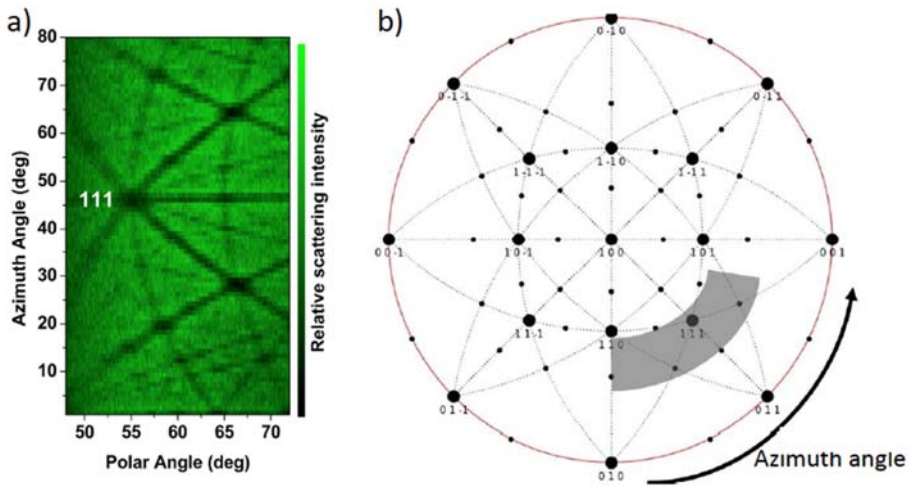

Figure 1 : (a) 2D map of ion scattering intensities as function of the polar and azimuth angle for a Si single-crystal. b) Stereographic projection of a FCC crystal (which encompass the Si crystal) on the [100] direction. The map on the left corresponds to the hachured area on the stereographic plot.

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