ESRF	**Experiment title:** Calibration of Raman coefficients for tensile strained Ge	**Experiment number**: **HC- 1129**
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Report:

The aim of this experiment is the calibration of Raman strain shift coefficients for highly tensile strained Ge. Therefore, Ge micro-structures were studied by nanofocus X-ray diffraction (XRD) and Raman spectroscopy (RS). Since quantitative data evaluation in RS relies heavily on phenomenological constants, which are so far not experimentally confirmed for large tensile strains, the gap should be closed with this experiment.

To access a large range of tensile strain values, Ge micro-bridges were used, where the strain enhancement has been achieved by force field concentration. The bridges were fabricated from Ge layers grown by plasma enhanced chemical vapour deposition directly on Si, which results in a tensile pre-strain of about 0.2 % (thermally induced). Strain enhancement by a factor of more than 20 of that value is achieved by the transfer of a dumbbell shape e-beam written pattern. Across the dumbbell shape, the tensile strain varies, so that from position dependent measurements a series of strain states can be accessed. Additionally, structures with the main strain directions in two or more crystallographic orientations will give certainty about the direction dependence of the phonon deformation potentials.

In order to map the strain state of different bridges X-ray diffraction measurements were conducted at beamline ID13 where a monochromatic beam of 15.2 keV energy was focused to a beamsize of 600 x 200 nm². The sample was placed on a scanning piezoelectric stage, which allowed its positioning with nanometer precision along its surface plane. A rotation below the sample stage around the horizontal direction was used for alignment of the Bragg reflections and for rocking scans. A Maxipix detector with 516 x 516 pixels and 55 μm pixel size was used for data collection.

For each studied bridge at least two different Bragg reflections were probed. Therefore, in a certain range around the nominal Bragg peak line scans along the bridge and mesh scans of a larger area including the bridgeheads were performed with the piezzo stage at fixed detector position. The obtained detector frames around the Bragg peaks at each spatial position were then reconstructed into 3D reciprocal space maps. The average Bragg position was obtained by computing the centre of mass (COM). After tilt correction the COM positions were then used to calculate the in-plane and out-of-plane lattice constants, and thereof to directly

determine the strain components ε_{zz} and ε_{yy}, respectively, averaged over the illuminated area. This analysis was performed at each real-space scanning point, effectively obtaining strain scans along the bridges and 2D strain maps of the different bridges.

Figure 1 shows preliminary strain scans along a bridge oriented along the [110] crystallographic direction. Figure 2 shows out-of-plane and in-plane strain maps of the [110] oriented bridge and the ones of a bridge oriented 27° with respect to the the [110] direction.

The determined strains from XRD will be used to fit the strain shift coefficients of the Raman peak shift in the tensile strain region as well as to fit the phonon deformation potentials of tensile strained Ge. While not very big deviations are expected from the extrapolations of compressive and low tensile strains used so far, the result will provide a reliable reference for future Raman experiments, thus increasing the accuracy of Raman investigations.

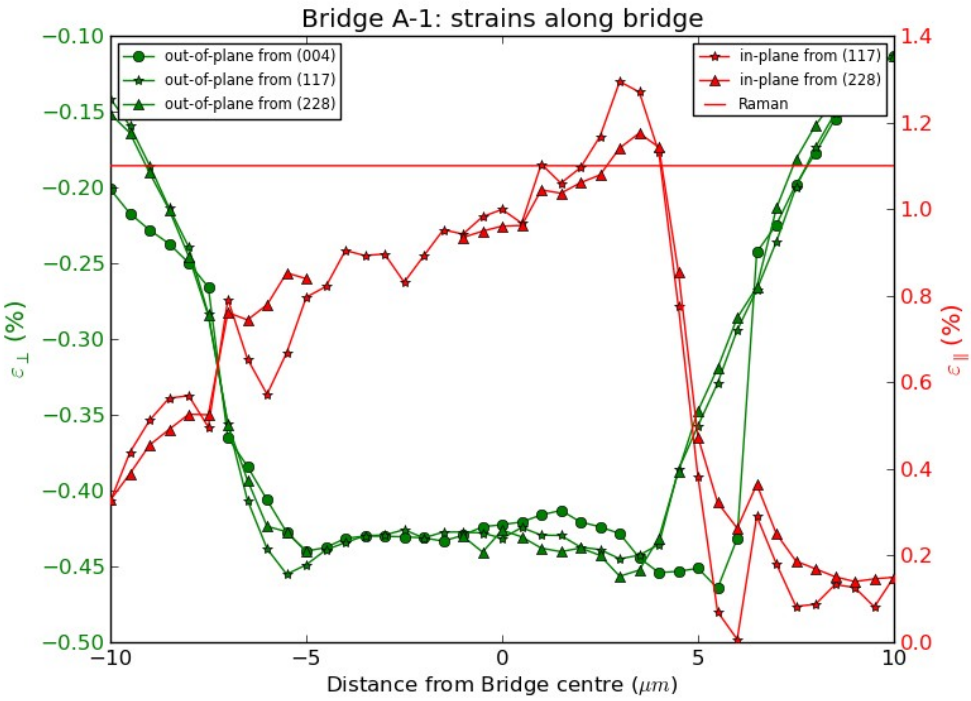

Figure 1: Determined in-plane and out-of-plane strain components along a bridge oriented along the [110] crystallographic direction. The red horizontal line denotes the strain determined with Raman spectroscopy at the centre of the bridge with the used strain shift coefficients extrapolated from compressively strained Ge.

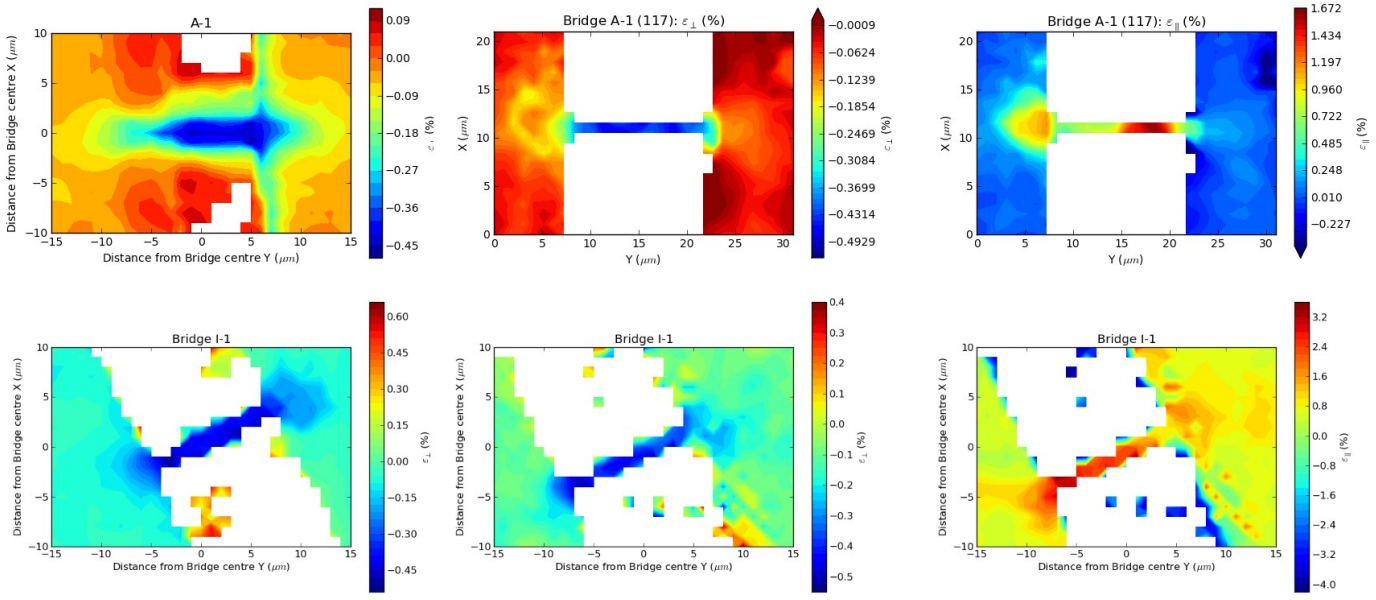

Figure 2: Inplane and out-of-plane strain determined from a smmetric and an asymmetric Bragg reflection for two differently oriented bridges with different strain values.