Abstract

During the last two decades, tremendous advances have been made in the miniaturization of opto-electronic devices and sensor-based nano-electromechanical systems by the integration of quasi one-dimensional nanowires. For the development of future generation nanowire-based devices, it is essential to investigate the underlying deformation mechanisms and their mechanics

The present work focuses on the mechanical response analysis of semiconductor gallium arsenide (GaAs) nanowires grown on silicon substrate via molecular beam epitaxy. The mechanical behavior of the nanowires is characterized via in-situ bending tests in a scanning electron microscope and in combination with x-ray diffraction. With the major development of x-ray focusing optics, sub-100 nm sized beams are readily available at synchrotron facilities enabling the study of single nanowires.

The first aim of this work is to investigate the impact of systematic dynamic loading, i.e., electromechanically induced vibrations on single nanowires by using Bragg diffraction imaging. A parametric study is carried out either by varying the amplitude of the vibration or the dwell time. The ex-situ experiment, planned to examine the crystalline structure of these vibrated NWs, was planned for March 2020, but due to the COVID-19 pandemic spread, the experiment has been shifted to a later time by the synchrotron facility.

The second aim of this work is to identify the anelastic strain relaxation of the nanowires which was observed as a direct consequence of cantilever bending tests and buckling tests on free standing Be-doped GaAs nanowires. The anelastic strain is derived by using a digital image correlation algorithm. The results are compared with FEM simulations used to solve a system of highly coupled nonlinear partial differential equations (elasticity and diffusion). The agreement between FEM simulations and measured data conclusively relates the anelastic relaxation in the investigated nanowires to the Gorsky effect, i.e. the coupling between point defects diffusion and stress gradient.

Be doped GaAs nanowires are further examined in the lateral three-point bending configuration by employing the Scanning Force Microscope for in situ Nanofocused X-ray diffraction (SFINX) and x-ray diffraction at beamline P23 at PETRA III. The bending of the nanowires was induced by the lateral movement of the tip of SFINX. The nanowires demonstrate elastic deformation, plastic deformation, and time-dependent anelastic relaxation. The anelastic relaxation yields a diffusion coefficient of 2.71 x 10^{-13} cm^2/s and is consistent with a Gorsky effect.