Strain mapping by scanning electron diffraction in hetero-nanowires based on tellurium and selenium compounds

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Bandgap and strain engineering are the promising way to improve the performance of emitters, sensors and solar cells. In the case of 2D epilayers such approach are limited by critical thickness and plastic relaxation. In the case of nanowires with big ratio of the surface to volume infinitive critical thickness is possible for small diameter of NWs what extend possibility of coherent bonding materials with different properties and allow producing devices impossible to obtain in 2D epitaxial layers.

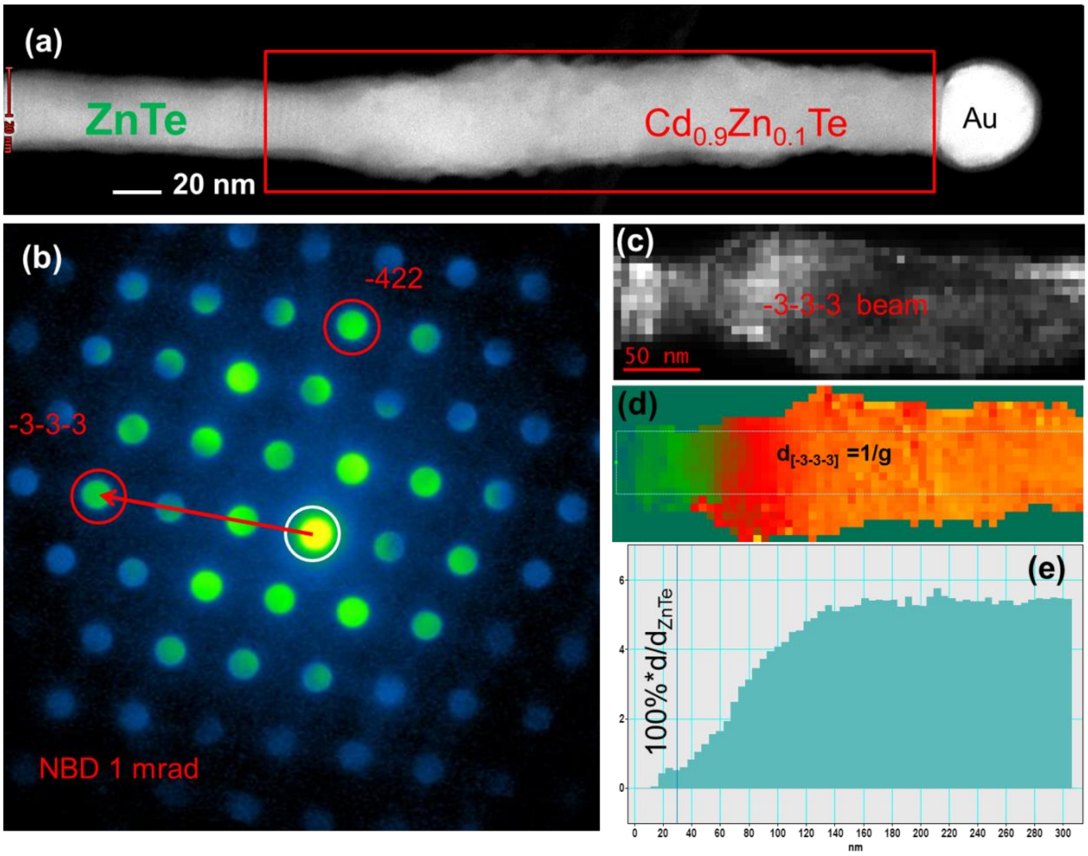

Figure 1. (a) STEM-HAADF overview of ZnTe/CdZnTe NW (b) NBD experimental patter , (c) 20x60 pixel map of amplitude of -3-3-3 beam, (d) 20x60 pixel map of local interplanar distance for [-3-3-3] plane, (e) averaging profile of % of relative interplanar change between ZnTe and CdZnTe part

(Zn,Cd,Mg,Mn)(Se,Te) semiconductor hetero nanowires (HNWs) were grown by molecular beam epitaxy (MBE) on (111) Si or GaAs substrate using Vapor-Liquid-Solid (VLS) mechanism. Due to high mismatch of the lattice constant of basic compounds which can reach more than 7%, the growth of NWs is challenging and their final shape and morphology is complex. The HNWs, observed by TEM are coherently strained but the **elastic relaxation** (by bending, twisting or morphological transformations) is clearly visible. In some cases the **plastic relaxation** occur with creation of the structural defect like stacking faults, misfit dislocations or partial dislocations appearing at the core/shell interfaces.

The Geometric Phase Analysis (GPA) is performed with the use of HR-TEM and HR-STEM images obtained from different zone axes in planar view or/and using perpendicular FIB cross-section of the HNWs. Due to the significant deformations of the HNWs we use also Scanning Electron Diffraction (SED) to map bending and twisting as well as elastic and chemical lattice distortions related to the changes in elemental composition. The series of nanobeam electron diffraction (NBD) patterns, obtained in STEM mode, were analyzed to map of components of lattice distortions. The local cross-correlation of the multislice CBED simulated and experimental patterns were used.

Figure 1a shows STEM-HAADF image overview of axial ZnTe/CdZnTe HNW - no defects are detected at transition zone despite of> 5% lattice mismatch between two parts of HNW. However SF perpendicular to NW axis is present in ZnTe part which was grow first. Figure 1b shows the one of 1200 NBD diffraction patterns used in this investigation. The virtual image of amplitude of $g_{[-3-3-3]}$ beam is shown in Figure 1c. The intensity variations are related to local lattice tilt. Color coded map of the 1/g is shown in Figure 1d showing the relatively smoot, 60 nm long transition zone what is related with the increasing Cd concentration as confirmed by EDS. The average distortion profiles in axial direction of HNW shown in Figure 1e prove the high degree of relaxation of CdZnTe segment achieved by morphological and elastic relaxation mechanism without defects creation. Our results are in agreement with theoretical models of plastic/elastic relaxation of axial and radial strained NWs.

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