Electronic-magnetic Properties and Electron-phonon Coupling in Co-doped N-GaN Nanowires

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The electronic properties of Co-doped GaN nanowires (NWs) were studied using x-ray absorption spectroscopy. Ga L_3-/K-, Co L_3-/K-, and N *K*-edge XANES were obtained at the National Synchrotron Radiation Research Center. The samples that were used are grown by vapor-liquid-solid (VLS) technique and have (001) oriented *n*-GaN NWs with 3-5 μm length and an average diameter of 80 nm and hence low energy implantation were performed with 0 – 3.85 at% cobalt in the *n*-GaN NWs.

Typical structural and morphological studies of the pristine GaN NWs and Co-doped GaN NWs are shown in Fig.1. The x-ray diffraction pattern of the pristine GaN NWs and Co-doped GaN NWs are similar features having similar diffraction peaks (inset in Fig. 1) indicating the structural behavior remains unchanged. Figure 1 also displays the Fourier transform (FT) of Ga and Co *K*-edge EXAFS k^3 data of GaN NWs, Co-doped GaN NWs along with references CoO and Co-foil. It reveals that the general line-shape and the radial distribution of the FT spectra of Co-doped GaN NWs are not identical and even not coincide to their peak positions with those of the pure GaN NWs, Co-foil and CoO that demonstrates the local atomic structures of Ga atoms in GaN NWs are dissimilar to GaN NWs. Notably, the intensities of the first two main peaks at ~1.60 Å and ~2.85 Å in the FT spectra, corresponding to the nearest-neighbor (NN) Ga-Co bond lengths, increases with Co-doping and are larger than the GaN NWs.

Figure 2 (a) and 2 (b) show Ga L_3- and Co $L_{3,2}$-edge XANES spectra of GaN and Co-doped GaN NWs. Features A_1 (1114 eV), B_1 (1116 eV) and C1 (1118 eV) in Fig. 2 (a) are associated with the transition of Ga 4*s*- and a mixture of Ga 4*s* and 4*d* states. The inset at the bottom of Fig. 2(a) is a magnified view of the near-edge features after the background has been subtracted using a best-fitted Gaussian curve indicated by the dotted line. The overall intensities of features A_1–C_1 decrease as the concentration of Co increases, indicating that the number of unoccupied GaN 4*sd* states near the conduction-band minimum is reduced. In contrast, the intensity of Co $L_{3,2}$-edges are increase with increase of Co-doping indicating the number of Co 3*d* unoccupied states increases as shown in the Fig. 2(b) after the background has been subtracted using a best-fitted arc-tan curve indicated by the dotted line. The absorption edge is also observed to be shifted slightly towards lower energy side in both Ga as well as Co L_3-edge XANES spectra as the Co-concentrations are increases in the GaN NWs. It is noted to be that there is an anomalous edge-shift is observed at higher energy side in Ga L_3-edge and overall intensity decrease in Co L_3-edge XANES spectra respectively for the 3.85 at% Co-doped GaN NWs. This may be due to formation of Co-cluster in the GaN NWs structure matrix rather than proper doping and hence anomalous changes occurs.

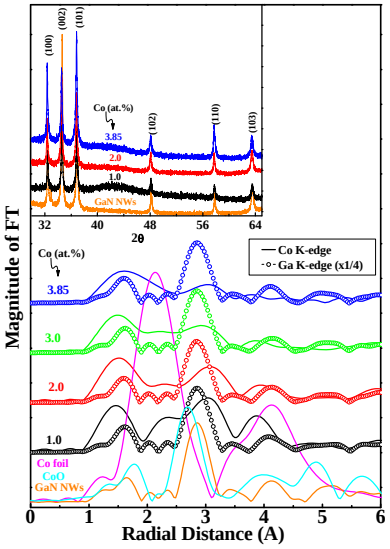

Fig. 1: XRD and EXAFS spectra

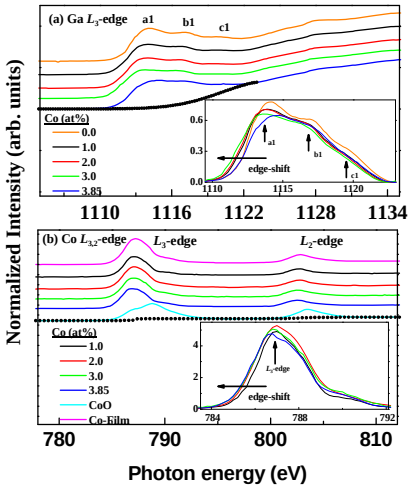

Fig. 2: Normalized (a) Ga L_3-edge and (b) Co $L_{3,2}$-edge XANES spectra