Extended Abstracts of the 1995 International Conference on Solid State Devices and Materials, Osaka, 1995, pp. 1055-1056

Reconstruction Dependent Electron-Hole Recombination on GaAs(001) Surfaces

Hiroshi Yamaguchi, Kiyoshi Kanisawa, and Yoshiji Horikoshi
NTT Basic Research Laboratories, Atsugi-shi, Kanagawa, 243-01, Japan
tel: +81-462-40-3475, fax: +81-462-40-4727

Electron-hole recombination on semiconductor surfaces influences the performance of semiconductor devices and also plays an important role in semiconductor physics, but the origins of the recombination have not yet been well clarified. Photoluminescence (PL) measurements of near-surface quantum wells (NSQW) are useful in characterizing surface recombination.[1)] Using this technique, we have studied the recombination on clean reconstructed (001) GaAs surfaces, and observed clear reconstruction dependence for the first time. Based on the obtained results and recent structural studies by scanning tunneling microscopy (STM), the origin of the surface recombination is discussed in detail.

We used an ultra-high-vacuum (UHV) low-temperature PL system, which is directly connected through the UHV to the molecular-beam epitaxy (MBE) chamber. With this system, we can cool the sample with liquid Nitrogen without breaking the surface structure established after the MBE growth, and the influence of the surface reconstruction on the surface recombination can be investigated. Figure 1 shows the quantum well (QW) structure used in our investigations. The PL intensity of the NSQW is influenced by the surface recombination because the $Al_{0.3}Ga_{0.7}As$ barrier thickness of 10nm is sufficiently small. The Ref-QW, which is far enough from the surface to avoid any influence from it, can be used as the PL intensity reference. The PL spectra of As-rich (2x4) and Ga-rich (4x6) surfaces are compared, the latter of which was prepared by depositing one atomic layer of Ga atoms on the (2x4) surface in the MBE chamber at 500°C.

Figure 2 shows the reflection high energy electron diffraction (RHEED) patterns obtained at 140K before the PL measurements for these two surfaces. Both (2x4) and (4x6) patterns were clearly confirmed even after the samples were cooled, showing no significant surface contamination by the sample transfer and the cooling procedures. Figure 3 shows the PL spectra obtained at 140K for these two surfaces. The sample with the (2x4) surface shows more intense luminescence from the NSQW than that with the (4x6). Additional As was deposited on the (4x6) surface at 500°C to recover the (2x4) surface again. The spectrum of the surface is almost same with that prior to the Ga and As deposition, indicating that this difference did not come from the increase in the top GaAs layer thickness by Ga deposition, but came from the faster surface recombination on the (4x6) surface than that on (2x4). A recent study of the atomic structure of the (4x6) surface with an STM revealed that the 6-fold periodicity came from the Ga cluster in the Ga-dimer vacancy rows.[2)] The faster surface recombination for the (4x6) surface can be due to the surface defects originated from the Ga clusters.

1) J.M. Moison et al., Phys. Rev. B**41**, 12945 (1990).
2) Q. Xue et al., Phys. Rev. Lett. **74**, 3177 (1995).

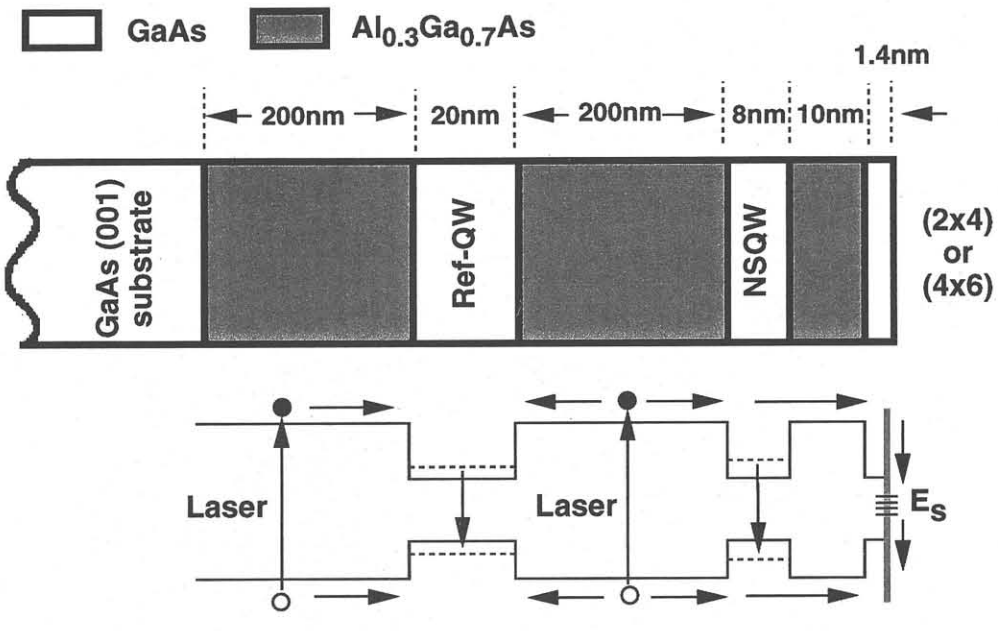

Fig.1: A schematic illustration of quantum well structure used in this study and its band structure.

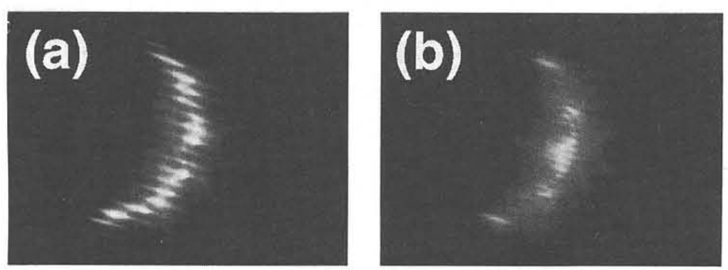

Fig.2: RHEED patterns obtained at 140K for (a) (2x4) and (b) (4x6) surfaces with the incident azimuth of [110].

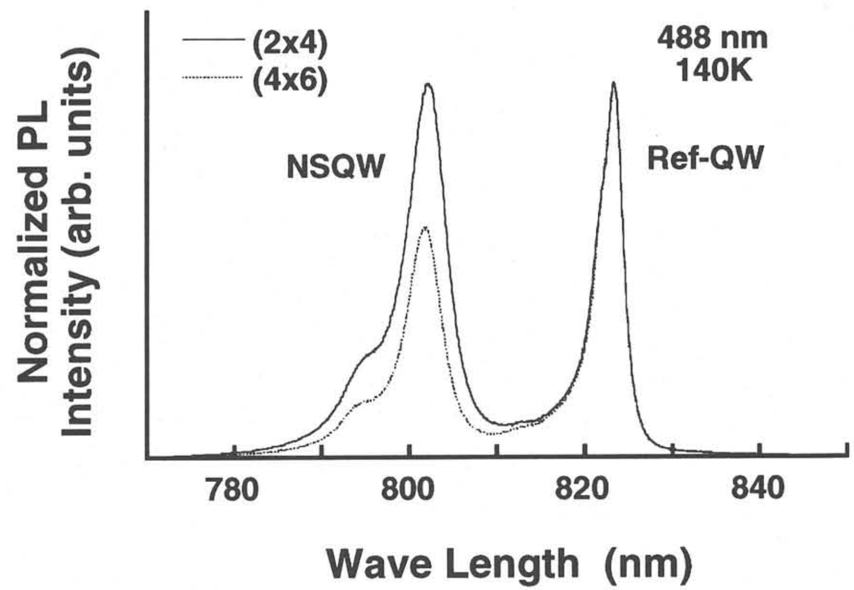

Fig.3: Photoluminescence spectra obtained at 140K for (2x4) and (4x6) surfaces. The PL intensity was normalized by that for Ref-QW.