Observation of GaAs p-n junction using electron holography, electron diffraction microscopy, differential phase contrast STEM, and shadow image distortion method.

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In order to develop and manufacture semiconductor devices, which are key components of the optical telecommunication products such as the semiconductor laser diodes, it is essential to confirm whether they were manufactured as designed. The electric potential distributions of the semiconductor devices are designed in nanoscale, so two dimensional methods to evaluate the electrical potential in semiconductors with a high spatial resolution are necessary for product verification. In this experiment, the observation of a p-n junction in the gallium arsenide specimen was carried out by using electron holography, differential phase contrast (DPC) scanning transmission electron microscopy (STEM), electron diffraction microscopy, and a shadow image distortion method.

The electron holographic reconstructed phase images and phase profiles of the p-n junctions are shown in Figs.1 (a) and (b). These observations were made with transmission electron microscopy (TEM) using a holographic electron microscope 300 kV HF-3300EH equipped with a cold field-emission electron gun and an electron biprism. We used a phase-shifting method to reconstruct a phase image from 25 holograms. The p- and n-type regions are clearly seen as the areas of dark and bright contrast. Figure 1(b) shows the averaged phase profile of the p-n junction and the potential profile, where the experimental phase profile is in agreement with the calculated potential profile. The DPC STEM images were taken with a 200 kV JEM-2100 STEM electron microscope equipped with an aberration corrector. Figure 2 shows the DPC STEM image of the GaAs p-n junction and intensity profile, where the p-n junction is clearly visualized.

Other evaluation methods for the semiconductor p-n junctions include electron diffraction microscopy, which is one of the phase reconstruction methods, and shadow image distortion, which is one of the TEM methods. They are effective as complementarily methods along with the electron holography and the DPC STEM. We will discuss in this presentation the application of these methods in semiconductors.

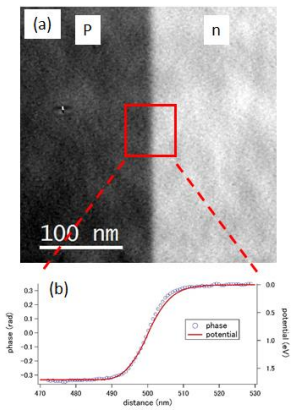

Fig. 1. Phase image and phase profile of p-n junction

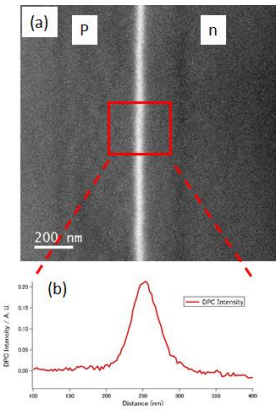

Fig. 2. DPC STEM image of GaAs p-n junction and intensity profile