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Observation of Compound Semiconductor P-N Junction by Electron Holography

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Electron holography has become an important technique for analyzing dopant distributions in semiconductor devices [1-3], because it allows us to measure the inner electrostatic potential on the scale of nanometers. However, there are significant problems leading to damaged layers induced on the specimen surfaces when a TEM specimen is prepared using the Focused Ion Beam (FIB) method. The damaged layers of compound semiconductors such as GaAs, InP, and GaN consist of amorphous and nano-crystal regions [4]. It is difficult to observe the dopant distribution in a compound semiconductor because a diffraction effect in the damaged layers causes a complicated phase image. Therefore, we prepared a wedge-shaped specimen by cleavage, and also developed a method that combines FIB and Ar ion milling (the FIB-Ar ion milling method) [5].

The procedure for preparing the cleavage specimen is shown in Fig.1. The n-p-n InP sample was cleaved twice, which revealed the cleavage surfaces. The cleavage specimen was attached to a TEM holder and tilted at 45 degrees. The FIB-Ar ion milling method is shown in Fig. 2. First, a thin aluminum foil was attached to a half copper plate with a single hole using epoxy resin. Then, a GaAs specimen picked up by micro-sampling was fixed to the cross section of the aluminum foil by tungsten deposition. After the specimen was thinned by FIB milling, the damaged layers on the both surfaces were removed by Ar ion milling. Finally, this specimen was analyzed by phase shift electron holography, which provides highly sensitive phase measurement.

The reconstructed phase image of the InP p-n junction prepared by cleavage is shown in Fig. 3, where the thickness of the specimen increases from bottom to top. The position of the p-n junction is indicated by the arrow. The p-n junction becomes clearly visible in the phase image as the thickness increases. Figure 4 shows a phase map across a p-n junction in a GaAs specimen prepared by the FIB-Ar ion milling method. The p- and n-type regions are clearly distinguished as areas of dark and bright contrast.

In conclusion, we succeeded in observing the p-n junction of a compound semiconductor by cleavage and FIB-Ar ion milling. These results indicate that these methods will be useful to the compound semiconductor industry.

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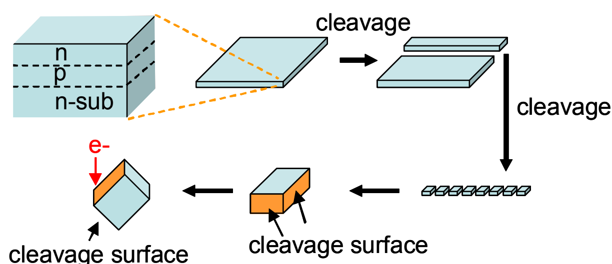

FIG. 1. Procedure for preparing cleavage specimen for electron holography.

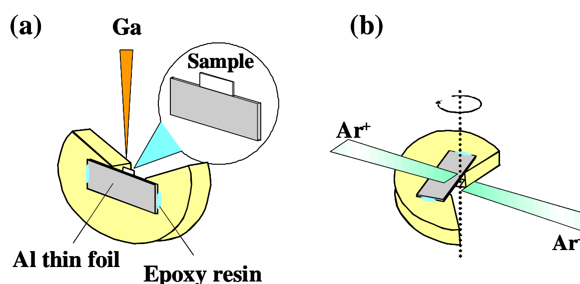

FIG. 2. FIB-Ar ion milling method. (a) Fixing GaAs specimen to the cross section of an Al thin foil and FIB thinning. (b) Ar ion milling.

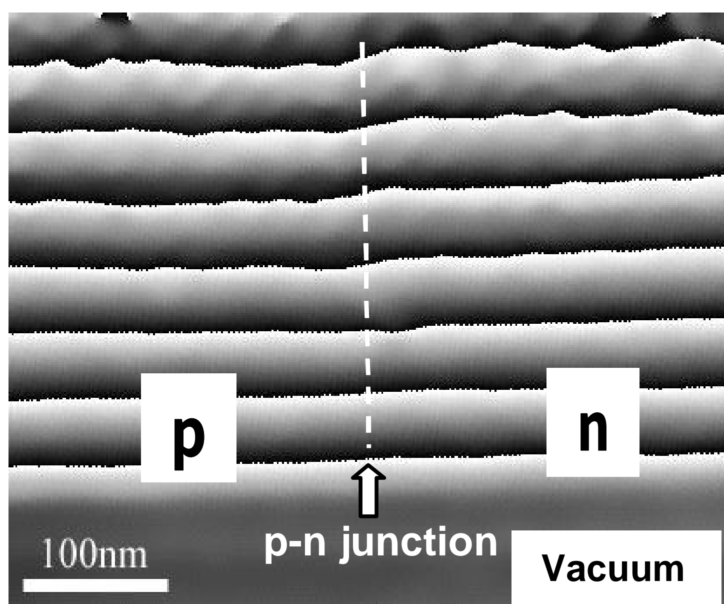

FIG. 3. Phase image of a p-n junction in InP cleavage specimen.

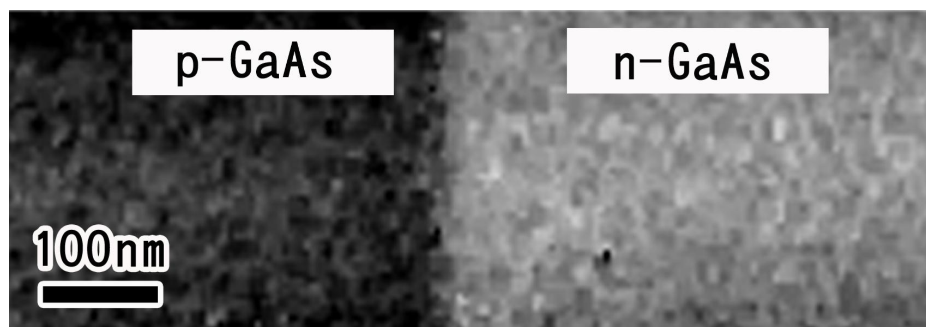

FIG. 4. Phase image of a p-n junction in GaAs specimen prepared by the FIB-Ar ion milling method.

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