Metalorganic CVD Growth Of Cubic P-Type Boron Phosphide (BP) For Formation Of Pn-Junction With Hexagonal N-Type Gan

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Boron phosphide (BP) has been utilized as one of Ⅲ-Ⅴ compound semiconductors to form hetero-junction with group IV semiconductors, such as Si [1,2] and SiC [3]. In this report, p-type BP was utilized to form hetero-junction with n-type hexagonal GaN, and electric and crystallographic features of the hetero-junction thus formed were investigated in detail.

Unintentionally doped BP layer was stacked at 1025℃ on (0001)-surface of the n-GaN which constituted an uppermost barrier layer in 5-periods GaInN/GaN MQW formed on an n- GaN/sapphire-substrate structure. The BP layer with 300 nm in thickness was grown by means of metalorganic (MO) CVD procedure using triethylboran $(C_2H_5)_3B$ (Rohm and Haas Electronic Materials, L.L.C.) and phosphine (PH_3) as source gases under atmospheric pressure. In the MOCVD growth of the BP, concentration ratio of the source gases fed into growth region, $PH_3/(C_2H_5)_3B$, was kept at 16. Crystalline feature at interface region between the BP and the GaN was investigated by means of transmission electron diffraction (TED) and transmission electron microscopy (TEM). Electrical property of the junction was also evaluated by use of scanning capacitance microscope (SCM).

The BP layer grown on the (0001)-surface of the n-GaN was transparent and was continuous with free from cracks. A TED pattern indicated that the BP layer grow epitaxially on the hexagonal (0001)-GaN with relation as follows:(0001),<a-axis>-GaN//(111),[110]-BP. Presence of extra diffraction spots in the TED pattern also indicated that the (111)-BP layer involved microtwins bounded on the (111)-BP planes. By high-resolution TEM observation, dislocations in the MQW structure were found to annihilate at the interface to penetrate into the (111)-BP layer. Electrical evaluation of the (111)-BP layer by means of conventional electrolyte C-V measurement clarified that the unintentionally doped BP layer exhibited p-type conductivity. Acceptor concentration measured with the C-V technique was approximately 2×10^{19} cm^{-3} at the surface of the p-type (111)-BP. The p-type (111)-BP layer was found through the SCM measurement to have sufficient p-type conductivity to form pn-junction with the n-type GaN. Figure 1 shows a SCM image at the junction of the (111)-BP and the (0001)-GaN with carrier concentration of 2×10^{18} cm^{-3}. Contrast of brightness in the SCM image indicated that pn-junction was actually formed between the p-type cubic (111)-BP and the n-type hexagonal (0001)-GaN. By utilizing the pn-junction which involved the p-type (111)-BP layer formed on the GaInN/GaN MQW, a double hetero (DH) structure blue light-emitting-diode (LED) was fabricated. The DH structure LED equipped with the p-type BP layer on the light emitting layer comprising from the MQW gave rectification property with forward voltage of about 3.5V at forward current of 20 mA.

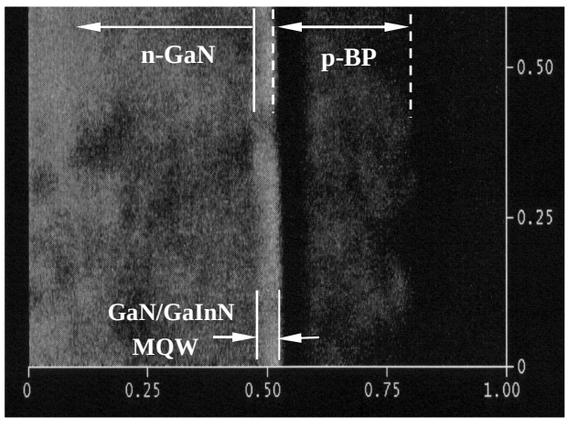

Fig.1. *Cross-sectional SCM image near interface of (111)-BP and (0001)-GaN. Region exhibiting n-type conductivity is shown with brighter contrast than that of p-type region. Horizontal and vertical axes indicate distances (unit:μm) scanned in horizontal and vertical directions at the interface region , respectively.*

References: [1] T. Takenaka, M. Takigawa, and K. Shohno, J. Electrochem. Soc.,125(1978),633. [2] T. Nishinaga et al., J. Crystal Growth, 13/14 (1972),346.

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