Optical Property of an AlGaN/GaN Hetero-Bipolar-Phototransistor

Robert Mouillet [1], Cyril Pernot [2], Akira Hirano [3],
Motoaki Iwaya [4], Theeradetch Detchprom [4], Hiroshi Amano [4] and Isamu Akasaki [4]
[1] Kansai Research Institute 17 Chudoji-Minami-machi, Shimogyo-ku, Kyoto 600-8813, Japan
[2] Groupe d'Etude des semiconducteurs, Universite Montpellier II, Place Eugene Bataillon, 34095 Montpellier cedex 05, France
[3] Research and Development Department, Osaka Gas Co. Ltd., 17 Chudoji-Minami-machi, Shimogyo-ku, Kyoto 600-8813, Japan
[4] Department of Electrical and Electronic Engineering Meijo University, 1-501 Shiogamaguchi, Tempaku-ku, Nagoya 468-8502, Japan

The cut-off wavelength of GaN-AlGaN-based ultraviolet (UV) photodetector is expected to be tuneable from 365nm to 200mn by changing AlN mole fraction. The main application of nitride detector is thought to be solar-blind flame detector by setting the cut-off wavelength at 280nm (1). However, the flame luminescence below 280nm(4.4eV) is as weak as 1nW/cm2 or less at the sensor setting position. This means flame signal is expected to be around 1pA, assuming a photodetector of $1mm^2$ active surface without gain. Therefore internal gain is strongly desired to realize flame detector. Phototransistor is thought to be one of the promising solutions (2), and keeping this in mind, we fabricated GaN/AlGaN hetero-bipolar-transistor using the low temperature interlayer technique (3) that drastically contributes to reduce the dislocation density in nitride, including AlGaN.

The growth sequence consists of the deposition, on sapphire substrate, of a low temperature (LT) AlN buffer layer, followed by a 1 μm-thick layer of undoped GaN and then by a LT AlN interlayer of 20nm. The HBT structure consists of 2 μm-thick Si-doped n-$Al_{0.2}Ga_{0.8}N$ emitter followed by 100nm-thick Mg-doped p-GaN floating base, and terminated by 0.6 μm-thick n-GaN:Si collector. The schematic design of this sample is illustrated in Fig.1.

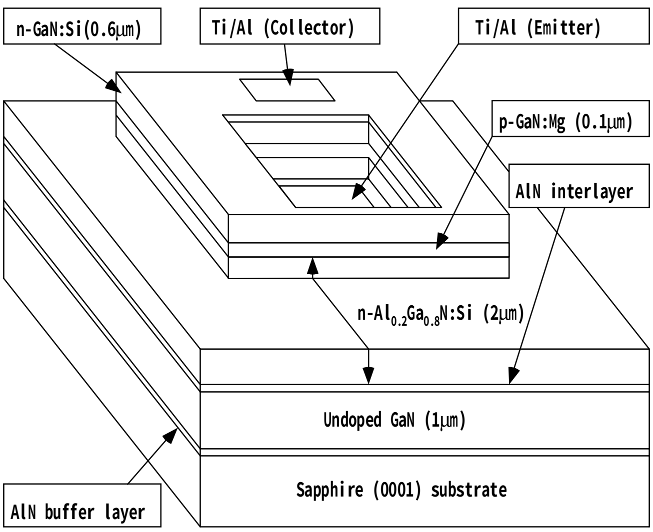

Fig.1: Device structure

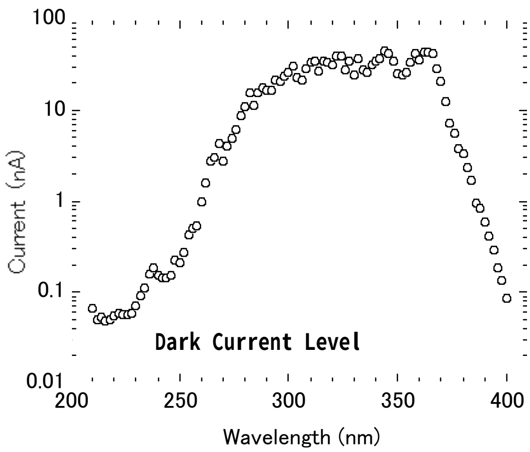

Fig.2: Photoresponse in function of wavelength

This device structure was not optimised as light detector. Outer and internal mesa sidewall are mainly thought to contribute to light detection. In fact, temperature and humidity have been noticed to have a huge influence, at room conditions, on the transistor when illuminated. This is probably due to the surface adsorption on mesa sidewalls of H_2O molecules those act as surface quenching. Therefore, experiments were carefully conducted at constant temperature and humidity.

Applying high collector bias before getting the photo current at low bias, the photocurrent was observed to stabilize faster, especially for the weak intensity illumination. Therefore, we set the standard measurement condition as follow: 150sec. at V_{CE} ($V_{COLLECTOR}$-$V_{EMITTER}$)$_{(1)}$ = 15V, then 200sec. at the measurement bias $V_{CE(2)}$.

Wavelength response of the transistor was scanned between 210nm and 400nm, under $V_{CE(2)}$ = 5V. The light source used for this scanning was a deuterium lamp followed by a double spectrometer having a resolution of 6nm at HWHM. The measures were conducted at a constant power of 2.2 µW/cm^2. The spectral response obtained is shown on figure 2. The dark current was as low as 30pA. The spectrum responsivity decreases for wavelengths below the band-gap of $Al_{0.2}Ga_{0.8}N$ (303nm); we may attribute this to the absorption of light and consecutive increase of holes concentration in the n type $Al_{0.2}Ga_{0.8}N$ emitter layer. There is a long-wavelength cut-off of about three orders of magnitude from 365nm to 400nm, which shows good rejection to the visible light.

To determine the photoresponse (fig.3) as a function of light intensity, illumination of the sample was performed with a low-pressure mercury lamp. Refering the spectral photoresponse of the sample and the intensity distribution of the lamp, only 7% of the total light intensity effectively contributes to the current. According to that, our transistor detects a light intensity as low as 0.78nW/cm^2, which is the criterion required for a flame detector. Also, the gain was found to be 0.2A/W at 4V when the whole surface of the detector is considered. We believe this responsivity is a very promising value, taken the device structure into account.

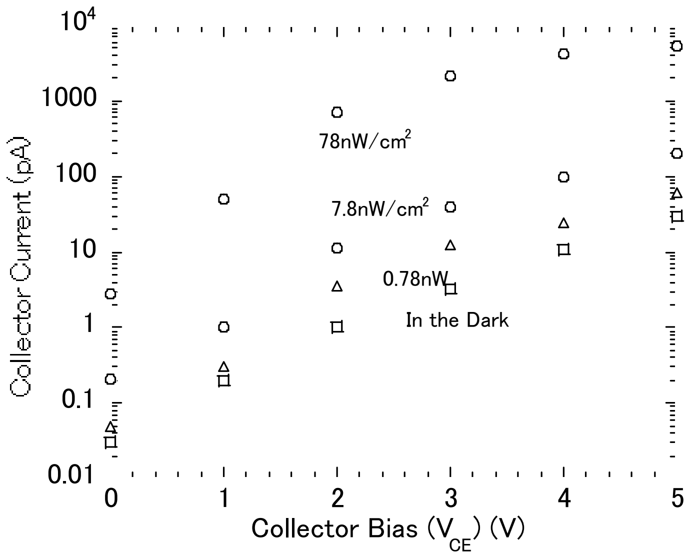

Fig.3 Current in function of calculated effective light intensity between 300 and 370nm

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