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Optical Absorption Properties of InP Porous Structures Formed by Electrochemical Process

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1. Introduction

High-density formation of semiconductor nanostructures — targeting applications such as quantum and optoelectronic devices — has been intensely researched. Among the various approaches, the electrochemical process that can form various semiconductor nanostructures in a self-assembled fashion [1-4] is one of the most promising processes due to its unique features such as being a low temperature process and a low cost. We have recently reported that extremely low reflectance below 0.4% was observed from the electrochemically-formed InP porous nanostructures in UV, visible, and near-infrared ranges [5]. In this paper, we investigated the optical absorption properties of InP porous structures formed on the p-n junction substrates.

2. Experimental

The device structure and experimental setup are schematically shown in **Fig.1**. This device has the porous structure formed in the n-type InP layer ($n=8\times10^{17}cm^{-3}$) grown on the highly-doped p-type substrate. The porous structure was electrochemically formed using a standard cell using the electrolyte consists of 1M HCl (200ml) with HNO_3 (3ml). To supply current, the AuZn/Ni-ohmic contact was first made on the backside of the p-type InP substrate. The anodic bias, V_a, and anodization time, t_a, were set at 7 V and 4 s, respectively, to form the porous structures only in the n-type layer. After the formation of the porous structures, the sample was partly etched to a convex shape by the photolithography and wet etching process, in which the GeAu/Ni ohmic contacts were formed.

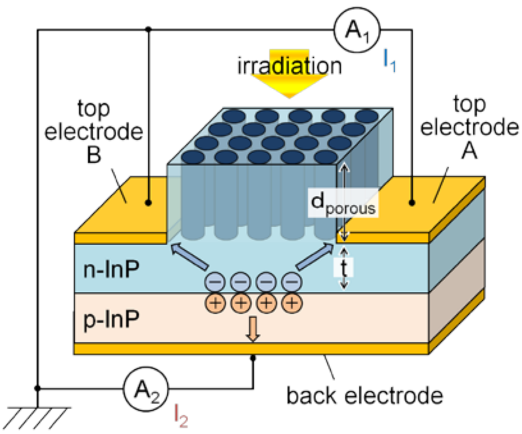

Fig.1 Device structure and experimental setup.

In this study, the photocurrents, I_1 and I_2, shown in **Fig.1** are measured under various light conditions using an Ar^+ ion laser with a wavelength of 514.5nm. Only the photo-carries generated near the p-n interface are separated by the electric field in the depletion layer and collected to the electrodes. Since such photo-carriers are generated by the photons reached to the p-n interface through the porous layer, the response of the current, I_1 and I_2, give us the information on the optical absorption properties of the porous structure.

3. Results and Discussion

Formation and Basic Device Performance

Figures 2(a) and **2(b)** show the photo image of the porous device and the scanning electron microscope (SEM) image of the porous surface, respectively. The present device has a 1-mm-distance porous region between the electrode A and B. In the present sample, the ordered porous layer with an average diameter of 180 nm was appeared after the removal of the irregular top layer by the photo-electrochemical (PEC) etching, as shown in **Fig.2(b)** [6].

Figure 3 shows the current ratio of I_1 to I_2 measured under the light irradiation as a function of the irradiation point, x, in the porous region shown in **Fig.2(a)**. As the irradiation point approached to the electrode A, the current ratio increased. Under the light irradiation at the center position (x=0), the current ratio showed almost half the value (~45%). This is because the electrons generated near the p-n interface were separately collected to the top electrodes A and B, but where the holes were collected to one electrode formed on the back surface. From these results, it

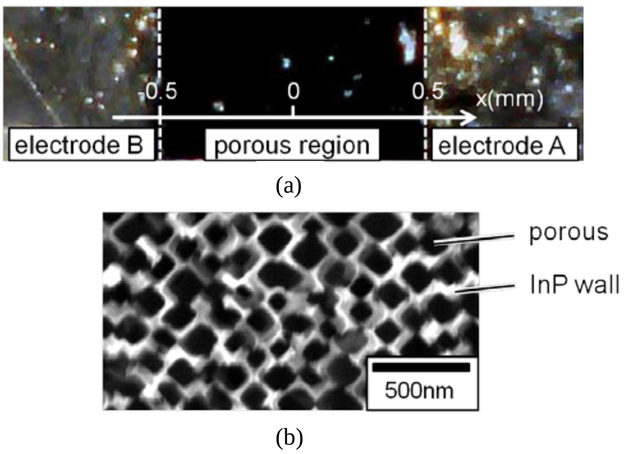

Fig.2 (a) Photo-image of porous device, and (b) SEM image of porous region.

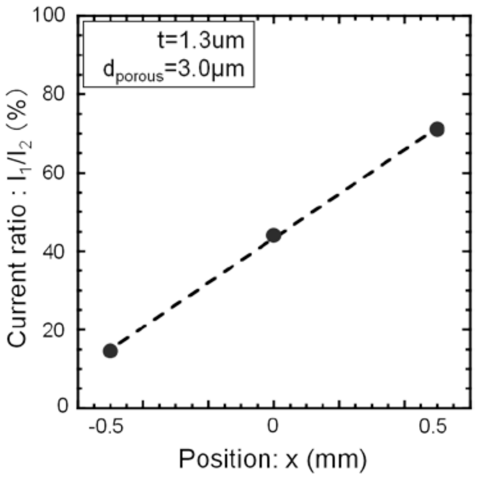

Fig.3 Correlation between current ratio, I_1/I_2, and position of light irradiation.

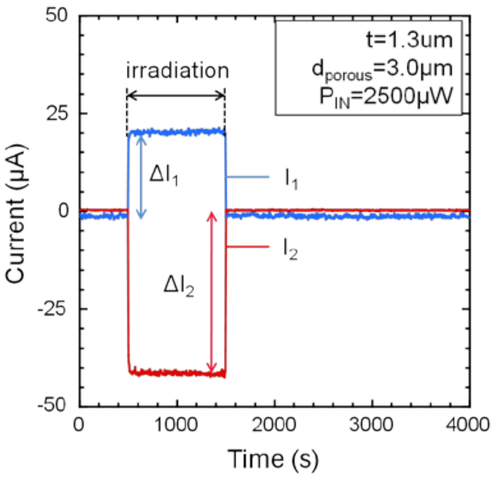

Fig.4 Current response of porous device.

was found that the current response in this device reflects an increase or decrease of the photo-carrier generated near the p-n interface.

Current Response Characteristics

Figure 4 shows the response of currents, I_1 and I_2, under the light irradiation with a power of 2500 μW. The current ratio of I_1 to I_2 was almost 50%, indicating that the irradiation point was around the center of the porous region. It was found that the photocurrents steeply changed in response to on-off signal of the light, as shown in **Fig.4**.

The absorption coefficient of InP epitaxial layer, α_{InP}, was estimated about 9740 cm^{-1} from the measurements on the planar samples with a different layer thickness. In the case of the porous layer, the absorption coefficient was estimated using the assumption that the photocurrents depends on the amount of photons reached to the p-n interface passing through the porous layer. The increase of the photo currents, ΔI_2, were plotted in **Fig.5** as a function of the light power. As expected, we obtained the linear relationship between the photocurrents and the light power. By using the device parameters such as α_{InP} = 9740 cm^{-1}, t = 1.3 μm

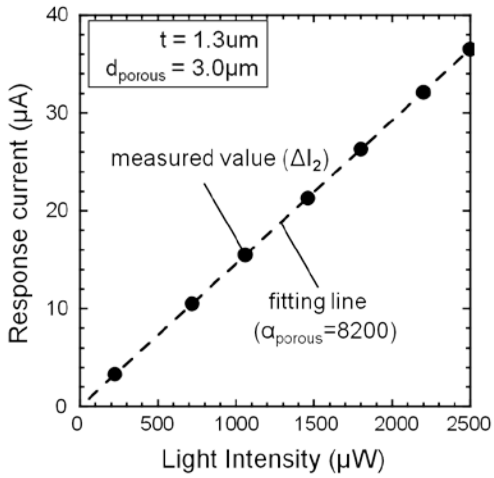

Fig.5 Response current plotted as a function of light intensity.

and d_{porous} = 3.0 μm, we obtained the absorption coefficient in range of 8000-9000 cm^{-1} on the porous structures, as shown in **Fig.5**. From these results, it was found that the absorption coefficient of the InP porous layer was slightly smaller than that of the InP epitaxial layer, but the porous layer surely inherits the material properties of InP.

4. Conclusions

The optical absorption properties of InP porous structures formed on p-n junction substrates were investigated. The photocurrents of the porous device steeply changed in response to on-off signal of the light, where the current response reflects an increase or decrease of the photo-carrier generated near the p-n interface. By theoretical fitting of the current response characteristics, the absorption coefficient in range of 8000-9000 cm^{-1} was obtained on the porous structures.

Acknowledgements

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