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Photocurrent Properties of AlGaN/GaN/AlGaN Photodetecters on Si

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1. Introduction

GaN material has attracted great interest for photodetectors in the visible-blind ultraviolet (UV) regions because of its direct and wide band gap. Most of these detectors were fabricated on sapphire or SiC substrate [1]. Si is one of the most promising substrates for the GaN heteroepitaxy, because of its high quality, large size, low cost and possibility of integrating Si-based GaN devices. However, it is difficult to grow quality GaN directly on Si substrate because of the large lattice mismatch and thermal mismatch between GaN and Si. Until now reports of GaN detectors fabricated on Si substrates are still few [2]. In this work, photoconduct detectors of AlGaN/GaN/AlGaN multilayer and GaN monolayer structures were fabricated on Si substrates by low-pressure metalorganic chemical vapor deposition. The photocurrent responses of these detectors were discussed.

2. Experiment

The 200nm AlN buffer layers, 500nm GaN epitaxial layers, and heterostructures including 15nm $Al_{0.2}Ga_{0.8}N$, 60nm GaN and 15nm top $Al_{0.2}Ga_{0.8}N$ layers were grown sequentially. In order for comparison, 600nm GaN monolayer structures were also grown epitaxially on AlN buffer layers under the same growing condition. The multilayer structure is schematically shown in Fig. 1. Interdigitated finger electrodes with 10μm-wide space were adopted for these detectors. Ti/Al was used to form ohmic contacts. The multilayer structures were annealed at 900°C for 1 min, so as to let the metal penetrate the AlGaN top layer and enter into the GaN layer.

3. Results and discussion

The spectral responses of the detectors were measured. The photocurrents as a function of wavelength for detectors of multilayer structure (sample A) and monolayer structure (sample B) under 5.5V bias are shown in Fig. 2. For sample A, the response shows a peak at a narrow range of wavelength from 352 to 385nm (the half peak value). The position of the peak wavelength is at 365nm, at which the responsivity is 24A/W under 5.5V bias. For sample B, the response decreases slowly at the wavelength from 360 to 250nm; a maximum responsivity of 7.0A/W was measured at 360nm under 5.5V bias.

For sample A, the $Al_{0.2}Ga_{0.8}N$ top layer absorbs the light with the photon energy larger than 3.8eV, and excites light-induced carriers. However, because of the great surface recombination and defect recombination, the light-induced electron-hole pairs in the thin $Al_{0.2}Ga_{0.8}N$ layer contribute very little to the photocurrent. Therefor, the response of short wavelength is quite low. The top $Al_{0.2}Ga_{0.8}N$ layer is transparent to the light with the photon energy smaller than 3.8eV. The light with photon energy of 3.4-3.8eV is absorbed by the GaN layer and forms the response of the narrow wavelength range.

The peak wavelength responsivity of sample A is much greater than that of sample B. The key reason of which is considered that a polarization electric-field E_p in the direction of substrate exists in the GaN layer of the AlGaN/GaN/AlGaN heterostructure. The polarization field has been observed in AlGaN/GaN heterostructure on sapphire substrate [3]. The schematic energy band diagram of the AlGaN/GaN/AlGaN heterojunction is shown in Fig.1. The light induced electron-hole pairs are separated immediately by the high polarization electric field in GaN layer. The electrons fall into the electron well at the interface of $Al_{0.2}Ga_{0.8}N$/GaN and the holes fall into the hole potential well at the interface of GaN/$Al_{0.2}Ga_{0.8}N$. The direct recombination of the electron-hole pairs is reduced due to the separation of the electrons and the holes in space. Additionally, the electrons and holes flowing through potential well to the electrodes also escape the surface recombination. The lifetime of the carriers generated by light will be much longer than that in GaN films without AlGaN layers. Therefore, due to the existence of the high polarization field, the responsivity for the detector of

AlGaN/GaN multilayer structure is much higher than that of GaN monolayer structure.

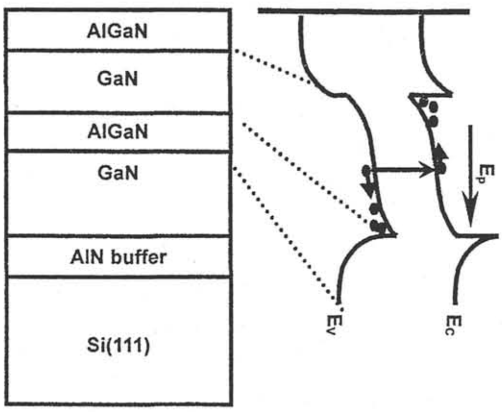

Fig.1. Schematic layer structure and energy band diagrams for the AlGaN/GaN/AlGaN multilayer structure

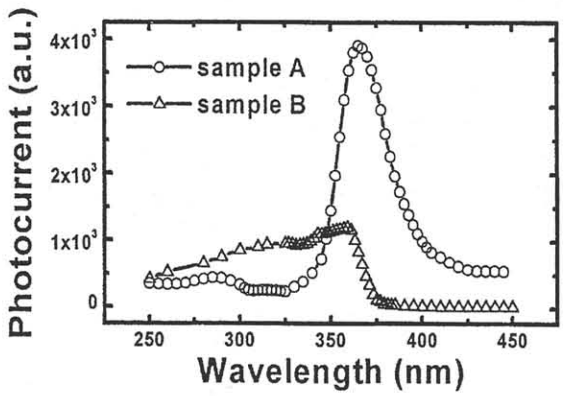

Fig.2. The spectral response for detectors of AlGaN/GaN/AlGaN multilayer structure and GaN monolayer structure under 5.5 V bias.

4. Conclusions

The photodetectors of AlGaN/GaN multilayler structures and of GaN monolayer structures were fabricated on Si (111) by MOCVD. The detectors of AlGaN/GaN/AlGaN multilayer structures showed a high response in a narrow range of wavelength. The peak wavelength is located at 365nm at which the resonsivity is as high as 24A/W at 5.5V bias; this is much higher than GaN monolayer detectors The high responsivity results mainly from the high polarization electric-field in the GaN layer of the AlGaN/GaN/AlGaN heterojunction.

Acknowledgments

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