第29卷 第12期 半 导 体 学 报 Vol.29 No.12
2008年12月 JOURNAL OF SEMICONDUCTORS Dec.,2008

Etching Process of Back-Illuminated ZnO Ultraviolet Focal Plane Array Imagers

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Abstract: Etching process of back-illuminated ZnO ultraviolet focal plane array imagers was investigated. The etching result of 128×128 array, in which the area of unit cell was 25μm×25μm, was studied. The profile angle was approximately 80°. There was a linear relationship between the etching depth and the etching time. The dependence of etching rate on NH_4Cl solution concentration was also studied. The photoresponsivity of the array's unit cells was measured. The UV-to-visible rejection ratio was around 60∶1.

Key words: etching; NH_4Cl; focal plane array
PACC: 2940P; 7280 **EEEACC**: 4250; 2250
CLC number: TN36 **Document code**: A **Article ID**: 0253-4177(2008)12-2304-03

1 Introduction

Ultraviolet (UV) detector imaging has been widely used in military surveillance and civil applications, such as missile threat detection, chemical and biological threat detection and spectroscopy, flame detection and monitoring, UV environmental monitoring, and UV astronomy[1,2]. As a wide bandgap II-VI semiconductor, ZnO has attracted much attention in the latest research for UV detectors because it has a direct wide bandgap of 3.37eV and a large excitonic binding energy of 60meV[3~6]. There are many reports of different kinds of ZnO detectors, such as ZnO metal-semiconductor-metal (MSM) detectors[7], ZnO p-i-n detectors, and ZnO Schottky detectors. However, there are no reports of ZnO focal plane array (FPA) imagers now, while there are many reports of AlGaN FPA imagers[2,8~10].

In this paper, we study the etching process of back-illuminated ZnO FPA imagers and test the *I-V* characteristic of the FPA's unit cells. The array consists of 128×128 individual ZnO unit detectors which are designed in vertical structure. The area of the unit detector is 25μm×25μm.

2 Experiment

The back-illuminated ZnO focal plane array was fabricated using RF magnetron sputtering technique. First, an ITO electrode layer was deposited on the sapphire as the bottom electrode of the unit detectors using RF magnetron sputtering technique. An ITO target (99.99%) was used for sputtering with the flux ratio of Ar∶O_2=3∶1. The ITO film was deposited at the RF power of 100W. And then a ZnO layer was deposited on the ITO layers using magnetron sputtering technique, which was used as the active layer of the ZnO unit photodetectors. A ZnO target (99.999%) was used for sputtering with the flux ratio of Ar∶O_2=2∶1. The ZnO active layer was deposited at the RF power of 100W. Photolithography was then processed using an appropriately-designed mask with a pattern of 128×128 array. Ammonium chloride was then employed in the wet etching process, using the photoresist as the resist layer to etch the ZnO active layer. In order to study the etching process, NH_4Cl solutions of different concentrations were used for wet etching process at room temperature (25℃). Samples with different thicknesses were deposited in order to investigate the etching rate and the relation between the etching rate and the concentration of the NH_4Cl solution. The thickness of these samples was 200, 600, 800, 1000 and 1300nm respectively.

The results of the ZnO focal plane array were studied using industrial microscopy (Nikon ECLIPSE LV150). The reaction of ZnO with the NH_4Cl solution is as follows[11]:

$$NH_4Cl = NH_4^+ + Cl^- \tag{1}$$

$$NH_4^+ + H_2O \rightleftharpoons NH_3 \cdot H_2O + H^+ \tag{2}$$

$$ZnO + 2H^+ = Zn^{2+} + H_2O \tag{3}$$

It was found that the etching rate of the ZnO can be controlled by the concentration of the NH_4Cl solution and linear etching process could be achieved using NH_4Cl solutions of different concentrations.

The *I-V* characteristic of the ZnO FPA's unit cell

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Received 25 May 2008, revised manuscript received 8 July 2008

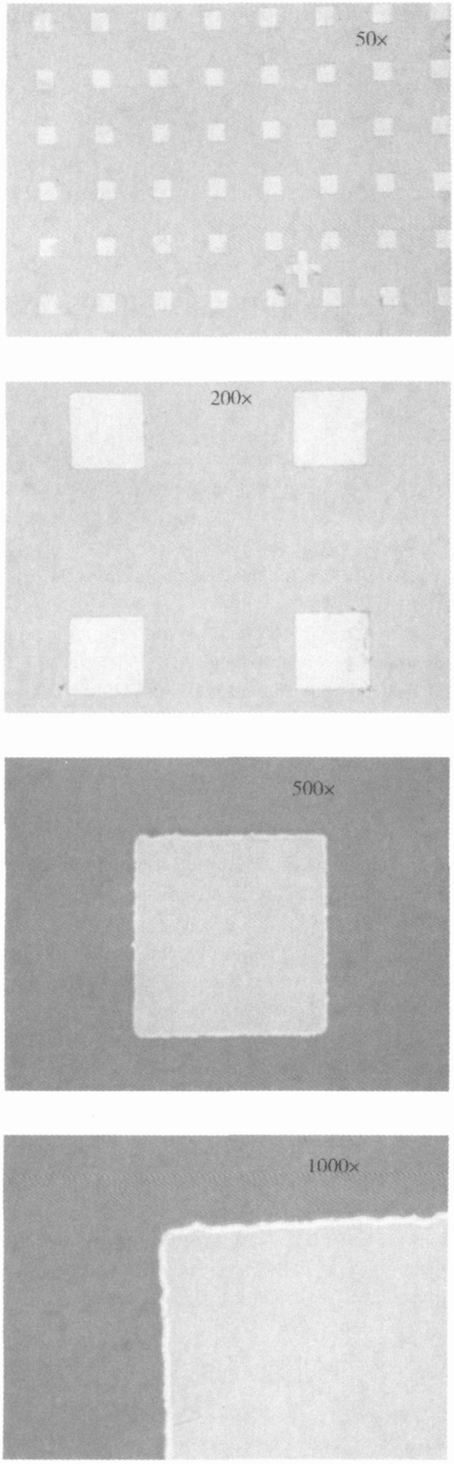

Fig. 1 Top view of the ZnO FPA imager

was tested using a picoammeter (Keithley Model 6478) under the illumination of an Hg lamp (365nm).

3 Results and discussion

Figure 1 shows the top view of the ZnO FPA imager with photoresist after etching. It was found that the photoresist can not be etched by NH_4Cl solution.

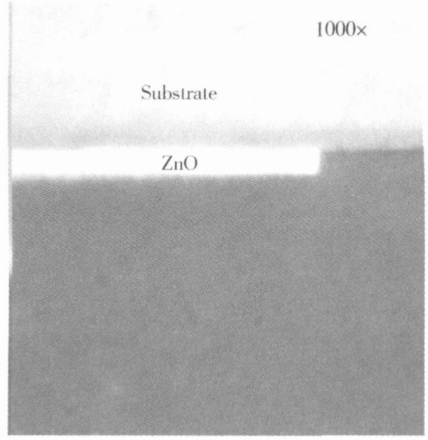

Fig. 2 Cross-sectional view of the ZnO FPA unit cell

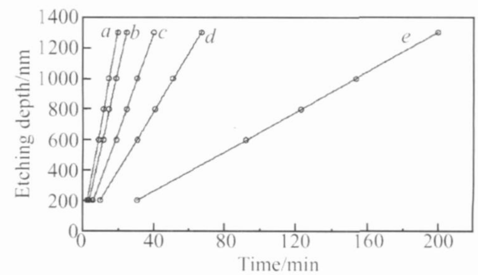

Fig. 3 Relationship between the etching depth and the etching time of NH_4Cl solutions of different concentrations *a*: 10%; *b*: 8%; *c*: 5%; *d*: 3%; *e*: 1%

Figure 2 shows the Cross-sectional view of the ZnO FPA unit cell. The etch profile angle was approximately 80°.

Figure 3 shows the relation between the etching depth and the etching time of different solutions (10%, 8%, 5%, 3% and 1%). There was a good linear relationship between the etching depth and the etching time, indicating that the etching depth can be easily controlled by the etching time of the etching process.

Figure 4 shows the relation between the etching rate and the concentration of NH_4Cl solution. There was a good linear relation between the etching rate and the concentration of NH_4Cl solution, indica-

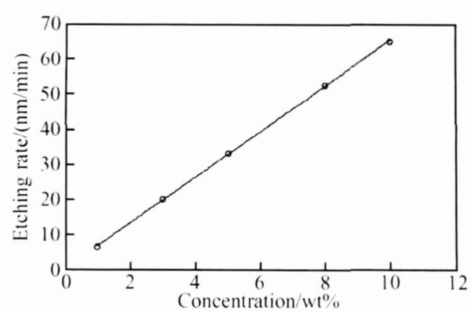

Fig. 4 Relationship between the etching rate and the concentration of NH_4Cl solutions

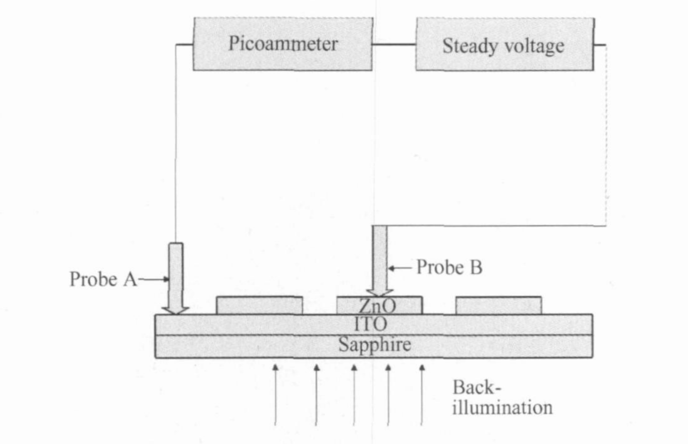

Fig. 5 Schematic illustration of the testing of FPA's unit cell

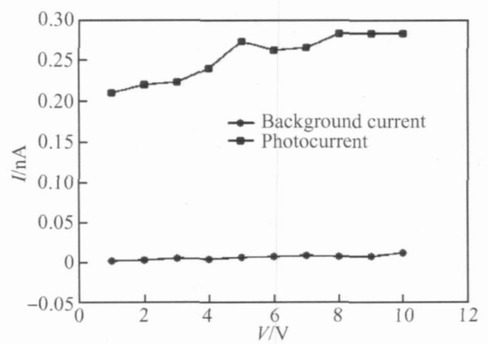

Fig. 6 *I-V* characteristic for the ZnO FPA's unit cell

ting that the etching rate depended on the H^+ concentration in the solution which increased linearly with the concentration of the NH_4Cl solutions. Thus, the etching rate increased linearly with the concentration of the NH_4Cl solutions.

Figure 5 shows schematic illustration of the testing for the photoresponsivity of the FPA's unit cell. An Hg lamp (365nm) was used as UV illumination. A picoammeter (Keithley Model 6478) was used to measure the dark current and the photocurrent.

Figure 6 shows the photoresponsivity of the FPA's unit cell under illumination of Hg lamp (365nm). The UV-to-visible rejection ratio was around 60 : 1.

4 Summary

In conclusion, we have realized wet etching of a back-illuminated ZnO focal plane array using NH_4Cl solutions. The wet etching using NH_4Cl solutions was controllable. In addition, the photoresponsivity of the FPA's unit cell was measured and discussed.

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背照式 ZnO 紫外焦平面成像阵列制作的刻蚀研究

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摘要: 研究了背照式 ZnO 焦平面成像阵列制作的刻蚀工艺. 该 ZnO 焦平面阵列为 128×128 阵列, 每个单元面积为 25μm×25μm, 对该阵列的刻蚀结果进行了研究分析. 刻蚀后阵列单元的剖面角约为 80°. 在刻蚀过程中, 刻蚀深度和刻蚀时间呈线性关系. 还研究了 NH_4Cl 溶液浓度和刻蚀速率之间的关系. 时刻蚀后的阵列单元进行了光电响应的测试, 得到明暗电流比约为 60 : 1.

关键词: 刻蚀; NH_4Cl; 焦平面阵列

PACC: 2940P; 7280 **EEACC**: 4250; 2250

中图分类号: TN36 **文献标识码**: A **文章编号**: 0253-4177(2008)12-2304-03

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2008-05-25 收到, 2008-07-08 定稿