Optics Communications 399 (2017) 68–72

Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

Surface plasmon-enhanced ultraviolet photodetectors by using Au nanoparticles embedded in MgZnO thin films

Z.X. Guo[a], D.Y. Jiang[a,b,*], M. Zhao[a,c], T. Zheng[a], J.W. Lv[a], J.N. Pei[a], N. Hu[a], S. Gao[a], Q.C. Liang[a], J.X. Zhao[a], J.H. Hou[a], J.M. Qin[a]

[a] School of Materials Science and Engineering, Changchun University of Science and Technology, Changchun 130022, China
[b] Engineering Research Center of Optoelectronic Functional Materials, Ministry of Education,Changchun 130022, China
[c] Special Service Department, Aviation University of Air Force, Changchun 130000, China

ARTICLE INFO

Keywords:
Surface plasmon
Au nanoparticles
MgZnO
Ultraviolet
Photodetectors

ABSTRACT

This paper demonstrates surface plasmons (SPs) enhanced MgZnO ultraviolet (UV) photodetectors grown by a radio frequency (RF) magnetron sputtering technique, and the magnesium concentration is 30%. Predominantly, well-defined Au NPs with different sizes were produced embedded in MgZnO thin films. Notably, at 30 V applied bias, the proper combination MgZnO/Au NPs (40 s), responsivity as high as 341.08 A/W is achieved after optimizing the process. Impressively, the excellent comprehensive performance of MgZnO/Au NPs UV photodetectors should have great applied potential, a physical mechanism is given to explain the above results.

1. Introduction

UV photodetectors have played an important role in some fields, such as environmental monitoring, large-area displays, and optical communications, and they are significant in both civilian and military fields [1–4]. In material selection, MgZnO, which is formed by alloying MgO with ZnO, shows the same material advantages as pure ZnO, and its band gap can be tuned sequentially from 3.37 eV (ZnO) to 7.8 eV (MgO). Therefore, it utilizes MgZnO alloys to obtain UV (200–400 nm) optoelectronic devices, which has developed the wavelength tunable. However, by reason of the complexity of obtaining high-quality MgZnO, the responsivity of the metal-semiconductor-metal (MSM) structured devices based on MgZnO films are quite low. As a result, improving the performance is still a hot topic of MgZnO-based MSM UV photodetectors, and persistent efforts should be provided for this problem.

In present years, a candidate technology that has emerged as SPs supported by metallic NPs, SPs is collective charge oscillations that occur at the interface between a metal and a dielectric. The resonant excitation of SPs can cause selective photon absorption and enhancement of local electromagnetic fields near the metal NPs by several orders of magnitude [5–15]. A novel feature is that, when metal NPs embedded in dielectric materials, the circuitry used to propagate SPs can also be applied in carrying electrical signals. Tian et al. proposed that metal (Pt) nanoparticles were deposited on the different situations of the MgZnO films. It is noted that the photoresponse of MgZnO-based photodetectors with Pt nanoparticles are enhanced, and the structure MgZnO+Pt+MgZnO has more obvious improvement than structure MgZnO+Pt and structure Pt+MgZnO [16]. Additionally, Au element has attracted significant attention on a plasmonic material due to stable and highest conductivity properties. For instance, a high-performance UV light photodetector fabricated by p-Si/n-ZnO nanorods decorated with Au NPs was obtained by Hwang et al. [17]. Unlike previous researches which have preferred to focus individual the metal particle shape. With the purpose of achieving the best performance, we design a more systematic investigation to further determine the SPs ability to couple to light, metal particle sizes, as well as to improve the light absorption.

In this work, a series of MSM structured ultraviolet photodetectors were fabricated embedded in MgZnO films grown by a radio frequency (RF) magnetron sputtering technique. We present that suitable Au NPs sizes (20, 30 and 40s) and effective coupling can dramatically increase the light absorption and responsivity. We provide the observations to the performance of SPs on promoting light absorption [18].

2. Experimental

The MgZnO films were deposited on quartz substrates by RF magnetron sputtering technique. The targets used in the deposition were prepared by a solid reaction method using a mixture of ZnO and

* Corresponding author at: School of Materials Science and Engineering, Changchun University of Science and Technology, Changchun 130022, China.
E-mail address: dayongjiangcust@126.com (D.Y. Jiang).

http://dx.doi.org/10.1016/j.optcom.2017.04.045
Received 27 February 2017; Received in revised form 14 April 2017; Accepted 19 April 2017

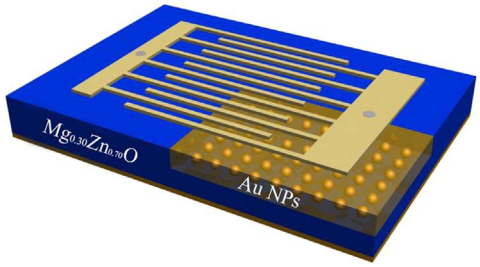

Fig. 1. The schematic of photodetectors with Pt nanoparticles sputtering embedded into the film.

Table 1
Thickness of each layer for samples.

Thickness (nm)				
Sample	Layer structure	Top layer	Au NPs	Bottom layer
S1	$Mg_{0.30}Zn_{0.70}O/Mg_{0.30}Zn_{0.70}O$	1 h	None	1 h
S2	$Mg_{0.30}Zn_{0.70}O$/Au NPs/ $Mg_{0.30}Zn_{0.70}O$	1 h	20 s	1 h
S3	$Mg_{0.30}Zn_{0.70}O$/Au NPs/ $Mg_{0.30}Zn_{0.70}O$	1 h	30 s	1 h
S4	$Mg_{0.30}Zn_{0.70}O$/Au NPs/ $Mg_{0.30}Zn_{0.70}O$	1 h	40 s	1 h

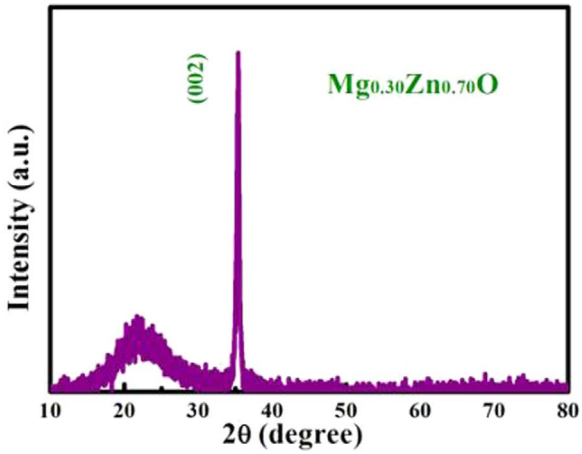

Fig. 2. XRD pattern recorded of the MgZnO thin films.

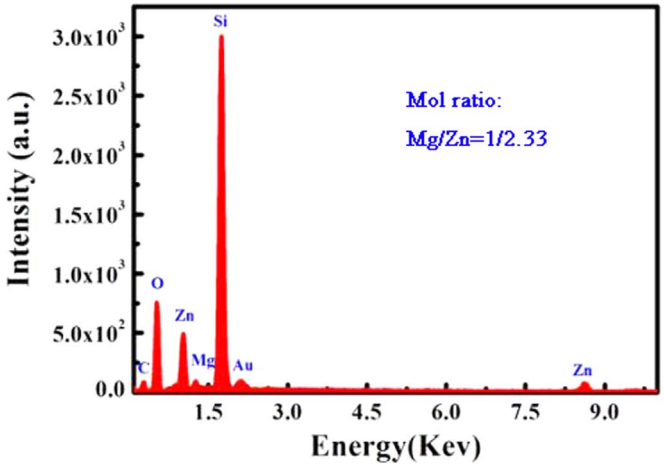

Fig. 3. A typical EDS spectrum recorded for the MgZnO thin films.

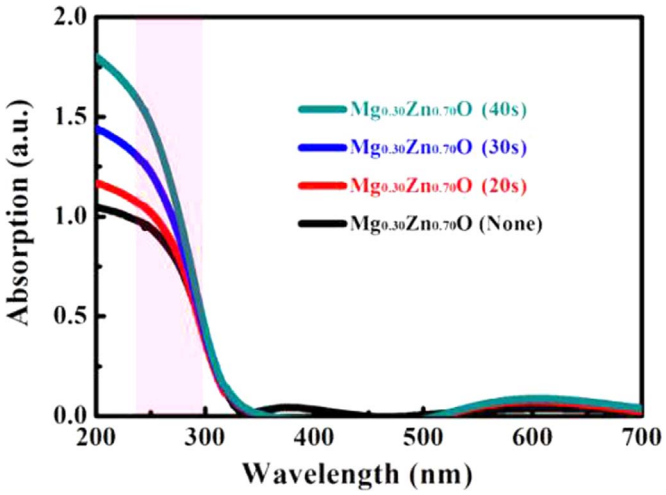

Fig. 4. The UV–visible absorption spectra of the S1, S2, S3, S4 thin films.

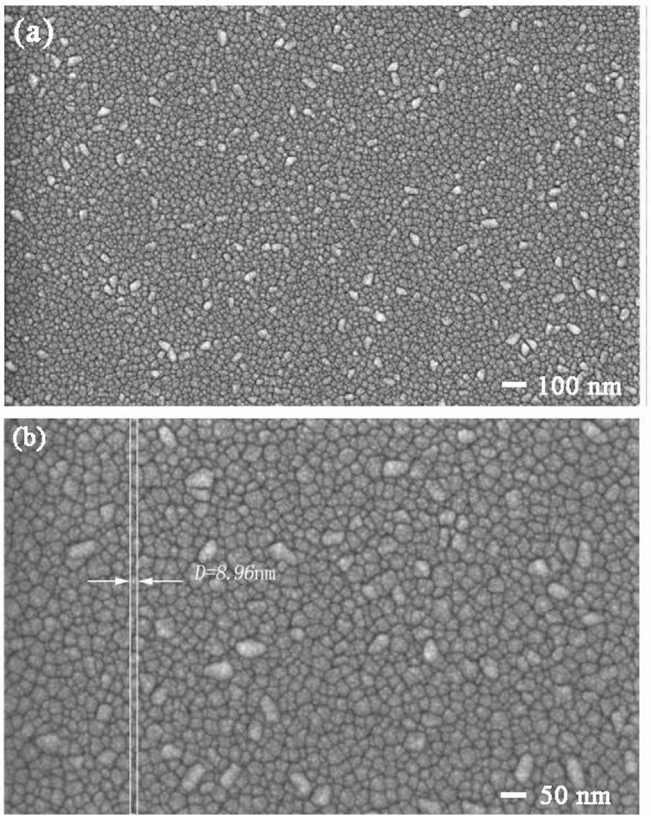

Fig. 5. (a) (b) shows SEM images of without Au NPs, with sputtering Au NPs time 40 s.

MgO powders. The atomic ratio of Mg and Zn (Mg: Zn) in the targets were 3: 7. The quartz substrates were cleaned 30 min with acetone, ethanol, and deionized water in turn. In order to achieve the films of high crystal quality, the temperature of the quartz glass substrates was kept at 673 K, and the sputtering time was 1.0 h. To ensure the uniformity of the deposited films, the objective table was twirling at the speed of 5.0 r/min. Au nanoparticles was sputtered on the same devices in the chamber of a JEOL JFC-1600 sputter coater for 20, 30 and 40 s, and the sputtering current was kept at 20 mA. All the Au nanoparticles sputtering were carried out at room temperature and no thermal treatment is involved during and after metallization. Then, we use the same method to sputter 1.0 h on these samples. To fabricate the MSM structure MgZnO UV photodetectors, the top Au finger electrodes were constructed through lithography and wet etching, which were