Journal of ELECTRONIC MATERIALS, Vol. 42, No. 5, 2013
DOI: 10.1007/s11664-013-2526-y

Nanoplasmonic Enhanced ZnO/Si Heterojunction Metal–Semiconductor–Metal Photodetectors

CHONG TONG,[1,2] JUHYUNG YUN,[1] ERIC KOZARSKY,[1] and WAYNE A. ANDERSON[1]

1.—Department of Electrical Engineering, State University of New York at Buffalo, Buffalo, NY 14260-1920, USA. 2.—e-mail: chongton@buffalo.edu

This paper presents a nanoplasmonic enhanced ZnO/Si heterojunction metal–semiconductor–metal (MSM) photodetector (PD). By depositing different thicknesses of Ag thin film and annealing at a moderate temperature, well-defined silver (Ag) nanoparticles (NPs) with different diameters, densities, and size distributions were produced on the surface of ZnO/Si MSM photodetector devices. By tuning the characteristics of these NPs, a higher-performance ZnO/Si MSM photodetector has been realized. The photocurrent of the detector with NPs was increased by 160% to 680%, depending on the applied voltage. The spectral photocurrent enhancement by a factor of 7 to 18 was broadband from 350 nm to 850 nm.

Key words: ZnO/Si heterojunction, nanoparticles, MSM photodetector, nanoplasmonic enhanced device

INTRODUCTION

ZnO is one of the promising materials for high-speed ultraviolet (UV) photodetectors (PDs), due to its direct wide bandgap (3.3 eV) and high exciton binding energy (60 meV). In addition, ZnO is also a low-cost, nontoxic transparent conducting oxide (TCO) that can be deposited at low temperatures.[1] The ZnO/Si heterojunction receives attention because of its low driving voltage and less fabrication expense. Reliable ZnO/Si heterojunction metal–semiconductor–metal (MSM) photodetectors (PDs) have been described in many previous reports.[1,2] To obtain higher photoresponse from ZnO/Si MSM-PDs, the importance of proper annealing conditions and the avalanche multiplication process in the ZnO layer were also investigated.[1] Recently, nanoplasmonic enhancement by using metallic nanoparticles has offered new opportunities to engineer and improve the performance of optoelectronic devices, such as solar cells and photodetectors. Through interacting with nanoparticles, the incident light can be scattered into photonic or surface plasmon polariton (SPP) modes, depending on the scattering nanoparticles and incident light wavelength.[3] Once these nanoparticles are integrated onto the surface of optoelectronic devices, incident light would be preferentially forward scattered into the active semiconductor region and much higher optical absorption can be achieved.[4] In many recent studies, Au nanoparticles were frequently used.[5,6] However, because of parasitic absorption, which refers to undesired losses arising from the resonant coupling of the incident light with the nanoparticles, Ag nanoparticles are considered to be a better material.[7] It has been reported that Ag nanoparticles exhibit lower parasitic absorption and higher scattering efficiency. This resonant scattering effect of Ag can reach as high as 80% for light with wavelength larger than 400 nm.[8] The plasmonic scattering efficiency of nanoparticles is also determined by the geometry of the plasmonic structure, such as the shape, size distribution, and density of the nanoparticles. This allows us to tune the surface plasmon resonance frequency to a desired wavelength range by tuning the characteristics of the nanoparticles.[8] In addition, the performance of photodetectors could be improved via this nanoparticle plasmonic effect without increasing the

(Received August 10, 2012; accepted February 5, 2013; published online March 9, 2013)