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Reflectance suppression of ZnO coated GaP nanowires

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ABSTRACT

This paper reports on the optical properties of GaP nanowire (NW) arrays covered with thin nanocrystalline ZnO films. The GaP NWs were grown by metal organic vapor phase epitaxy from Au seeds created from a very thin Au layer deposited on top of a GaP substrate. ZnO films were deposited on the GaP nanowires by RF sputtering using different sputtering conditions. Reflectance of different ZnO covered GaP NW structures was measured. We experimentally show the reflectance suppression of ZnO coated NWs in the wide range of angles.

Keywords: nanowire, ZnO film, reflectance, solar cells

1. INTRODUCTION

It is very much desirable to enhance light absorption in optoelectronic devices, such as photodetectors, sensors, and solar cells, to improve the efficiency of light-energy conversion [1, 2]. For example, in solar cells, the standard double layer antireflection (AR) coatings are not sufficient for reducing the reflection over a broad wavelength range. Four-junction solar cells require an antireflection coating operating from ~350 nm to ~1700 nm. For maximum efficiency broadband antireflection layers are necessary [3].

An AR layer with a graded refractive index properties can also be made of nanowires (NWs). GaP NW arrays attract our attention for years [4-7] and have more and more applications [8]. It was recently demonstrated that nanowire assemblies possess broadband and omnidirectional AR properties. Thus, they are very suitable for an AR coating on top of multijunction solar cells. As in such systems some light is always incident upon solar cells at oblique angles, omnidirectional AR coatings are therefore indispensable for them.

This can be achieved by multilayer stacks and structures whose size is comparable with wavelengths within the operating spectral range of the cells. Another principle utilizes small structures in lateral directions as different antireflection surface structures or arranging three-dimensional nanostructures as nanopillars and nanowires. Such structures can also be formed with other compound semiconductors [9].

GaP-ZnO NWs are believed to be promising candidates for future nanoelectronic and optoelectronic devices [10]. If such heterostructure NWs are integrated on top of a multi-junction solar cell, its spectral sensitivity can potentially be extended to cover also the 350-480 nm part of the solar spectrum, and in addition, photon absorption can be enhanced and light reflection from the cell surface reduced [11,12]. ZnO is a semiconductor with excellent thermal and chemical stability in the air and these properties make it attractive for use in blue and ultraviolet region [13], while GaP NWs exhibit a spectral sensitivity range between 520 and 700 nm. This paper reports on optical properties of GaP/ZnO NWs measured in reflectance angular dependencies. The results show how using ZnO shell on GaP/ZnO NW structure can considerably reduce the angular reflectance of GaP/ZnO NWs if an appropriate ZnO film is deposited.

2. EXPERIMENTAL DETAILS

GaP NWs were grown on a GaP substrate by metal organic vapour phase epitaxy (MOVPE) using vapour–liquid–solid mode [14]. GaP nucleated into NWs at Au seed particles, which coalesced from a sub-nanometre thick Au layer deposited on the substrate by evaporation. Upon deposition of the Au layer, the substrate was heated under a gradually increasing PH_3 flow in an AIX 200 low-pressure MOVPE reactor, at the temperature of 650 ºC for 10 min. This led to the formation of Au seeds with 20-40 nm in diameter and a density of 400 seeds per 1 square micrometer. GaP NW growth was subsequently performed from PH_3 and TMGa at a temperature of 500 ºC and pressure of 100 mbar. Achieved bottom diameter of NWs was 80-100 nm, diameter at top was limited by size of Au seeds (cca 30 nm) and their length was close to 400 nm [12].

The NWs were subsequently covered with a thin nanocrystalline GaP-doped ZnO layer by sputtering in a Perkin-Elmer planar RF diode system, using a ceramic $ZnO:Ga_2O_3$ target, 100 mm in diameter. The RF-sputtering conditions were