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UV nanophotodetectors: A case study of individual Au-modified ZnO nanowires

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ABSTRACT

In this work, ultraviolet (UV) nanophotodetectors based on individual gold-functionalized ZnO nanowires (Au/ZnO NWs) with different diameters and with different Au content were fabricated using a focused ion beam/scanning electron microscopy (FIB/SEM) system. The influence of the Au content, the diameter of the NWs, the applied bias voltage, the temperature and the relative humidity during operation on the UV sensing properties was investigated in detail. The necessity of a higher Au nanoparticles (NPs) coverage of individual Au/ZnO NWs in order to obtain higher UV response is demonstrated for the first time. A high UV response (I_{UV}/I_{dark}) of 21 for an individual Au/ZnO NW (with ∼ 6.4% Au NPs coverage) was obtained, which is by a factor of 17 higher compared to unmodified ZnO NWs. The investigation regarding the NW diameter confirmed that thinner NWs are more suitable for UV sensing applications due to the greater influence of surface phenomena on electrical properties. Most importantly, the elaborated nanophotodetectors in this work, based on individual Au/ZnO NWs, show an extreme low influence caused by water vapors, i.e. relative humidity on UV response, which is critical for practical applications of high performance UV photodetectors in normal ambient conditions. Our experimental results demonstrate clearly that the *n*-type Au/ZnO NWs with enhanced optoelectronic properties are highly promising building nano-blocks for near future nano-optoelectronic devices and possible for biosensing applications.

1. Introduction

One-dimensional (1-D) ZnO nanostructures, such as nanowires, nanobelts, nanotubes and nanorods are ideal building blocks for high-performance electronic, optoelectronic and sensing devices for environmental applications [1–9]. In the case of sensing devices (e.g. UV photodetectors and gas sensors) the high influence of surface phenomena, such as adsorption/desorption of gaseous species on the electrical transport through a restricted conduction channel of 1-D nanostructures paves the way to fabricate highly sensitive UV photodetectors and gas sensors based on individual nanostructures [3,7,8,10–15]. The main advantage of UV photodetectors based on individual ZnO NWs is the high internal gain, which is attributed to the presence of oxygen-related hole-trap states at the NW surface which prevents charge-carrier recombination through prolongation of the photo-carrier lifetime [16].

Different methods were reported in order to considerably enhance the UV sensing properties of individual ZnO NWs, such as doping [11], surface functionalization with noble metals [3], formation of individual Schottky contacts at one end of the NW [6], as well as functionalization with other metal oxide NPs [13], and the utilization of the piezo-phototronic effect [17]. For example, Hu et al. fabricated UV photodetectors based on a ZnS/ZnO biaxial nanobelt with high spectral selectivity and wide-range photoresponse in the UV—A band [18]. Lao et al. demonstrated that the UV response of individual ZnO nanobelts can be enhanced by almost 5 orders of magnitude by surface functionalizing with a polymer that has a high UV absorption ability [19]. While the UV sensing properties of photodetectors based on Au-modified ZnO micro- and nanostructures have been reported many works [20,21], only the several results were reported based on individual Au-modified ZnO structures [3,22]. For example, Liu et al. fabricated the UV photodetectors based on an individual ZnO NW with and without Au NPs and observed that surface-functionalization with Au NPs can dras-

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