SYNTHESIS AND CHARACTERIZATION OF GOLD NANOPARTICLES-DOPED ZINC OXIDE NANOSTRUCTURES FOR ULTRAVIOLET PHOTODETECTOR APPLICATION

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ABSTRACT

Zinc oxide nanostructures (ZONSs) doped with different noble metallic nanoparticles (NPs) with customized structures, morphologies and optical characteristics have immense fundamental and applied interests. The potential of the gold nanoparticles (AuNPs)-doped with ZONSs for the photodetectors and solar cells applications have rarely been explored. Based on these facts, in this study, a series of AuNPs-doped ZONSs were prepared and characterized systematically via diverse analytical techniques. The effects of the substrates type, thickness, and growth parameters on the structural, morphological and optical properties of the proposed AuNPs-doped ZONSs were determined. In addition, the optimum sample from each series was selected to fabricate the metal-semiconductor-metal (MSM) ultraviolet (UV) photodetector. First, the ZONSs were deposited (at a rate of 0.3 A°/sec) on the borosilicate glass and three types of n-Si (100) (plain, polished and etched with surface treatment) substrates using the versatile radio frequency (RF) sputtering method operated at 300°C, RF power of 100 W, Argon flow of 10 sccm and pressure of (-5) millibar. The layer of thickness of the deposited ZONSs on both substrates were varied in the range of 100 to 400 nm. The optimum substrate was found to be the etched n-Si (n-ESi) with the thickness of 300 nm. Next, the colloidal AuNPs were synthesized inside deionized water (DW) using the laser ablation in liquid technique. In this process, a gold target was ablated using the Nd-YAG laser (1064 nm) operated for 6 minutes at different energies (96.6, 226, 286 and 336 mJ) and fixed frequency of 6 Hz. The formation of the AuNPs inside DW was verified using the high-resolution transmission electron microscopy (HrTEM), field emission scanning electron microscopy (FESEM) and UV absorption spectroscopy. The AuNPs colloidal suspension prepared at laser energy of 286 mJ was the optimum one and selected for doping into ZONSs. Later, the droplets of the optimum AuNPs colloidal suspension were soaked (both at dark and room temperature for 48 hours) on the deposited optimal ZONSs film to achieve the best AuNPs-doped ZONSs useful for the photodetector fabrication, Finally, the silver (Ag) electrodes were deposited on the AuNPs-doped ZONSs film using the RF sputtering to design the MSM (Ag/n-ESi/ZONSs-AuNPs/Ag) UV photodetector. The current-voltage (I-V) characteristics of the obtained photodetector were measured in the dark and under UV light (380 nm) illumination. The photoluminescence spectra of the optimum AuNPs-doped ZONSs showed an intense near band edge UV peak at 380 nm corresponding to the band gap energy of 3.26 eV. The best MSM UV photodetector revealed a very high responsivity (3.05 A/W), good photosensitivity (1044.5), fast response time (0.29 s) and very short recovery time (0.26s). It was demonstrated that the UV photodetector performance of the ZONSs can remarkably be improved via the AuNPs doping. Additionally, carefully adjusting the nature of the substrates, growth parameters of the RF sputtering and laser ablation technique the structures, morphologies, optical and electrical traits of AuNPs-doped ZONSs can tailor the UV photoreactor productions for different applications. The proposed MSM UV photodetectors may be advantageous for various optoelectronic applications.

ABSTRAK

Struktur nano zink oksida (ZONS) yang didopkan dengan pelbagai zarah nano logam asli (NP) dengan struktur, morfologi dan ciri optik yang disesuaikan mempunyai kepentingan dan tarikan yang tinggi. Potensi zarah nano emas (AuNP) yang didopkan ke dalam ZONS untuk aplikasi pengesan foto dan sel suria masih jarang diterokai. Berdasarkan fakta-fakta ini, dalam kajian ini, satu siri ZONS yang didopkan dengan AuNP disusun dan dicirikan secara sistematik melalui pelbagai teknik analisis. Kesan jenis substrat, ketebalan, dan parameter pertumbuhan terhadap sifat struktur, morfologi dan optik ZONS yang didopkan AuNPs seperti yang dicadangkan telah ditentukan. Tambahan lagi, sampel optimum dari setiap siri telah dipilih untuk membuat pengesan foto ultraungu (UV) logam-semikonduktor-logam (MSM). Pertama sekali, ZONS didepositkan (pada kadar 0.3 A°/ saat) pada kaca borosilikat dan tiga jenis substrat n-Si (100) (polos, digilap dan diukir dengan rawatan permukaan) menggunakan kaedah sputtering frekuensi radio serbaguna (RF) yang dikendalikan pada 300 °C, kekuatan RF 100 W, aliran Argon 10 sccm dan tekanan (-5) milibar. Lapisan ketebalan ZONS yang didepositkan pada kedua-dua substrat divariasikan dalam julat 100 hingga 400 nm. Ia didapati bahawa substrat terbaik adalah n-Si yang diukir (n-ESi) dengan ketebalan 300 nm. Seterusnya, koloid AuNP disintesis di dalam air yang deionisasi (DW) menggunakan teknik ablasi laser dalam cecair. Dalam proses ini, sasaran emas dikeringkan menggunakan laser Nd-YAG (1064 nm) yang dikendalikan selama 6 minit pada tenaga yang berbeza (96.6, 226, 286 dan 336 mJ) dan frekuensi tetap 6 Hz. Pembentukan AuNP di dalam DW disahkan menggunakan mikroskop transmisi elektron resolusi tinggi (HrTEM), mikroskop pemindaian pelepasan medan elektron (FESEM) dan spektra penyerapan UV. Koloid AuNP terampai yang dihasilkan dengan tenaga laser 286 mJ adalah yang paling optimum dan dipilih untuk didopkan ke ZONS. Seterusnya, titisan terampai koloid AuNP yang optimum direndam (pada suhu gelap dan suhu bilik selama 48 jam) dan didepositkan pada filem ZONS terbaik untuk mencapai ZONS yang didopkan dengan AuNP optimum yang berguna untuk penghasilan pengesan foto. Akhir sekali, elektrod perak (Ag) didepositkan pada filem ZONS yang didopkan dengan AuNP menggunakan RF sputtering untuk mereka bentuk pengesan foto UV MSM (Ag / n-ESi / ZONSs-AuNPs / Ag). Ciri arus voltan (I-V) yang diperoleh dari pengesan foto tersebut diukur dalam pencahayaan gelap dan bawah sinar UV (380 nm). Spektrum foto luminesens ZONS yang didopkan dengan AuNP optimum menunjukkan puncak UV tepi jalur yang kuat pada 380 nm yang berpadanan dengan jurang tenaga 3.26 eV. Pengesan foto UV MSM optimum menunjukkan daya tindak balas yang sangat tinggi (3.05 A / W), kepekaan fotosensitiviti yang baik (1044.5), masa tindak balas yang cepat (0.29 s) dan masa pemulihan yang sangat singkat (0.26s). Ini menunjukkan bahawa prestasi pengesan foto UV ZONS dapat ditingkatkan dengan baik melalui pengedopan AuNP. Selain itu, dengan menyesuaikan sifat substrat, parameter pertumbuhan RF sputtering dan teknik ablasi laser dengan teliti, struktur, morfologi, sifat optik dan sifat elektrik ZONS yang didopkan AuNP dapat disesuaikan untuk pengeluaran reaktor foto UV yang bermanfaat untuk aplikasi yang berbeza. Pengesan foto UV MSM yang dicadangkan mungkin bermanfaat untuk pelbagai aplikasi optoelektronik.

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LIST OF ABBREVIATION

a. u. - Arbitrary unit
A1 - Gold nanoparticles 96.6 mJ
A2 - Gold nanoparticles 226 mJ
A3 - Gold nanoparticles 286 mJ
A4 - Gold nanoparticles 336 mJ
AFM - Atomic force microscopy
APDS - Avalanche photodiode
AuNPs - Gold nanoparticles
BG - Borosilicate Glass
C2H5OH - Ethanol
CB - Conduction Band
CdS - Cadmium sulfide
CdTe - Cadmium telluride
CO_2 - Carbon dioxide
c-Si - Crystallite silicon
DC - Direct current
DI - Distilled water
DW - Deionized Water
ECE - Electrochemical etching
EDX - Energy dispersive x– ray
e^--h^+ - Electron – hole
EMT - Effective mass theory
ES - Etched Silicone
FWHM - Full width at half maximum
G - Photo carrier –generation rate
H_2O_2 - Hydrogen peroxide
He-Cd - Helium cadmium
HF - Hydrofluoric acid
KOH - Potassium hydroxide
MS - Metal semiconductor

MSM	-	Metal Semiconductor Metal
NBE	-	Band edge emission
nm	-	Nanometer
n-PSi	-	nano – porous silicon
NS	-	Normal silicone
P	-	Porous
PEC	-	Photo –electrochemical etching
PINs	-	Positive intrinsic negative photodiode
PL	-	Photoluminescence
PLAL	-	Pulsed Laser Ablation in Liquid
PS	-	Polished Silicone
PSi	-	Porous silicon
Pt	-	Platinum
PV	-	Photovoltaic
RCA	-	Radio corporation of America
RF	-	Radio frequency
RMS	-	Root mean square
rpm	-	Round per minute
RT	-	Room temperature
SEM	-	Scanning electronic microscopy
Si	-	Silicon
SiO_2	-	Silicon dioxide
UV	-	Ultra violet
UVPDs	-	Ultraviolet Photodetectors
VB	-	Valance band
XRD	-	X -ray diffraction
Z nO	-	Znic oxide
ZONSs	-	Zinc oxide nanostructures

LIST OF SYMBOLS

D - Average Crystallite size

ΔD - Average discrepancy

I - Current

I-V - Current Voltage

J - Current density

JV - Current density–voltage

P - Density of bulik silicon

θ - Diffraction Bragg angle

m_d - Dissolved silicon mass

m_e^* - Effective mass of the electron in the conduction band

m_h^* - Effective mass of the hole in the valance band

m_o - Electron rest mass

eV - Electron volt

J_{ep} - *Electropolishing voltage*

E_g - Energy band gap

E_{ex} - Energy band gap excitation light source

E_s - Energy excited surface state

E_v - Energy of carriers at the bottom of the VB edge

S - Etched wafer area

m_d - Dissolved silicon mass

ν - Frequency

P_{in} - Incident solar power

a_{bs} - Lattice constant of bulk silicon

a_{ps} - Lattice constant of PSi layer

C - Lattice constant of the strained ZnO filim

c_o - Lattice constant of the unstrained ZnO filim

I_m - Maximum current

J_m - Maximum current density

P_m - Maximum power output

E_{ph} - Photon energy

h - Planck’s constant

d - Pore diameter

ε_{zz} - Strain

d_1 - Thickness of porous layer

m_t - Total mass of etched Si

V - Voltage

m_2 - Weight of the Si after etching

m_3 - Weight of the Si after removal of the porous layer

m_1 - Weight of the Si before etching

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

In 1959, the American physical society at California institute of technology has witnessed the presentation of the monumental talk about "things on an ultra-small" by Professor Richard Feynman (Samavati and Ismail 2019) which opened up new gateways of nanoscience and nanotechnology nowadays. The possibility of direct utilization of individual atoms stronger than artificial chemistry, those used at that time was considered. After that talk world observed the extraordinary developments in nanotechnology (C. T. Chen, Chrzan, and Gu 2020). In 1974, the Late Norio who was the researcher in the university of Tokyo used the term nanotechnology for the first time to refer to materials at the scale of nanometer.

Recently design, characterization, production, and application of materials, which involve the manipulation of matter at the smallest scale, have been widely used as current meaning of nanotechnology rather than just materials. Three distinct aspects can be considered for evolution of nanotechnology such as indirect, direct, and conceptual. The advanced miniaturization of obtainable technologies, which opened up new areas of application for those technologies, can be explained by indirect aspect. Direct refers to the application of novel nanoscale artifacts to improve the performance of presented process and materials or for completely novel purposes. Finally, there is a conceptual aspect of nanotechnology, in which all materials and process considered from molecular or even atomic viewpoint especially in living system and biology. Now a few areas of technology are exempt from the advantages of nanotechnology (A. Singh, Dubey, and Dubey 2019). The information and communication systems such as novel semiconductor and optoelectronic device, environment (filtration), energy (reduction of energy, consumption increasing, the efficiency of energy production nuclear accident cleanup and waste storage), heavy industry (aerospace and catalysis), and consumer goods are some applications of nanotechnology(Yetisen et al. 2016).

Amongst various thin films, ZnO thin films have been extensively studied as the preferable semiconductor because of their potential applications, as piezoelectric transducers, optical waveguides, acousto-optic media, surface acoustic wave devices, conductive gas sensors(L. Zhu and Zeng 2017), transparent conductive electrodes, solar cell windows, and varistors (Si et al. 2017), Thus numbers of oxide materials are being explored to establish correlation among morphology and properties. One such example is ZnO that has been reported to be the richest family in terms of different morphologies and material structures. Depending upon morphology, ZnO has vast area of application in electronics(Mora-Fonz et al. 2017).

It is proven that the properties materials at nanoscale are very different from their bulk counterpart. The large surface area to volume ratio and the quantum confinement or quantum size effects make low dimensional distinct compared to bulk materials. For example, metals (e.g. Au and Ag) at nanoscale possess an enhanced absorption and scattering properties for visible light due to the influence of surface plasmon resonance (SPR) (Louis and Pluchery 2017). Whereas, semiconductors materials (e.g. ZnO and TiO_2) at lower dimensions (nanometer size) show emerging optical and electronic structure properties due to quantum size effects. Several studies revealed that the effect of quantum confinement in semiconductor nanostructures appears more prominent at length scale comparable to exciton Bohr radius, where energy levels become quantized (Filikhin, Matinyan, and Vlahovic 2014; Senger and Bajaj 2003).

Certainly, nanotechnology offers diverse prospective applications in the field of optics, energy system, electronics, biomedicine, biology, environment, security, gas sensing etc. to cite a few(Karim et al. 2019). Depending on the dimension of nanostructures, materials are categorized as zero dimensional (0D) called nanoparticle (NP); one dimensional (1D) called nanowire (NW) and nanorod (NR); two dimensional (2D) known as quantum well (QW) and three dimensional (3D) flowerand multipod- like nanostructures as shown in Figure 1.1 (G. Cao 2004; Vanalakar et al. 2015; N. Wang, Yang, and Yang 2011).

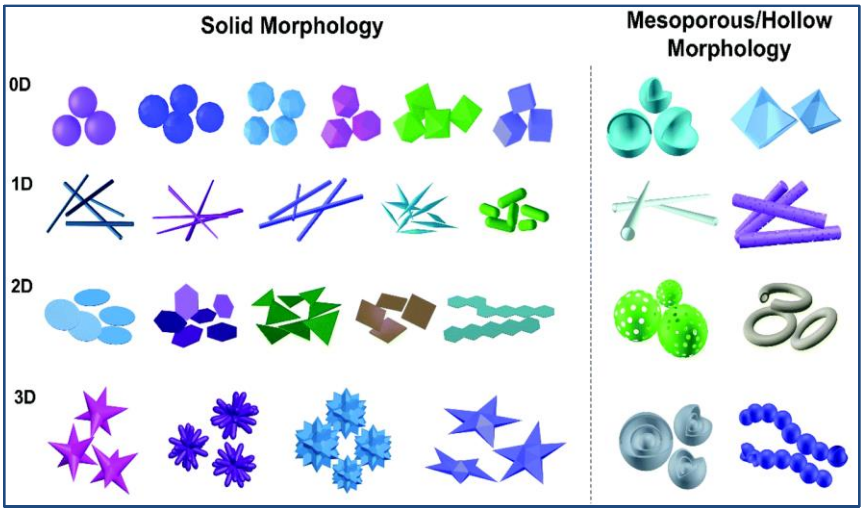

Figure 1.1 Overview of different structures and geometries at nanoscale (Wu, Yang and Wu, 2016).

Amongst various wide band-gap semiconductor nanomaterials, zinc oxide (ZnO) nanostructures (ZNSs) are very prospective in broad array of technological applications owing to their excellent electronic structure properties together with biocompatibility. Diverse nanostructures of ZnO with unique features can easily be achieved using different synthesis methods (Djuriić, Ng, and Chen 2010). These nanostructures possess outstanding optical properties which are advantageous for the advancement of photovoltaic and optoelectronic nanodevices. Furthermore, control of ZnO epitaxial layer quality together with native and dopant point defects remains a vital issue for direct nanodevice production (UTLU 2019).

In the past, numerous techniques are developed and utilized for the production of diverse ZNSs under specific controlled growth conditions (Van Khai et al. 2018). These methods include pulsed laser deposition (PLD), sol-gel processing, spray pyrolysis, electrochemical deposition, pulse laser ablation in liquid (PLAL), metal organic chemical vapour deposition (MOCVD), molecular beam epitaxy (MBE), radio-frequency (RF) sputtering, hydrothermal etc (UTLU 2019). Different techniques produce different kinds of ZNSs morphology such as ZNPs, ZNWs, ZNRs, ZnO nanoleafs (ZNLs), ZnO nanobelts (ZNBs), ZnO nanocages (ZNCs), ZnO nanoflowers

(ZNFs) etc. Figure 1.2 shows the scanning electron microscope (SEM) images of different types of ZNSs.

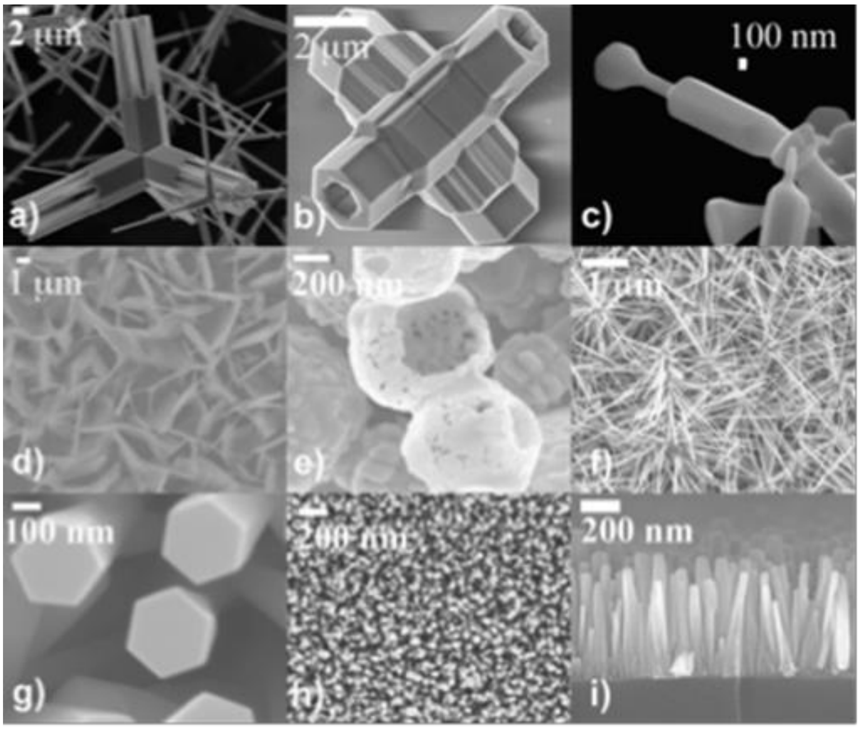

Figure 1.2 SEM images of some examples of various morphologies of ZnO nanostructures: (a), (b) tetrapod structures; (c) variable diameter structures; (d) nanosheets; (e) nanoshells; (f) multipods; (g), (h), and (i) nanorods.

Despite much progress in the preparation methods, controllable growth of ZNSs with desired properties are still demanding for several applications including electronics, optoelectronics, gas sensing, energy conversion/storage devices and photocatalysis (Ansari et al. 2018). Research revealed that the characteristics of produced ZNSs and their subsequent applications are critically decided by the nature of growth technique and the inter-play of different growth parameters (temperature, time, precursor type and concentration, seed layer, nutrient pH value etc.) (Kasim et al. 2018). All these parameters associated with the conventional growth techniques revealed their strong influence on the quality of ZNSs such as morphology, structure quality, size, density, alignment, electrical and optical properties and so on (Hynek et al. 2014). Earlier, many attempts are made to control the physical, structural, electrical and optical properties of ZNSs under different growth conditions. The main aim was to determine the significant behaviors of ZNSs towards the advancement of novel and efficient nanodevices (Kuriakose, Satpati, and Mohapatra 2020; Öztürk et al. 2019; Yi Zhou et al. 2019).

In addition, metal doping such as Au, Pt or Pd, etc. in oxide semiconductors is a typical method used to enhance ZnO nanostructures properties. The metal dopant acts as a catalyst to modify surface reactions of metal oxide semiconductors. Several studies have been reported on the enhancement of sensitivity and stability of nanostructures using doping with metal catalysts for example, Pd-doped ZnO nanotetrapods as an ammonia sensor showed that the sensitivity, response time and stability of Pd-doped ZnO sensor have been enhanced. Also, Pt-coated ZnO nanorods and thin films for hydrogen sensing at room temperature. It was found that the nanorods showed higher responses to hydrogen than these of thin films (N. Hongsith, C. Viriyaworasakul, P. Mangkorntong, N. Mangkorntong 2018). ZnO is an n-type semiconductor, which is widely used in various practical applications such as sensors, biodegradable and biocompatible electronics, photo catalysis, solar cells, transparent electrodes and photodetectors (Bandi et al. 2019; Deka Boruah 2019; Shetti et al. 2019).

ZnO is a nontoxic inorganic semiconductor which could provide several potentially useful features as high mobility, excellent thermal and chemical stability, biocompatibility and high transparency, therefore has been extensively studied for various applications (Shetti et al. 2019). As the UV light only takes up 5% of sunlight reaching on earth's surface, the practical application of ZnO photocatalysts is largely restricted due to its large energy gap (Eg = 3.37 eV). In recent years, many practical procedures have been applied to inforporate noble metals Au (P. K. Chen et al. 2018), Ag (Ansari et al. 2014) and Pt (J. Yuan et al. 2019)) onto ZnO such as sputtering methods, thermal strategies, chemical approach and photodeposition routes (Kochuveedu, Jang, and Kim 2013). These efforts have been dedicated in order to inhibit charge recombination and make it possible for ZnO to be applied in visible-light photocatalytic process. Noble metal nanoparticles have been confirmed to increase the photoenergy conversion efficiency of semiconductors by contributing the separation of charge carrier and extending the light absorption by surface plasmon resonance (SPR) effect. In fact, this is a collective oscillation of the free conduction-band electrons at the interface between noble metal nanoparticles and dielectrics driven by the electromagnetic field of incident light in visible regions(John Peter et al. 2017). Among them, Au was proved to be a useful material for the range of applications leading to improvement in catalytic properties due to the versatile properties such as the capacity to alter the physicochemical properties, surface plasmon resonance (SPR) phenomenon, conductivity and chemically stable(Zainab N. Jameel* 2017). And Au/ZnO nanocomposites have been found in numerous applications such as dye-sensitized solar cells, photocatalysis, gas sensing, antibacterial and biological detection due to their distinctive physical and chemical properties such as nonlinear optical property and efficient fluorescence resonance energy transfer property (Manish Deshwal 2018). Although considerable efforts have been made on the synthesis of a serious Au/ZnO hybrid, most of the reported nanostructures were formed by ZnO supporter with Au nanoparticles deposited (Ghaemi-moghadam, Hasanzadeh, and Rahmati 2021).

1.2 Problem Statement

Some reports have already been demonstrated the potential of gold nanoparticles (AuNPs)-doped zinc oxide nanostructures (ZONSs) for the ultraviolet (UV) metal-semiconductor-metal (MSM) photodetectors (PDs) and solar cells applications (GuruSampath Kumar , Xuejin Li , YuDu , Youfu Geng 2019). Only few studies have been on the fabrication of ZONSs with different thickness of layers via radio frequency (RF) sputtering and the effects of various processing parameters on the structures (Chianese et al. 2019), morphologies and optical traits of ZONSs. In addition, the mechanism of the growth evolution and the prodetector performance of the AuNPs-doped ZONSs have not clearly been understood. Thus, it is important to synthesize good quality ZONSs doped with different noble metallic nanoparticles with customized structures, morphologies, electrical and optical characteristics for functional devices applications which are still lacking (Hossein-Babaei and Akbari-Saatlu 2020). The RF sputtering method being versatile can be used to tailor various properties of the grown ZONSs (Ekem et al. 2009), where different system parameters

(RF power, gas flow rate, nature of gases, types of substrates, growth temperature and time) can be controlled. Meanwhile, pulse laser ablation in liquid (PLAL) technique has shown great promise to produce high quality and accurate colloidal nanoparticles of various organic and inorganic materials with narrow size distribution. A combination of these two growth methods for the production of metals NPs-doped ZONSs has seldom been implemented (Dwivedi, Srivastava, and Kumar 2020). In this view, the present study intends to combine these two methods to produce a series of AuNPs-doped ZONSs.

So far, no studies have been conducted to optimize the growth parameters of the AuNPs-doped ZONSs for outperforming UV photodetectors fabrication. Before designing the photodetectors and evaluating their performance (K. Omri , A. Alyamani 2019), it is essential to characterize the synthesized these NSs thoroughly. It is believed that in addition to the processing conditions the nature of substrates play a significant role on the overall properties of the synthesized ZONSs (Soni, Mulchandani, and Mavani 2020). Therefore, to get the best ZONSs and AuNPs-doped ZONSs UV photodetectors it is vital to optimize substrate and other growth conditions. Previous studies showed that by doping ZONSs with metallic element such as Ag or Pt it is possible improve the sensitivity of the gas censor and photodetectors performance (Ansari et al. 2014; Y. Liu et al. 2021). Yet, the effects of AuNPs doping in ZONSs and obtained MSM UV photodetector performance have not been evaluated systematically. In this thesis, an attempt has been made to combine two growth methods (under optimum growth condition) for improving the structural, optical, electrical and morphological properties of the as-prepared ZONSs and AuNPs-doped ZONSs samples.

Systematic analyses and measurement of various properties of the samples and performance evaluation are prerequisite for the optimization and photodetectors device fabrication (Sohrabnezhad and Seifi 2016). Despite many research efforts, so far, only few studies have been performed to get AuNPs-doped ZONSs-based MSM UV photodetectors with high efficiency (Patrícia Pereira-Silva 2020). Based on these factors, efficient AuNPs-doped ZONSs-based MSM UV photodetectors have been fabricated to evaluate their overall performance. Properties of the AuNPs-doped

ZONSs PDs were shown to be improved and the modifications in the overall behavior of the ZONSs samples could achieve optimized MSM UVPD characterized by large surfaces and high-quality structures that required for diverse functional applications(GuruSampath Kumar , Xuejin Li , YuDu , Youfu Geng 2019; B. Yao et al. 2019). The optimally synthesized ZONSs and AuNPs- doped ZONSs-based MSM PDs revealed high efficiency and fast response. It was shown that by choosing the appropriate synthesis method and growth parameters the structure, morphology, optical and electrical properties (I-V curves, rise time, recovery time, sensitivity and responsivity) of the AuNPs-doped ZONSs-based MSM PDs can be tuned.

1.3 Objectives of the Study

(i) To synthesize high quality AuNPs in liquid, ZONSs and AuNPs-doped ZONSs on various types of substrates at constant temperature using different techniques for getting optimum sample.

(ii) To determine the structure, morphology and optical properties of the prepared AuNPs, ZONSs and AuNPs-doped ZONSs needed for photodetectors fabrication.

(iii) To evaluate the current voltage characteristics of the photodetectors designed using the optimum undoped ZONSs and AuNPs-doped ZONSs.

(iv) To determine the performance of the designed MSM photodetectors in terms of I-V curves, rise time, recovery time, sensitivity and responsivity.

1.4 Scope of the Study

The research scope of this thesis includes:

(i) Deposition of ZONSs (at a rate of 0.3 A^{o}/sec) on the borosilicate glass and three types of n-Si (100) (plain, polished and etched with surface treatment) substrates using the versatile radio frequency (RF) sputtering method at optimum operation condition.

(ii) Control of the layer thicknesses of the deposited ZONSs on both substrates were varied in the range of 100 to 400 nm.

(iii) Determination of the optimum substrate and thickness.

(iv) Preparation of the colloidal AuNPs inside deionised water (DW) using the pulse laser ablation in liquid (PLAL) technique from gold target ablation via the Nd-YAG laser (1064 nm)

(v) Characterization of the AuNPs inside DW using the high-resolution transmission electron microscopy (HRTEM), field emission scanning electron microscopy (FESEM) and UV absorption spectroscopy.

(vi) Selection of the optimum AuNPs colloidal suspension for doping into ZONSs.

(vii) Soaking of the optimum AuNPs colloidal suspension under both at dark and room temperature for 48 hours on the deposited optimal ZONSs film to achieve the best AuNPs-doped ZONSs useful for the photodetector fabrication.

(viii) Deposition of the silver (Ag) electrodes on the AuNPs-doped ZONSs film using the RF sputtering to design the MSM (Ag/n-ESi/ZONSs-AuNPs/Ag) UV photodetector.

(ix) Measurement of the current-voltage (I-V) characteristics of the obtained photodetector in the dark and under UV light (380 nm) illumination.

(x) Optimization of substrates and the growth parameters of radio frequency (RF) sputtering methods for the synthesis of ZONSs on for type of substrates.

(xi) Characterizations of the structural, morphological and optical properties of the ZONSs and AuNPs-doped ZONSs samples at room temperature using X-ray diffraction (XRD), energy dispersive X-ray (EDX) spectroscopy, Raman spectroscopy, atomic force microscopy (AFM), field emission scanning electron microscopy (FESEM), UV-Vis absorption spectroscopy, and photoluminescence (PL) spectroscopy.

(xii) Fabrication of MSM UV PDs using the optimally synthesized ZONSs and AuNPs doped ZONSs.

(xiii) Performance evaluation of the proposed photodetectors (MSM UV PDs) in the dark and under UV light illumination.

(xiv) Measurements of the I-V characteristics of the designed MSM UV PDs.

(xv) Comparison of the detection performances of the PDs fabricated from ZONSs and AuNPs doped ZONSs samples.

1.5 Significance of the Study

The results of this study are expected to contribute to the benefit in science and technologies those semiconductor (ZnO) nanostructures, AuNPs and AuNPs-doped ZONSs-based UV photodectors. The ever-growing demands for the high performance applications indeed justify the requirement of effective and enhanced ZONSs with optimum and customized properties that are advantageous for diverse application. The RF sputtering method for the production of high quality ZONSs and the preparation of AuNPs of narrow size distribution is vital for various applications. This study can improve the performance of the NSs and NPs with optimized growth parameters. In addition, the basic mechanism behind the growth evolution of the produced NSs and the function of the photodectors will be understood. For the first time, the synergy between RF sputtering and PLAL method producing the optimum doped samples will be elucidated. The generated knowledge will be helpful for the future development of AuNPs-doped ZONSs-based UV photodectors and other optoelectronic devices.

1.6 Thesis Organization

Chapter 1 presents a brief background on the subject matter and an overview of the syntheses of ZnO films as well as the significance of photodetectors. Chapter 2 provides a comprehensive literature review and theoretical background of the formation and deposition of n- ZONSs layers and AuNPs doped ZONSs in addition to their photodetector applications. The basic principle and mechanism of photodetector operation is also presented in this chapter.

Chapter 3 presents in detail the research methodology, which comprises experimental set up of the various synthesis methods of AuNPs and AuNPs doped ZONSs, description of the characterization tools, fabrication of the MSM UV photodetector and the process of doping. The preparation of the Si samples used to synthesize layers was also described in this chapter. Furthermore, this chapter explains the process of fabricating the undoped Pt/ZONSs/AuNPs/Pt UV photodetector. The performance of the undoped and doped Pt/ZONSs/AuNPs/Pt UV photodetectors is compared.

Chapter 4 presents the results on the effect of varying the current density of RF Sputtering method on the structural and optical properties of ZONSs layers deposited on three type of Si wafer of (100) (normal, polished, etching and Glass). Afterwards, the ZONSs layer with optimal current density (from each orientation) was selected as the best substrate to grow AuNPs using the RF sputtering technique. The properties of the samples required for the fabrication of the photodetector device and the effects of doping AuNPs on the morphology, structural, and optical characteristics AuNPs doped ZONSs arrays synthesized on Si and glass substrate are discussed. The ZONSs layer with optimal thickness (from each orientation) was selected as the most suitable substrate for fabrication of the photodetector device. In addition, the results on the doping of AuNPs on the structural and optical properties of undoped ZONSs and ZONSs-doped AuNPs s are presented in this chapter. The results are comparatively analysed in this chapter. Chapter 5 concludes the thesis with deductions inferred from the results..

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