SYNTHESIS AND CHARACTERIZATION OF $Cu_2Zn_{1-x}Cd_xSnS_4$ QUINTERNARY ALLOY NANOSTRUCTURES USING SOL- GEL ELECTROSPINNING TECHNIQUE

by

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LIST OF SYMBOLS

T	Thickness
a, b, c	Lattice Parameters
hkl	Miller Indices
d_{hkl}	Inter Planar Spacing
Λ	The Wavelength
β	The Full Width at Half Maximum
θ	Bragg Angle
δ	The dislocation density
Ε	Micro Strain
Κ	Boltzmann's Constant
T	Temperature
A	the absorption
Α	Absorption Coefficient
E_t	the tail width
P_{max}	maximum power point
E_g	Energy Band gap
D	The crystallite size
T	Transmission of Light
$h\nu$	Photo Energy
E_{phonon}	The Phonon Energy
P	Density
B_0	the observation
I	Current

A	Area of Contact
Q	Electron Charge
ρ	Resistivity
I_{ph}	The Photocurrent
I_{dark}	Current in dark
Δm	difference of substrate weight
C	Velocity of light
H	Efficiency
Δ	the dislocation density
I-V	Current–Voltage
R	Responsivity
S	The Photoconductor Sensitivity
T	Time
J_m	current density
V_m	Voltage
H	Efficiency
FF	fill factor
J_{SC}	current density
P	power density
V_{OC}	open circuit voltage
J_{SC}	Short circuit current
R_{sh}	shunt resistance
P_{in}	incident light power density

LIST OF ABBREVIATIONS

2-D	Two Dimensional
3-D	Three Dimensional
a. u.	Arbitrary Unit
AFM	Atomic Force Microscope
CZCTS	$Cu_2ZnCdSnS_4$
CZTS	Cu_2ZnSnS_4
EDX	Energy dispersive X-ray
F-SEM	Field Emission-Scanning Electron Microscope
FWHM	Full Width at Half Maximum
M	Molarity
Ms	number of moles
M_{wt}	molecular weight
PD	Photodetector
PL	Photoluminescence
PS	porous silicon
R_{ec}	Decay Time of Photoconductive Device
R_{es}	Rise Time of Photoconductive Device
RMS	Root Mean Square
UV-Vis	Ultraviolet-Visible
V	liquid size
W	weight
XRD	X-ray Diffraction

Sintesis, Analisis Dan Pencirlan Struktur Nano Aloi Kuinterari Quinteranry Menggunakan Kaedah Sol- Gel elektrospinning teknik

ABSTRAK

Tujuan utama kerja penyelidikan yang dibentangkan dalam tesis ini adalah mensinstesis struktur nano $Cu_2Zn_{1-x}Cd_xSnS_4$ dengan kepekatan Cd (x=0 to 1) di atas gelas, silikon berliang (PS), silikon teroksida (SiO_2) and substrat GaN menggunakan kaedah berbeza penyalutan spin dan teknik elektrospinning bagi heterosimpang, sel solar dan aplikasi pengesan DNA Denggi jenis-2. Dalam kerja ini, kami telah mengkaji kesan kepekatan (0.3, 0.5, 0.7 dan 0.9 mol/L) tembaga (Cu) yang berbeza ke atas sifat struktur, morfologi, optikal dan elektrikal struktur nano aloi kuinterari $Cu_2Zn_{1-x}Cd_xSnS_4$ yang disediakan menggunakan kaedah penyalutan spin. Luang jalur terus struktur nano aloi kuinterari $Cu_2Zn_{0.8}Cd_{0.2}SnS_4$ menurun apabila kepekatan Cu meningkat daripada 1.81 eV pada 0.3 M kepada 1.60e V pada 0.9 M. Nilai penghantaran dalam julat 63-49% juga bergantung kepada kepekatan Cu. Indeks refraktif dan pemalar dielektrik optikal dikira dan selaras dengan hasil eksperimen dan teori. Sifat elektrik dikaji oleh ukuran kesan Hall menunjukkan kenkonduksian jenis-p dengan pembawa kepekatan antara 7.819×10^{12} cm^{-3} dan 3.76×10^{14} cm^{-3}. Ia mencerap penurunan linear dalam luang jalur $Cu_2Zn_{1-x}Cd_xSnS_4$ / struktur struktur nano aloi kuinterari gelas seperti peningkatan kepekatan Cd. Nilai penghantaran adalah 73% pada x = 0 and 39% pada x = 1. Ukuran Kesan Hall menyarankan supaya semua struktur nano matang mempunyai konduksi jenis-p. Keputusan XRD menunjukkan struktur nano aloi kuinterari $Cu_2Zn_{1-x}Cd_xSnS_4$ mempunyai polihabluran pelbagai fasa dengan orientasi utama bersama arah (112) dan (312) dengan struktur kesterit pada x=0 dan struktur stannit pada x=1. Struktur nano aloi kuinterari $Cu_2Zn_{1-x}Cd_xSnS_4$ atas PS (63.93%) dan si substrat dengan kepekatan Cd berbeza dimasukkan melalui penyalutan spin yang berjaya diuji bagi heterosimpang. Arus ke voltan (I-V) heterosimpang Ag/n-PS/$Cu_2Zn_{1-x}CdSnS_4$/Ag x= 0, 0.6, 1 dicirikan. Photosensitiviti meningkat apabila kepekatan Cd meningkat kepada (3401.36) bagi x=0.6 berbanding (282.40) bagi x=0 dan (567.68) bagi x=1. Kaedah berbeza bagi teknik elektronikspinning digunakan bagi pensintesisan nano optik aloi kuinterari $Cu_2Zn_{1-x}Cd_xSnS_4$. Sifat optikal yang dikendalikan melalui UV-Vis menunjukkan bahawa luang jalur menurun daripada 1.75 eV kepada 1.61 eV apabila kepekatan Cd meningkat. ZnO:Al/CdS/$Cu_2Zn_{0.4}Cd_{0.6}SnS_4$/Al/gelas dipilih bagi menfabrikasikan sel solar di bawah AM 1.5 G pencahayaan solar yang disimulasi dengan keamatan 100 mW/cm^2 kecekapan penukaran tertinggi 3%. struktur nano aloi kuinterari $Cu_2Zn_{1-x}Cd_xSnS_4$ dengan kandungan Cd x=0, 0.6, 1 yang berbeza disediakan menggunakan teknik penyalutan spin ke atas substrat GaN. Pencirian elektrik diod Ag/n-GaN /$Cu_2Zn_{1-x}Cd_xSnS_4$/Ag melalui arus kepada pencirian voltan (I-V) menunjukkan respon-foto tertinggi komposisi $Cu_2Zn_{0.4}Cd_{0.6}SnS_4$. Akhir sekali, struktur nano aloi kuinterari ($Cu_2Zn_{1-x}Cd_xSnS_4$) dengan kepekatan Cd yang berbeza melalui teknik penyalutan spin ke atas substrat SiO_2 disintesis. Saiz biasa bijian struktur nano aloi kuinterari ($Cu_2Zn_{1-x}Cd_xSnS_4$) adalah diantara 27.06 nm bagi Cu_2ZnSnS_4 dan 43.12 nm for Cu_2CdSnS_4. Anjakan luang jalur PL daripada 1.79 eV (x=0) kepada 1.69 eV (x=1) diperhatikan. Tambahan lagi, struktur novel yang dihasilkan dikenal pasti lebih sesuai bagi biopengecaman, seperti yang dibuktikan oleh pengesan DNA jenis-2 Denggi dengan ketentuan/spesifisiti tinggi. Biopenderia menunjukkan struktur nano aloi kuinterari boleh memperoleh sensitiviti sehingga 100fM dan boleh membeza layan DNA tertentu daripada denggi untuk melawan satu atau tiga salah padanan.

Synthesis and Characterization of $Cu_2Zn_{1-x}Cd_xSnS_4$Quinternary Alloy Nanostructures Using Sol- Gel Electrospinning Technique

ABSTRACT

The principal aim of the research work presented in this thesis is to synthesise nanostructured $Cu_2Zn_{1-x}Cd_xSnS_4$with different Cd concentrations (x=0 to 1)on glass, porous silicon (PS), oxidized silicon (SiO_2) and GaN substratesusing different methods of spin coating and electrospinningtechniquesfor heterojunction, solar cell and Dengue type-2 DNA detector applications. In this work, we have studied the different effect copper (Cu) concentrations (0.3, 0.5, 0.7 and 0.9 mol/L) on the structural, morphological, optical and electrical properties of $Cu_2Zn_{0.8}Cd_{0.2}SnS_4$quinternary alloy nanostructures prepared by spin coating technique. The direct band gap of $Cu_2Zn_{0.8}Cd_{0.2}SnS_4$quinternary alloy nanostructures decreases as Cu concentration increases from 1.81 eV at 0.3M to 1.60eV at 0.9M. The transmittance value in the range 63-49% was also dependent on Cu concentration. The refractive index and optical dielectric constant are calculated and gave good agreement with experimental and theoretical results. Electrical properties studied by Hall Effect measurement, showed p-type conductivity, with a carrier concentration between 7.819×10^{12} cm^{-3} and 3.76×10^{14} cm^{-3}.It was observed a linear decreasing in the band gap of $Cu_2Zn_{1-x}Cd_xSnS_4$/glassquinternary alloy nanostructures as Cd concentration increases.The transmittance value was 73% at x = 0 and 39% at x = 1. Hall Effect measurements suggest that all the grown nanostructures have p-type conduction. XRD results showed that $Cu_2Zn_{1-x}Cd_xSnS_4$quinternaryalloy nanostructures has multiphase polycrystalline with preferential orientation along (112) and (312) directions with kesterite structure at x=0 and stannite structure at x=1.The $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructures on PS (63.93%) substrate with different Cd concentration deposited via spin coating technique were successfully examined for heterojunction. The current-to-voltage (I-V) of Ag/n-PS/$Cu_2Zn_{1-x}CdSnS_4$/Ag heterojunction at x= 0, 0.6, 1 was characterized. The photosensitivity increases as Cd concentration increases to of (3401.36) for x=0.6 compared with (282.40) for x=0 and (567.68) for x=1 respectively. Different method electrospinningtechnique is used to synthesise of $Cu_2Zn_{1-x}Cd_xSnS_4$quinternaryalloynanofibres. Energygap wasdecreasedfrom1.75eV to 1.61eV as Cd concentration increases.ZnO:Al/CdS/$Cu_2Zn_{0.4}Cd_{0.6}SnS_4$/Al/glass were selected to fabricate solar cellsunder simulated AM 1.5 G solar illumination with intensity of 100 mW/cm^2 the highest conversion efficiency of 3%.Also$Cu_2Zn_{1-x}Cd_xSnS_4$quinterary alloy nanostructures with different Cd contents x=0, 0.6, 1 were prepared using spin coating technique on GaN substrate. The electrical characterization of the Ag/n-GaN /$Cu_2Zn_{1-x}Cd_xSnS_4$/Ag diode through current to voltage (I–V) characterization showed the highest photo-response of $Cu_2Zn_{0.4}Cd_{0.6}SnS_4$ composition.Finally, The quinternary alloy ($Cu_2Zn_{1-x}Cd_xSnS_4$) nanostructure with different Cd concentrations via spin coating technique on SiO_2 substrate was synthesised. The average grain size of $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructure was between 27.06 nm for Cu_2ZnSnS_4 and 43.12 nm for Cu_2CdSnS_4 nanostructures . A shift of PL band gap from 1.79 eV (x=0) to 1.69 eV (x=1) was observed. Furthermore, the generated novel structure was found to be more suitable for biorecognition, as evidenced by Dengue type-2 DNA detection with higher specificity. The biosensor shown with quinternary alloy nanostructure could attain the sensitivity to

100 fM and able to discriminate specific DNA from dengue against single and triple mismatches.

CHAPTER 1

INTRODUCTION

1.1. Overview

The need for sustainable energy sources is always current and solar cells can be one of the main solutions. Especially thin film solar cells have a high potential since only a small amount ofactive material is needed for every solar cell. $Cu(In,Ga)Se_2$(CIGS) is one of the most highperforming,commercial alternativesbut due to the high price and limited availabilityofthe metal indiumit has been increasingly interesting to search for replacementsfor this material. One of the most promising alternatives is Cu_2ZnSnS_4(CZTS) and Cu_2CdSnS_4 (CCTS)(Katagiri et al.2001; Kamoun et al. 2007; Levcenco et al. 2012) .

$Cu_2B^{II}B^{IV}(S; Se)_4$ (B^{II} = Mn, Fe, Co, Ni, Zn, Cd, Fe and Hg; B^{IV} = Si, Ge, and Sn), is a quinternarysemiconducting material which has been generating interest over the last decade for applications in photovoltaics. Cu_2ZnSnS_4 offers favorable optical and electronic properties that are useful for thin film applications, and is composed of abundant in the crust of the earth and non-toxic elements. Furthermore, CZTS film has high absorption coefficients ($>10^4$ cm^{-1}), an optimal direct band gap (Ito & Nakazawa, 1988; Katagiri et al., 2001; López-Vergara et al 2013).Kesterite Cu_2ZnSnS_4, (CZTS), is a quaternary semiconducting material which has been generating interest over the past decade for applications in thin film photovoltaics. CZTS offers favorable optical and electronic properties that are advantageous for thin film applications, and is composed of abundant, non-toxic elements. The current record for CZTS photovoltaic efficiency is 6.7% (Todorov et al 2010), although higher effciencies are necessary for the commercialization of CZTS.Current processing methods for CZTS are either expensive or detrimental to the environment, requiring harsh organic solvents and/or energy-intensive procedures. Nanocomposite techniques present aunique alternative to explore crystal growth in complex chalcogenide alloys, and could allow for thelarge-scale deployment of CZTS-based thin flmphotovoltaics for energy generation. The use of stable, solid phase precursors and environmentally benign processing methods may allow for successfulscalability of CZTS(Shiet al., 2013; Kabalah et al., 2013; Michael et al., 2013; Malerbaet al.,2014;).

1.2. Problem Statement

At present, facing the increasingly serious global energy crisis, it is of pressing importance for material research to explore environment-friendly, effective-cost, and high-efficiency solar cells (Beek, Wienk et al. 2004, Su, Ke et al. 2012, Kosten, Atwater et al. 2013). Among various kinds of solar cells, the $CuIn_{1-x}Ga_xSe_2$ (CIGS) thin-film solar cell has been paid much attentions due to its high power conversion efficiency and stability (Ramanathan, et al. 2005, Schmidt, Ras et al. 2012). However, the high costs of gallium and indium obstruct further development in the field of thin-film solar cell (Wadia, Alivisatos et al. 2009). In recent years, some efforts have been made to find lower cost materials with earth-abundant elements. Cu_2ZnSnS_4 (CZTS), as a potential material to substitute CIGS, has attracted great interest due to its direct band gap (E_g= 1.5 eV) with high absorption coefficient and earth-abundant elements by replacing In with Zn, Ga with Sn and Se with S (Todorov and Mitzi 2010, Rath, et al. 2012, Tablero 2012, Li, Li et al. 2013, Shin, Gunawan et al. 2013).

Furthermore, to improve CZTS-based solar cells, and a good choice to fabricate multi-junction solar cells of different energy band gaps with various junctions can hopefully span the whole wavelength range in the solar spectrum via $CuIn_{1-x}Ga_xSe_2$, $In_xGa_{1-x}P$ and $In_xGa_{1-x}As$ quinternary, alloys that have been used to fabricate multi-junction solar cells due to their tunable band gap by controlling In concentration. Therefore, it is important to find a band gap-tunable material based on Cu_2ZnSnS_4 (CZTS), Cu_2CdSnS_4 (CCTS) for realizing the future of effective-cost tandem solar cells with earth-abundant elements. Recently, copper-based quaternary semiconductors, such as Cu_2ZnSnS_4 (CZTS) and Cu_2CdSnS_4 (CCTS) have attracted high interest due to their potential applications in thin film solar cells (Guan, Shi et al. 2014, Li, Cao et al. 2015). In addition, the band offset at interface is one of the most fundamentally physical parameters, which is often used to assess some important interface effects, i.e., quantum confinement and carrier transport, in particular, for the design of solar cells and other optoelectronic devices.

Thin CdS buffer layer is invariably made use in the solar cells fabrication. Indeed, CdS remains the best-suited buffer materialfor using in chalcopyrite-based thin film solar cells.Rusu et al. (Rusu et al. 2009) have used elastic recoil detection analysis to show thatthe Cd and S diffuse into the absorber layer in $CdS/CuGaSe_2$chalcopyrite solar cells. Cadmium and sulfur concentrationsare found to be more than 0.1% even deep inside the absorber layer. Similar diffusion of Cd and S into the absorber layer inCdS/Cu_2ZnSnS_4 solar cells can lead to the formation of a mixed$Cu_2Zn_{1-x}Cd_xSnS_4$ solid solution at the interface. Thus, it is important to study the band gap variations, structural, morphological, optical and electrical properties of $Cu_2Zn_{1-x}Cd_xSnS_4$ layers with various Cd contents in order to optimize the solar cell efficiency. All the constituents of The $Cu_2Zn_{1-x}Cd_xSnS_4$ alloy quaternary compound are abundant in the earth's crust reducing concerns of materials costs. CZCTS is derived from compound chalcopyrite $CuInS_2$ by replacing indium element (In) which belongs to the third group III) elements by cadmium (Cd)and zinc (Zn) in the second group II) and the element of tin (Sn) in the fourth group (IV) by ratio of 50:50.The $Cu_2Zn_{1-x}Cd_xSnS_4$ alloy quaternary has a direct band gap, a high absorption coefficient at the visible solar spectrum wavelengths and a p-type conductivity as well as non-toxicity. Because of that considerable work is being carried on the quinternarycompound semiconductor $Cu_2Zn_{1-x}Cd_xSnS_4$ so as to optimize its opto-electronic properties for using as absorber layer of thin film solar cells.

1.3. Research Objective

The objective is as the followings:

1- To study of various Cd concentration on the structural, morphological, optical and electrical properties of the $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructures using spin coating and electrospinning technique grew on glass substrate

2- To research the of copper (Cu) concentration on the structural, morphological and optical properties of $Cu_2Zn_{0.8}Cd_{0.2}SnS_4$quinternary alloy nanostructures grew on glass substrate.

3- To elaborate the effect of etching times porous silicon (PS) as substrate prepared by electrochemical etching method followed by deposited $Cu_2Zn_{1-x}Cd_xSnS_4$ for characterization, analysis, optical properties and electrical properties of current–voltage (I–V) characteristics and UV photoresponse of the Ag/n-PS /$Cu_2Zn_{1-x}Cd_xSnS_4$/Agheterojunction when x= 0, 0.6, 1.

4- To investigate the effect of various Cd concentretion on the structural, morphological and optical properties of $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructures using spin coating technique prepared on oxidized silicon (SiO_2) substrate and their application in the detection of DNA sequence from Dengue type-2

5- To study the effect of various Cd concentration on the structural, morphological, optical and electrical properties of the $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructures using spin coating technique grew on GaN substrate .

1.4. Scope of research

The significance of this study includes **firstly**, the preparation of $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructures for photovoltaic (PV) absorber layers using a sol-gel spin coating and electrospinning technique without sulfurization was investigated. The obtained $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructures were analyzed, characterized and simulated on glass substrate, and the optimum Cd content (x) for PVs applications was determined. **Secondly,**prepared $Cu_2Zn_{0.8}Cd_{0.2}SnS_4$

quinternary alloy nanostructures withe different copper (Cu) concentration (0.3, 0.5, 0.7 and 0.9 mol/L) also were analyzed, characterized and simulated on glass substrate. **Thirdly,**the formation of porous silicon prepared by electrochemical on n-type Si (100) substrate. The process of etching time is 30, 60 and 120 min and the current density is 5 mA/cm^2 DC. The selected optimal etching parameters to control the shape, size, and surface morphology were using as substrate to study the structural properties and optical properties of $Cu_2Zn_{1-x}cd_xSnS_4$ quaternary alloy nanostructures. In addition to investigate the electrical properties of Ag/n-PS/$Cu_2Zn_{1-x}Cd_xSnS_4$/Ag heterojunction at x= 0, 0.6, 1.**Fourthly**, the sol–gel method was used for the preparation of a novel $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructure with different Cd concentrations (x = 0. 0.2, 0.4, 0.6, 0.8, 1) on oxidized silicon substrate. Further,we characterized $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructures and investigated how the stacking order of the precursor films affected the structural, morphological, and optical properties of the resultant CZTS nanostructures. The novelty of this $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructure was evidenced by demonstrating with the detection of DNA sequence for Dengue serotype-2, the obtained results displayed high-performance of $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructure to be used as a biosensor. **Lastly.** study, high quality $Cu_2Zn_{1-x}Cd_xSnS_4$ quinternary alloys nanostructures were deposited on GaN substrates with Cd concentration (x=0, 0.6, 1) and study the structural properties given by X-ray diffraction (XRD) and field emission-scanning electron microscope (FE-SEM), and optical properties of $Cu_2Zn_{1-x}d_xSnS_4$ quaternary alloy nanostructures by PL, in addition to investigate the electrical properties of Ag/n-GaN/$Cu_2Zn_{1-x}Cd_xSnS_4$/Ag heterojunction at x = 0, 0.6, 1.

1.5. Novelty of research

Deposited $Cu_2Zn_{1-x}Cd_xSnS4$ quaternary alloys nanostructures onto n-type porous silicon (PS) and GaN substrates, and to investigate the electrical properties of Ag/n-PS/$Cu_2Zn_{1-x}Cd_xSnS_4$/Ag, and Ag/GaN/$Cu_2Zn_{1-x}Cd_xSnS_4$/Ag heterojunction at x= 0, 0.6, 1 for heterojunctionapplications through (I–V) characterization.It is indicated that $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructure was evidenced by demonstrating with the detection of DNA sequence from Dengue type-2, the obtained results displayed high-performance of $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructure to be used as a biosensor.

1.6. Outline of the Thesis

The thesis is organized into five chapters. The first chapter describes the overview of Cu_2ZnSnS_4, problem statement, objectives, and scope of research. It briefly highlights study importance and associated problems to solve the current limitation, significances of overall structure of the thesis.

Chapter two present two physical properties of Cu_2ZnSnS_4 and reviews the literatures on the properties and application ofCu_2ZnSnS_4in solar cell.

The third chapter depicts the deposited $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructures on glass substrate using by spin coating technique with different Cd concentration (x=0-1),the $Cu_2Zn_{0.8}Cd_{0.2}SnS_4$quinternary alloy nanostructures with different Cu concentrations 0.3, 0.5, 0.7 and 0.9 Mol/L on glass substrate.The results obtained from the research are analyzed and characterized by techniques are X-ray diffraction (XRD), scanning electron microscopy (FE-SEM), EDX, atomic force microscopy (AFM), UV-Vis spectroscopy, PL and Hall measurement performed at room temperature. Also the deposited $Cu_2Zn_{1-x}Cd_xSnS_4$ quaternary alloy nanostructures onto n-type porous silicon (PS) substrate, oxidized silicon. The results obtained from the research are analyzed and discussed. The current to voltage (I-V) and current to time (I-t) characterisesunder illuminating were 490 nm and 3mW on/off for Ag/n-PS/$Cu_2Zn_{1-x}Cd_xSnS_4$/Agheterojunction at x= 0, 0.6, 1.Displays electrospinning technique alternative synthesis route for preparation of $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanofibres for photovoltaic (PV) absorber layers without sulfurization and all samples annealed at 300 °C under N_2 atmosphere for 40 min, focuses on the properties and preparation of nanostructured $Cu_2Zn_{1-x}d_xSnS_4$ quaternary alloy on oxidized silicon under different Cd concentration , and its applications to $Cu_2Zn_{0.2}Cd_{0.6}SnS_4$quinternary alloy nanostructures in the detection of DNA sequence from Dengue type-2. The current to voltage (I-V) and current to time (I-t) characterizedunder illuminating were 490 nm and 3mW on/off for Ag/n-Si/$Cu_2Zn_{1-x}Cd_xSnS_4$/Agheterojunction at x= 0, 0.6, 1. Also used sol–gel method for preparation $Cu_2Zn_{1-x}Cd_xSnS_4$quinternary alloy nanostructures with different Cd contents (x = 0. 0.6, 1) on GaN substrates. Analysis and characterization techniques, are (XRD), FE-SEM and AFM. In addition to investigate the electrical properties of Ag/GaN /$Cu_2Zn_{1-x}Cd_xSnS_4$/Ag diode at x= 0, 0.6, 1 for heterojunction applications through (I–V) characterization and current to time (I-t) characterizationilluminating were 490 nm and 3 mWon/off.

Finally, the conclusion of the overall works and suggestionsfor the future works that could be summarized in chapter four