1.1 Introduction

The technology of wide band gap semiconductors has been taking much more attention in ultraviolet (UV) potential applications. The UV region covers the spectral wavelength of 400–10 nm. The UV radiation is commonly classified into three regions: UV-A, (Near UV: 400–320 nm), UV-B, (middle UV: 320–280 nm), UV-C (far UV: 280–10 nm) [1]. The UV radiations are highly ionizing, which sparks several chemical processes and also harmful for health because these radiations are carcinogenic. The sunlight is the foremost source of the UV radiations on earth and its exposure on land is biggest and pronounced issue as the size of the ozone hole in the Antarctic stratosphere increases. UV radiation generates free radicals of chemical species that participate in the development of various pathologies, such as cancer, aging, Alzheimer’s disease, inflammatory disorders, and other ailments.

It is well known that UV radiations emitted by the sun fall on the earth are in the range 200–400 nm. The terrestrial atmosphere contains major components those are strong absorbers of radiation at wavelengths below 300 nm. At extreme ultraviolet (EUV) wavelengths (110 nm) in electromagnetic spectrum, atomic and molecular gases become strong absorbers. Almost all the radiations in the region UV-C and UV-B are absorbed primarily by ozone and molecular oxygen, respectively. As per the classification of the UV light mentioned above the largest wavelength radiations of the UV-A band can reach the Earth’s surface and many researches showed that UV-A light may cause a skin cancer [2, 3]. Therefore, development of effective UV detector that shows high UV-A sensitivity but blind towards standard visible radiation has great importance for safety of life.

A photodetector is a device that measures the photons or optical power by converting the energy of the absorbed photons into measurable form. The photodetectors has commonly two principle classes, thermal detectors and photoelectric detectors. Thermal detectors works on principle of the photothermal effect, which converts optical energy into heat energy. The thermal detectors are
comparatively slow and not much more efficient, as time is required to show effect of temperature change. The principle of the photoelectric detector is based on the photoelectric effect, which refers to the emission or ejection of electrons or electron-hole pair from the surface of the material in response to the incident light. The response of the photoelectric detector is based on the wavelength of the optical signal incident on it whereas thermal detectors are wavelength independent. The photoelectric detectors have much more spectral sensitivity than the thermal detector. Some of photoelectric detectors have capability of counting photons that is not possible with the thermal detector [4]. Thermal detectors are mostly used in the infrared region; optical power measurement etc. The photoelectric detectors are often used for the detection of optical signals in optoelectronic devices. The photoelectric effect divides in to two classes external photoelectric effect and internal photoelectric effect [4].

1.1.1 Photoelectric effects

a) External photoelectric effect

Photodetectors based on the external photoelectric effect are the photoemissive detectors such as, vacuum photodiodes, the photomultiplier tubes, etc. If the energy of a photon incident on the material in vacuum is sufficiently large, the excited electron can escape over the potential barrier of the surface of the material and be liberated into the vacuum as a free electron; this process is called as photoelectron emission. Fig.1.1 illustrates the external photoelectric effect for (a) metal and (b) semiconductor.

Due to the incident photon of energy hv a free electron from the partially filled conduction band is released. Energy conservation requires the electrons emitted from below the Fermi level, where they are plentiful, have a maximum kinetic energy [5]

\[ E_{\text{max}} = h\nu - W \]  \hspace{1cm} (1.1)
The equation (1.1) is known as Einstein’s photoemission equation. The electron which initially lies at the Fermi level can get sufficient amount of kinetic energy to liberate in vacuum level and the electrons which are lying at a deeper level require additional energy to transport it to the Fermi level and therefore these liberated electrons are reducing their kinetic energy. In semiconductor (Fig. 1.1(b)), the photoelectrons are released from the valence band,

$$E_{\text{max}} = h \nu - (E_g + \chi)$$  \hspace{1cm} (1.2)

where, $E_g$ is the band gap energy and $\chi$ is the electron affinity of the material (the energy difference between the vacuum level and the bottom of the conduction band). The photodetectors based on the external photoelectric effect are photomultiplier tubes, vacuum diodes etc.

Fig. 1.1 External photoelectric effect [6]
Photoemissive detectors

The photoelectrons are emitted from the surface of the photoemissive material, known as a photocathode, when sufficient amount of photoenergy is incident on it. The lowest vacuum energy level, $E_{\text{vac}}$, for an electron is higher than the Fermi level of the material. The energy barrier between the lowest vacuum level and the Fermi level is defined as the work function of the material. For a semiconductor, the difference between the lowest vacuum level and the conduction band edge is known as the electron affinity (Fig. 1.1(b)). Photoemission occurs only when the incident photon has an energy higher than or equal to the certain threshold energy ($E_{\text{th}}$), corresponding to an optical wavelength shorter than a threshold wavelength ($\lambda_{\text{th}}$) [6]. The values of $E_{\text{th}}$ and $\lambda_{\text{th}}$ are characteristics of a given material.

In a metal, shown in Fig. 1.1(a), electrons lie in the energy levels below the Fermi level. The threshold photon energy required for the emission of a photoelectron from a metal is $E_{\text{th}} = e\phi$, where $e\phi$ is the work function of the metal.

In nondegenerate semiconductor, shown in Fig. 1.1(b), the electrons lies in the energy levels below the valence band edge as Fermi level lies within the band gap of the material. For nondegenerate semiconductor, the threshold photon energy is $E_{\text{th}} = e\chi + E_g > e\phi$. In a degenerate semiconductor, Fermi level is the highest occupied level by electrons. Therefore, the threshold energy for photoemission from a degenerate semiconductor is the work function of that material.

![Vacuum diode diagram](image_url)

**Fig. 1.2 Vacuum diode [5]**
Introduction and theoretical background

For an n-type degenerate semiconductor, $E_{th} = e\phi < e\chi$ shown in Fig. 1.1(c), as the Fermi level lies in the conduction band. For a p-type degenerate semiconductor, $E_{th} = e\phi > e\chi + E_g$ as shown in Fig. 1.1(d), because the Fermi level lies in the valence band [6]. The photoemissive detectors are vacuum diodes, photomultiplier tubes, etc. The vacuum photodiode shown in Fig. 1.2 is a simple device that consists of a photocathode and an anode enclosed in a vacuum tube. The tube can also be filled with a small amount of inert gas, such as argon, to get a small internal gain through ionization of the gas by the collision of photoelectrons. The gas-filled photodiodes are no longer competitive and therefore are not practically useful because they have a limited gain and a low speed.

A photomultiplier tube (PMT) shown in Fig. 1.3 is a kind of vacuum photodiode. A PMT consists of a photocathode, an electron multiplier consisting of a chain of dynodes for secondary electron emission, and an anode to collect the electrons for the output signal. The photoelectrons which are emitted by the photocathode are accelerated towards the first dynode by applying high voltage between the photocathode and first dynode with an energy of typically 100–200 eV. When these high energy electrons hit the next dynode, a number of secondary electrons are ejected. This process goes through the adjacent dynodes.

![Fig. 1.3 Photomultiplier tube [5]](image)

A variety of photocathodes are currently used to improve the sensitivity of photoemissive detectors. The choice of photocathode material is based on the
spectral range where the device response is essential. Alkali halides have been proved to be efficient photoconverters in the extreme ultraviolet (EUV) and far ultraviolet (FUV) wavelength ranges [7]. Cesium iodide (CsI) is known to be one of the most efficient materials among them, and therefore it is widely used in many detecting devices [8]. Cs₂Te is also an extensively studied semiconductor for the application of photoemissive detector. Michelato et al [9] have studied spectral responses of Cs₂Te photoemissive film. Taft et al [10] and Powell et al [11] have studied the photoemissive properties of Cs₂Te. Recently Rai et al [12] have reported the performance of CsI as a reflective photocathode.

b) Internal photoelectric effect

The modern photodetectors are based on the internal photoelectric effect in which photogenerated charge carriers remain in the material, help to increase its conductivity. The photon of energy equal to the band gap energy of the material is incident on the material producing electron-hole pairs which are separated by an applied electrical field [13]. Depending on the photogeneration process of charge carriers, there are two principal types of photoconductivity, (a) intrinsic photoconductivity and (b) extrinsic photoconductivity [6]. The intrinsic photoconductivity is because of the excess electrons and holes that are generated by the absorption of incident photons in the intrinsic semiconductors and band-to-band transition occurs in the semiconductor, as shown in Fig. 1.4 (a). The extrinsic photoconductivity is lent by the charge carriers that are generated by transitions occurred within impurity levels present in the band gap of an extrinsic semiconductor. In an n-type extrinsic semiconductor, the impurity levels called as donor levels with energy E_d present below the conduction band, electrons are excited from these donor levels to the conduction band, as shown in Fig. 1.4 (b). In a p-type extrinsic semiconductor, the impurity levels called as acceptor levels with energy E_a are present above the valence band; electrons are excited from the valence band to these acceptor levels, as shown in Fig. 1.4(c). Photoconductive
detectors cover a broad spectral range of the electromagnetic light spectrum from the ultraviolet to the far infrared. Both direct and indirect semiconductors are used for the Photoconductive detectors.

Many intrinsic semiconductors like group IV semiconductors, III–V, II–VI and IV–VI compounds are being used as intrinsic photodetectors. These intrinsic photodetectors mainly shows spectral responsivity in the visible and near infrared regions. Im et al [14] have fabricated efficient PbS sensitized photovoltaic photodetectors on a mesoporous TiO$_2$ film via the spin-assisted successive ionic layer adsorption and reaction (SILAR) method and observed 9.3% external quantum efficiency (EQE) at wavelength 1140 nm and which were capable of processing signals up to 1 kHz.

![Photoconductive detectors diagram](image)

**Fig. 1.4 Internal photoelectric effect [6]**
Szendrei et al [15] have demonstrated hybrid organic–inorganic blend of a fullerene derivative [6,6]-phenyl-C61-butyric acid methyl ester (PCBM) and PbS nanocrystals as the active medium in photodetectors. They mentioned that the detectivity of these devices compares well with that of commercial photodetectors sensitive to near-IR wavelengths. Sun et al [16] have fabricated NIR photodetectors based on CVD-grown graphene and PbS quantum dots (QDs). It has been shown that, the responsivity of the devices is much higher than those of any photoconductors based on graphene or PbS QDs reported before. Qian et al [17] have studied PbSe superlattices based infrared photodetector and measured the detectivity at -3 V under 830 nm IR irradiation. Guimaraesa et al [18] have studied InSb based IR photodetector using liquid-phase epitaxy (LPE) system. Lee et al [19] have fabricated a modulation-doped mid-infrared photodetector using self-assembled InAs quantum dots. Chang et al [20] have studied a surface plasmon enhanced infrared photodetector based on InAs quantum dots. Liu et al [21] have studied single crystalline InAs nonowire photodetectors which gives high sensitivity and high stability over a broad spectral region from UV to near infrared region.

Meanwhile most of extrinsic semiconductors like GaN, AlGaN, SiC, AlN, V2O5, Ga2O3, Nb2O5, ZnO, ZnSe, WO3, SnO2 show photosensitivity in the UV–A spectral region. GaN and AlGaN are considered as promising candidates for UV photodetectors application as it has wide band gap (3.4–6.2 eV) in the UV photon energy region [22-27]. Silicon carbide (SiC) material is known for the high-temperature and high-frequency electronic applications owing to its wide band gap (3.23 eV), high breakdown electrical field, high thermal conductivity and low thermal expansion properties [28]. It is used for the UV detection purpose, due to the good material quality and large band gap 3.23 eV [29]. Zhai et al [30] have studied V2O5 Nanowires for the application of photoconductive detector.

Kokubun et al [31] have used Ga2O3 for the application of UV–B photodetector as it has wide band gap (~ 4.9 eV) so that it is blind to wavelengths above 280 nm, the so called solar-blind photodetector. Fang et al [32] have reported
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ultraviolet photodetector based on individual Nb$_2$O$_5$ nanobelts. It is transparent to visible light, and having reliable optoelectronic properties comparable to those of existing well known optoelectronic oxide semiconductor based devices. Li et al [33] have studied WO$_3$ nanowires based UV photodetector in UV-A spectral region. SnO$_2$ is also studied for UV photodetector as it has wide band gap and good transparency in visible region [34]. Hu et al [35] have fabricated SnO$_2$ nanowires ultraviolet photodetectors. ZnSe semiconductor is more sensitive to blue/UV light and having good optical properties. ZnSe has been widely studied for the UV photodetector [36-39].

ZnO has been regarded as versatile material due to its interesting structural, optical, electrical properties and its prominent applications in the field of optoelectronic devices. ZnO nanostructures has wide spread applications in the field of UV photodetector because of its inherent properties like wide band gap (3.4 eV) and large binding energy (60 meV), which is considerably larger than other conventional semiconducting materials [40]. Because of its wide band gap energy, the ZnO metal oxide has been employed mainly as LED rather than GaN [41]. As this metal oxide is highly sensitive in the UV region, it is significantly applicable in optoelectronic devices such as UV photodetector. Such detectors are used in space research, monitoring system, optical communications etc. [42].

Among various metal oxides, ZnO based UV detector have attracted considerable attention recently because of its properties like non-toxicity, high radiation hardness and higher transparency in the visible region. It has been well known that the conductivity of ZnO can be dramatically increased under UV illumination and fact has been used in UV sensor applications.

M. Razeghi and A. Rogalski [13] have done comparative study between photoemissive and photoconductive UV detectors as mentioned below in Table 1.1.
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<thead>
<tr>
<th>Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Photoemissive UV detector</td>
<td>Easy to operate</td>
<td>Low quantum efficiency</td>
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<td></td>
<td>High sensitivity</td>
<td>Strong spectral dependence of responsivity</td>
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<td>Solar blind</td>
<td>Sensitiveness to surface contaminations</td>
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<td>photoconductive UV detectors</td>
<td>Broad spectral responsivity</td>
<td>Induced aging effects</td>
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<td>Excellent linearity</td>
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<td>High quantum efficiency</td>
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<td>High dynamic range of operation</td>
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<td>Large-format image arrays</td>
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1.1.2 General properties of photodetector

There are many parameters that describe the performance of the photodetector. These parameters specify the response of the detector and they are discussed below.

a) Quantum efficiency

The quantum efficiency \( \eta \) of a photodetector is the probability that a single photon incident on the device will generate a pair of electron and hole that contributes to the photocurrent. Not all incident photons produce electron-hole pairs because not all of them are absorbed. As illustrated in Fig. 1.5, some of the photons are reflected at the surface of the material while others fail to be absorbed because the material does not have sufficient penetration depth. Moreover, some electron-hole pairs quickly recombine because of the large quantity of recombination centers present on the surfaces, and are therefore not available to contribute to the photocurrent. The quantum efficiency can therefore be written as [5]

\[
\eta = (1 - R) \xi [1 - \exp(-\alpha d)] = \frac{I_{ph}/e}{P/h\nu} 
\]  
(1.3)
where $R$ is the optical power reflectance at the surface, $\xi$ the fraction of electron-hole pairs that successfully contribute to the detector current, $\alpha$ is the absorption coefficient of the material (cm$^{-1}$) and $d$ the photodetector depth, $I_{ph}$ is photocurrent, $P$ is incident optical power, $e$ charge on electron, $h$ is planks constant and $\nu$ is the frequency. The first factor, $(1-R)$, represents the effect of reflection at the surface of the device. The second factor $\xi$ is the fraction of electron-hole pairs that avoid surface recombination and contribute to the photo current. Surface recombination can be reduced by careful material growth and device design. The third factor, $[1-\exp(-\alpha d)]$ represents the fraction of the photon flux absorbed in the bulk of the material. The quantum efficiency is a function of wavelength, as the absorption coefficient $\alpha$ is wavelength dependent [5].

**b) Responsivity**

The responsivity of a photodetector is the ratio of photocurrent $I_{ph}$ flowing in the device circuit to the optical power $P$ incident on it. If every photon generates a pair of electron–hole pair, a photon flux $\phi$ (photons per second) will produce an electron flux $\phi$ (electrons per second) in the photodetector circuit, corresponding to a short circuit electric current $I_{ph} = e\phi$. Thus, an optical power $P = h\nu\phi$ (watts) at
frequency $\nu$ would give rise to an electric current $I_{ph}$. However, since the fraction of photons producing detected electrons is $\eta$ (unity), the responsivity of the detector is

$$R = \frac{I_{ph}}{P} = \frac{\eta e}{h \nu}$$  \hspace{1cm} (1.4)$$

Responsivity is also determined by the quantum efficiency ($\eta$) and photocurrent gain ($g$). Photocurrent gain is nothing but the number of carriers passing contacts per one generated pair [42].

$$G = \frac{N_{el}}{N_{ph}} = R \frac{1240}{\lambda (nm)} = \frac{\tau}{\tau_{tr}} = \frac{I_{ph}}{qf}$$  \hspace{1cm} (1.5)$$

So,

$$R = \frac{\lambda \eta}{hc} qg$$  \hspace{1cm} (1.6)$$

Where $\lambda$ is the wavelength, $h$ is Planck’s constant, $c$ is the light velocity, $q$ is the electron charge, and $g$ is the photoelectric current gain.

c) Response time

![Photodiode Voltage response](image)

**Fig. 1.6 Photodetector response pulse signal** [6]

The photodetector response time is described by the decay time, $\tau_d$ (or rise time $\tau_r$), defined as the time required to drop the photocurrent from 90% to 10% (or raise from 10% to 90%) of its maximum value [6] as shown in Fig. 1.6. The
response time is determined by two factors, drift of the electrons and holes that are photogenerated in the depletion layer and diffusion of the electrons and holes that are photogenerated in the diffusion regions. Drift of the carriers across the depletion layer is a fast process given by the transit times of the photogenerated electrons and holes across the depletion layer. Diffusion of the carriers is a slow process caused by the optical absorption in the diffusion regions.

1.1.3 Types of the UV photodetector

ZnO UV photodetector with various device structures has been fabricated such as metal-semiconductor-metal (MSM) photodetector, Schottky photodiodes, p-n junction photodiodes. A brief summary about the performance and the recent progress in these device structures has been discussed.

a) ZnO based MSM UV photodetector

The MSM photodetector is the simplest device consisting of a semiconductor with two ohmic contacts of the metal on the top surface. A variety of materials has been used for the contact electrode in ZnO photodetector, such as Au, Al, Pt, Al/Au, Ni/Au, ITO, FTO and so on [43]. When an incident photon has energy greater than the band gap energy of ZnO, an electron–hole pair is generated. The electron and hole are separated by the applied bias. These photogenerated electrons are collected by the contact electrodes of the samples under the influence of applied bias. The schematic structure of the MSM photodetector is shown in Fig. 1.7.

![Fig. 1.7 The schematic structure of the MSM photodetector](image-url)
 MSM detectors exhibit high internal gain which is due to the trapping of hole carriers at the semiconductor–metal interface [44]. Even with high internal gain, MSM structured UV detectors based on ohmic junction have very long decay time, large photoresponsivity and large dark current.

Zhu et al [45] have fabricated ZnO nanofibers (NFs) based UV detector with high responsivity. They observed linear I–V curve which indicating ohmic behavior of the ZnO/Au contacts. A very good detection is observed in the UV region, and the UV responsivity of device will get higher with the increasing of bias voltage. Li et al [46] have studied ZnO-based MSM UV photodetectors. Al has used as contact electrode which shows good ohmic contact with ZnO films, and higher efficiency to collect photogenerated carriers. The excellent ohmic contact between ZnO and contact electrode can create conductive paths so that a large number of photoelectrons in ZnO can be transferred to electrodes and extracted to the external circuit rapidly. Therefore, ohmic contacts will not only greatly improve the extraction number of photoelectrons, but also shorten the extraction time in polycrystalline ZnO thin films and furthermore high responsivity and short response time will be achieved. Yang et al [47] have tested performance of the ZnO MSM photodetector for both Schottky and ohmic contacts using Al, Ag and Au electrodes. Their results indicate that the Schottky contact has not given higher responsivity and faster response and recovery speeds than the ohmic contact. Fan et al [48] have studied ZnMgO photodetectors for UVB applications with MSM configuration and reveal that the ZnMgO UVB photodetectors exhibits ohmic contacts and display a fast response speed (90–10% decay time is around 24 ms) with good reproducibility and stability. Chiu et at [49] have composed MSM structured UV photodetector based on GZO and ZnO nanowires. Dai et al [50] have reported single ZnO microrod MSM ultraviolet photodetector with ohmic contact with Ag electrode and they observe that the recovery process is also much faster than those ZnO UV photodetectors with ohmic contact. Liu et al [51] have used
quartz substrates to fabricate ZnO MSM UV photodetector with preferred c-axis orientation of the film by RF magnetron sputtering.

**b) ZnO based Schottky barrier UV photodetectors**

Schottky photodiodes based on ZnO have been used as UV photodetector because of many advantages like fast response speed, higher quantum efficiency, extremely low dark current, high UV/visible contrast ratio, and it is possible to operate device at even zero bias [13,52]. The schematic of the device structure is shown in Fig. 1.8. The metal-semiconductor junctions exhibit rectifying behavior. One of the Schottky contacts is in reverse bias and the other forward bias. The rectifying property of the metal-semiconductor contact arises from the presence of an electrostatic barrier between the metal and the semiconductor which is due to the difference in work functions $\Phi_m$ and $\Phi_s$ of the metal and semiconductor, respectively [13].

![Schematic of the device structure](image)

**Fig. 1.8 The schematic of the device structure**

The I-V characteristic shows that the current increases and then saturates from low to high bias voltage, which is due to the expansion of the depletion region of the reverse biased contact and the flat-band effect of the forward biased contact, respectively [53]. The nonlinear behaviors of the I-V curve is due to the Schottky barriers formed between the semiconductor and the metal electrodes and shape of the curve depends on the height of the Schottky barriers at the interface of metal
and semiconductor. So, a same Schottky barrier height gives symmetrical I-V curves in forward and reverse bias. Liu et al [54] have fabricated ZnO UV photodetector with Ni as contact electrode show better performance both in the aspect of photocurrent and response time, it gives larger Schottky barrier at the Ni/ZnO interface. A self-powered Schottky type UV photodetector with Al–Pt interdigitated electrodes has been fabricated based on selectively grown ZnO nanowire arrays by Bai et al [55]. At zero bias, the fabricated photodetector exhibited high sensitivity and excellent selectivity to UV light illumination with a fast response time. Jiang et al [56] have fabricated Mg$_{0.40}$Zn$_{0.60}$O thin films based Scottky barrier UV photodetector. Au was chosen as the Schottky metal contact because of its comparatively high work function (Φ=5.1 eV). It has been reported that the very low dark current is due to the wide band gap and Schottky barrier height. Lu et al [57] have reported flexible self-powered ZnO/Au-based Schottky junction UV detector, and studied influence of the ZnO/Au Schottky junction on its photovoltaic performance. It has been observed that the self-powered behavior of device accompanied by its fast response speed relative to photoconductive photodetectors relies on the driving force of the Schottky barrier at the ZnO/Au interface rather than the oxygen absorption and desorption process at the surface of the ZnO wire. Li et al [58] have studied vertical MgZnO Schottky UV photodetector with Al doped MgZnO transparent electrode and demonstrated that the MgZnO:Al film as a transparent electrode is a feasible way to improve the properties of the metal/semiconductor contact and the photon detectors.

c) ZnO p–n junction photodiodes

As prepared ZnO has always n-type of conductivity and it is difficult to grow p-type ZnO films so that fabrication of p–n homojunctions of ZnO is not yet fully developed. A lot of efforts have been taken for fabrication of p–n heterojunctions by combining n-type ZnO with other p-type materials. The junction will be formed
due to the electron–hole diffusion and recombination between a p-type doped and the adjacent n-type doped semiconductor.

Fig. 1.9 The schematic of the p-n junction photodiode [13]

A built-in electric field is formed near the junction of the n-type to the p-type semiconductor due to the depletion of carriers in the space charged region [13]. When the photodiode is under illumination, the photons with energy greater than the energy gap, incident on the front surface of the device, electron–hole pairs are generated in the space charge region of the device that will be separated and collected by the contact electrode generating photoresponse current [59]. The schematic of the p-n junction photodiode is illustrated in Fig. 1.9.

As the stable and reproducible p-type ZnO is still a great challenge, the fabrication of UV photodetector based on the ZnO p–n homojunction have been extremely difficult task. Shi et al [60] have successfully fabricated a highly efficient UV photodetector on a Sb-doped p-type ZnO microwire p–n homojunction which consisted of a single Sb-doped p-type ZnO microwire and a single undoped ZnO microwire. I-V curve of the constructed homojunction shows well defined current rectification characteristics. The photodetector showed high wavelength selectivity with a full width at half maximum of 6 nm for the photoresponse peak located at 386 nm. Highly spectrum selective photodetectors have been proposed and fabricated from i-ZnO/n-ZnO structure by Ni et al [61]. Duan et al [62] have studied
ZnO homojunction UV photodetector based on p-type dual doped film and n-type nanorods. The homojunction photodetector is more reliable than the heterojunction photodetector as it shows good rectifying behavior, high spectrum selectivity and fast response time. The spectrum selectivity of a heterojunction photodetector is usually not good enough because the heterojunction consists of two materials with different band gaps, so homojunction is a preferable photodetector structure. Sun et al [63] have constructed ZnO p–i–n homojunction structured UV photodetector. The obvious photoresponse observed at 0 V bias is a typical character of p–i–n structured photodetectors, confirming that the photoresponse comes from the p–i–n homojunction. Due to the difficulties in the fabrication of high quality p-type ZnO, the n-ZnO/p-semiconductor (especially the small lattice mismatch with ZnO) heterojunction devices as an alternative approach have attracted considerable attention of researchers for their similar physical properties [64-68].

1.1.4 Working principle of ZnO MSM UV photodetector

There are two main mechanisms of the ZnO photoresponse in an inorganic semiconductor: one is fast response and other is slow response. The fast response results from the reversible solid state process, such as intrinsic inter band or excitonic transition, while the slow one is due to the surface related oxygen adsorption and photodesorption process, or by the bulk defect related recombination process [69-71]. In polycrystalline ZnO thin films, the slow photoreponse mechanism is observed [72,73]. The slow photoresponse process in the polycrystalline ZnO proceeds in a two step process [1]

i. Under the dark condition, the oxygen molecules absorb on the ZnO surface and occupies the surface states (e.g. oxygen deficiency sites) and capture the free electrons present in an n-type oxide semiconductor:

\[ O_2(g) + e \rightarrow O_2^-(ad) \]
Thus, a depletion region and band bending are created near the surface, resulting in a decrease of the film conductivity (Fig. 1.10).

ii. When the ZnO thin film is illuminated by a UV light with a photon with energy greater than the energy gap ($E_g$) of the ZnO, the electron–hole pairs are generated. The holes migrate to the surface and discharge the negatively charged absorbed oxygen ions through surface electron–hole recombination

$$h^+ + O_2^- (ad) \rightarrow O_2(g)$$

This process is called the photodesorption of $O_2$ (Fig. 1.11). The extra electrons are collected at the electrode.


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1.2 Literature survey

1.2.1 ZnO based UV photodetector

ZnO is one of the most useful semiconducting materials and have been widely studied in various fields. The ZnO exist in wurtzite crystal structure has an ABAB hexagonal close packing (HCP) structure and shows higher growth rate along the c-axis with lattice parameters of a=0.3296 nm and c= 0.52065 nm. The c/a ratio varies in a slightly wider range, from 1.593 to 1.6035. The ZnO is composed with alternating planes O²⁻ and Zn²⁺ ions which are tetrahedrally coordinated and stacked along the c-axis. This tetrahedral coordination is typical of sp³ covalent bonding.

ZnO is well-known for its eye catching properties like n-type conductivity, direct wide band-gap, (3.34 eV), large excitonic binding energy (60 meV) at room temperature [74-77]. The direct band gap and high exciton binding energy make ZnO as prominent candidate for the application of optoelectronic devices. Zinc oxide is multifunctional material, due to its unique physical and chemical properties, such as high chemical stability, high electrochemical coupling coefficient, broad range of radiation absorption and high photostability [75-77]. ZnO can be grown with various structures which are having potential applications in field of nanotechnology. Zinc oxide can be grow in one-dimensional (1D) and two-dimensional (2D) and three-dimensional (3D) structures, which includes the morphologies like nanoroads [78], nanosail [79], nanowires, nanopellets, nanosheet [80,81], 3D interconnected metal-oxide nano-microstructures networes [82].

From the technological viewpoint, ZnO receives prime importance of young researchers, as it is applicable in various fields like transparent conducting oxide [83], smart windows [84,85], solar cell [86], gas sensor [87], supercapacitor [88], photocatalysis [89], UV photodetector [90]. ZnO has wide spread applications in the field of UV photodetector because of its inherent properties like wide band gap (3.4 eV) and large binding energy (60 meV), which is considerably larger than other conventional semiconducting materials. Many other wide band gap semiconductors
like GaN, AlGaN, SiCN , SiC, ZnSe, ZnS etc. shows good UV sensing properties. Initially, GaN, AlGaN, and ZnSe have been used frequently for UV photodetector devices. GaN is considered to be the best candidate for the fabrication of optoelectronic devices. However, ZnO has great advantages that it has high exciton binding energy ~ 60meV as compared with GaN (~ 25 meV) which enhances the luminescence efficiency of light emission for light emitting diodes and laser diodes [91]. Furthermore, ZnO has very excellent radiation hardness which becomes very suitable for UV photodetector application to use in harsh environments. Its radiation hardness is more than Si, GaAs, SiC and GaN [92].

The UV photoresponse of the ZnO was first studied by Mollwo [93] in year 1940. At the beginning, the devices usually have simple structure and the properties were not very good. With improvement of the fabrication of the ZnO based films using different techniques, many complex ZnO based photodetectors (such as p-n junction, p-i-n junction and Schottky junction, etc.) with high performance were reported.

Fabricius et al [94] have studied UV sensitive Schottky-barrier diode based on sputtered ZnO layer and a gold layer was used for the contact. The diode structure consisted of a glass substrate with Mn electrode as the bottom contact material to the ZnO-Au diode. The quantum efficiency of these diodes was of the order of 1%. This value is relatively low and probably caused by the large amount of recombination centers present. Liu et al [95] have synthesized high quality ZnO epitaxial films which were grown on R-plane sapphire by metalorganic chemical vapor deposition (MOCVD) at temperatures in the range of 350°C to 600°C. MSM UV sensitive photodetectors were successfully fabricated on N-doped ZnO epitaxial films. The low photoresponsivity in the order of 400 A/W at 5 V bias was obtained. The devices show high response speed with the rise time and fall time about 1 µs and 1.5 µs, respectively. Liu and Kim [96] have investigated the effects of oxygen plasma treatment on the UV detection properties of ultrathin ZnO epitaxial films. They reported that the oxygen plasma treatment dramatically enhances the UV
detection performance of ZnO based detector, reducing the decay time constant and increasing the on/off ratio of photocurrent. The observed responsivity was about 1–10 A/W. Liang et al [97] have prepared n-type ZnO epitaxial films grown on R-plane sapphire substrates by metalorganic chemical vapor deposition. For comparison they have fabricated Schottky UV photodetectors using Ag as Schottky metal contact and photoconductive detectors using Al as ohmic metal contact and observed that the Schottky photodiode exhibits a leakage current approximately 5 orders of magnitude smaller than that of its photoconductive counterpart. Basak et al [98] have reported the photoconductive UV detector synthesized by sol gel ZnO film with Au–ZnO metal–semiconductor junction. I-V characteristics of the device show perfect ohmic nature. The responsivity and quantum efficiency of the devices was 0.040 A/W and 14% were achieved at 350 nm respectively. Xu et al [99] have prepared C-axis oriented ZnO thin films on quartz substrates by RF sputtering. The planar interdigital electrodes (ITD) were deposited on ZnO surface by lift off technique through UV lithograph using vacuum evaporating of aluminum. The 16 Al fingers (8 up and 8 down) in ITDs were having thickness 200 nm, 3mm wide and 500mm long, with a 3mm gap. The result shows the photoresponsivity is about 18 A/W at 365 nm at 5 V bias and fast photoresponse with a rise time of 100 ns and fall time of 1.5ms. Soci et al [100] investigated the photoconductive properties of ZnO nanowire (NW) for visible-blind UV photodetectors and fast optoelectronic applications. They predicted that this model, broadly applicable to low dimensional semiconductors with high density of surface trap states, and also demonstrates the uniqueness of NW as photodetectors with ultrahigh sensitivity and low power consumption for applications such as sensing, imaging, optical communications, and memory storage. Hullavarad et al [101] have prepared UV photosensor based on nanostructured ZnO spheres in network of nanowires and studied the effect of multiple shapes involving the spheres in network of nanowires and the electrode spacing on the sensor responsivity. It is well know that the ZnO nanostructures are promising candidates for new generation high sensitivity UV photodetectors due to
their wide band gap and large aspect ratio. Lupan et al [102] have studied the single ZnO nanorod photodetector fabricated using the in-situ lift-out technique. With a source wavelength of 370 nm and an applied bias of 1 V, the responsivity of the ZnO nanorod is 30mA/W. Huang et al [103] studied the effects of buffer layers on the physicochemical properties of the ZnO film and UV sensing properties of the photodetectors. The experimental results suggested that the buffer layer is helpful in improving the crystalline quality of ZnO films. The electrical property of the ZnO photodetectors is relative to the crystalline quality of ZnO films. They showed that the higher value of photoresponsivity and better time dependent photocurrent characteristic of the detector based on ZnO with buffer depends on the crystalline quality, which can be explained by the carrier trapping effect. Ismail et al [104] fabricated an isotype n-Al:ZnO/n-Si heterojunction photodetector using the chemical spray pyrolysis technique. They reported that the photodetectors have good photoresponse both in UV and visible regions around 0.1 A/W at 375 nm and 0.47 A/W at 700 nm. Their results have suggested that the Al dopant could be a good choice to fabricate the doped ZnO/Si devices for photodetection purpose. They have also studied the effect of SiC buffer layer and observed the improvement in junction characteristics using buffer layer which modulates the lattice mismatch between Si and ZnO. Du et al [105] have studied double heterojunction solar blind UV photodetector and also studied the effect of low concentration Mg:ZnO buffer layer. They have developed interfacial layer for the growth of solar-blind wurtzite Mg$_{0.55}$Zn$_{0.45}$O epilayer, in which a low Mg content Mg$_{0.2}$Zn$_{0.8}$O buffer layer is employed as a quasi-homoepitaxy template to accommodate the big difference in bonding configurations between Mg-O and Zn-O in a wurtzite structure. The device performance successfully showed the applicability of this bandgap engineering method in photoconductive solar-blind UV detector fabrication. Chaia et al [106] have used self assembled crossed ZnO nanorods for the fabrication of the UV photodetector constructed by the in situ lift-out method in a focused ion beam system. The I–V characteristic show linear ohmic behavior of the device and
exhibits the photoresponse $\sim 15$ mA/W for UV light of wavelength 361 nm under 1 V bias. Liu et al [107] have grown ZnO nanorods on the ZnO seed layer which could help to grow nanorods laterally between the interdigitated electrodes. ZnO nanorod UV photodetector with different metal contacts have been fabricated and measured its performance. It has been observed that the difference in performance between device with Ni electrode and device with Sn electrode was attributed to the effect of a higher injection barrier at the Ni/ZnO interface that blocks the charge injection. The ZnO nanorod devices were visible-blind and have great response even in mid UV region. Peng et al [108] have fabricated ZnO nanobridge photodetector using conventional photolithography. The device has been compared with conventional thin film photodetectors, the nanobridge devices show enhanced photosensitivity and blue shift (30 nm) of the spectral response. These enhancement is caused due to the surface effects of the ZnO nanobridge and strain induced polarization effects, leading to band structure change. Jandow et al [109] have successfully deposited ZnO thin films on PPC plastic substrates by DC sputtering and measured photocurrent was about 0.7957 $\mu$A and 126.5163 $\mu$A at dark and under UV light illumination. These results have been showed that the fabrication of ZnO MSM UV photodetector on plastic substrates at room temperature is possible by using DC sputtering technique. Su et al [110] have fabricated and characterized MSM UV photosensors with ZnO nanorods (NRs) and ZnO thin film at 5 V applied bias under 370 nm illumination and measured photoresponsivity about 41.22 and 0.13 A/W, respectively. It was observed that the carrier lifetime of film photosensors (2.42 s) was shorter than that of NRs photosensors (15.44 s); thus, the longer carrier lifetime can be attributed to an obvious PPC effect in NR devices. Mamat et al [111] studied aluminium doped zinc oxide nanorod–nanoflake network thin film UV photodetector grown on the seed layer coated glass substrate. The Au was used as metal contact, for UV photoconductive sensor responded well to the UV light. It showed a responsivity of 33.6 mA/W under a bias voltage of 10 V. The seed layer effect has also been observed and resulted that its photoresponse
characteristics are enhanced 1.5 times than those of the seed layer. The photoresponse of the device with the seed layer was improved due to better crystallinity. Furthermore, the high photocurrent value is also observed due to Al doping. The mobility of the photogenerated carriers is improved due the Al doping in ZnO. Due to the Al doping, the carrier concentration of ZnO nanostructures could be improved, because substitution of Al$^{3+}$ at the Zn$^{2+}$ site, creating one extra free carrier in the process. He et al [112] have fabricated a low cost MSM structure, consisting of ZnO nanowires film which is bridged between two electrically interdigitated metal electrodes for collecting photo generated charges. They have verified the surface depletion effect by modifying nanowire surfaces using surface passivation with polymer and Ar ion bombardment. It has been shown that transient response for the detector with the polymer passivation become much faster than that of original one without the passivation. Gu et al [113] have demonstrated a MSM UV photodetector based on ZnO nanofibers (NFs) fabricated by electrospinning method. Au electrodes with different interdigital spacings (IDS) have been deposited on the ZnO NFs. They have compared three devices with different IDS (20, 40 and 60 μm) and observed that the proper reduction of the interdigital spacing is beneficial for the improvement of device performances. Li et al [114] have studied zinc oxide ultraviolet photodetectors with different contacts. A polydimethylsiloxane (PDMS) layer have been used as the encapsulation to protect the devices from ambient effects. The two UV photodetector devices have been fabricated and compared for ohmic and Schottky contact that were formed with aluminum and silver electrodes, respectively. Schottky contact devices were shown to be able to achieve rapid response with the recovery time not affected by the encapsulation. Ali et al [115] have done comparative study of three different MSM UV photodetectors. Specifically, devices having structures (1) Pd Schottky contacts based on undoped ZnO, (2) Pd doped ZnO and (3) Pd microplates embedded ZnO films were compared, where the films were prepared by the sol gel technique. They
observed the improved performance of the Pd microplates embedded ZnO film device. Chen et al [116] have demonstrated a novel type of ZnO self-powered photodetector based on the asymmetric MSM structure: one Au ID electrode with wide fingers and the other one with narrow fingers. They observed that with increasing the asymmetric ratio (the width of wide fingers: the width of narrow fingers) of the ID electrodes, the responsivity of the ZnO self powered UV photodetectors was enhanced obviously, reaching as high as 20 mA/W when the asymmetric ratio was 20:1. Park et al [117] prepared NiO/ZnO heterojunction UV photodiode by sol gel processing. The p–n heterojunction photodiode exhibited a good rectifying behavior at room temperature. The heterojunction showed a distinct photoresponse with responsivity of 21.8 A/W and quantum efficiency of 88% at 310 nm. Tian et al [118] have prepared MSM structured UV detector on the metal (Pt) nanoparticles (NPs) coated ZnO film deposited by radio frequency magnetron sputtering technique. It has been found that the responsivity of the device is enhanced by up to 56%. Authors have proposed that the Pt NPs have enhanced the scattering of incident light, which made more light scatter on the ZnO thin film, and it is such a result that the light absorption is enhanced. Ko et al [119] have studied nanostructured NiO/ZnO coaxial p–n heterojunction via thermal oxidation and hydrothermal growth processes. On applying the reverse bias of −3.5 V, the observed responsivity and external quantum efficiency were 7.37 A/W, 28.1% respectively at the incident light wavelengths of 365 nm. Thus from last few years numbers of researchers are taking interest in development of ZnO semiconductor based UV photodetector devices. The survey of their work is given in Table 1.2.
### Table 1.2 The survey of the work carried out on the development of ZnO based UV photodetector

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Film</th>
<th>Technique</th>
<th>Properties studied</th>
<th>Photocurrent, responsivity, rise and fall time</th>
<th>Reference No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ZnO</td>
<td>RF sputtering</td>
<td>I-V characteristic, sensitivity, rise and decay time</td>
<td>20 μs and 30 μs</td>
<td>94</td>
</tr>
<tr>
<td>2</td>
<td>ZnO</td>
<td>MOCVD</td>
<td>I-V characteristic, Responsivity</td>
<td>4.5μA, 400A/W at 5V, 1 &amp; 1.5 μs</td>
<td>95</td>
</tr>
<tr>
<td>3</td>
<td>ZnO</td>
<td>MOCVD</td>
<td>I-V characteristic, Responsivity, rise and fall time</td>
<td>0.9μA, 1.5A/W at 5V, 12 &amp; 50ns</td>
<td>97</td>
</tr>
<tr>
<td>4</td>
<td>ZnO</td>
<td>Sol-gel method</td>
<td>I-V characteristic, Responsivity</td>
<td>7μA, 0.04A/W</td>
<td>98</td>
</tr>
<tr>
<td>5</td>
<td>ZnO</td>
<td>Rf sputtering</td>
<td>I-V characteristic, photoresponsivity, response time spectrum</td>
<td>882μA, 18A/W at 5V, 100ns &amp; 1.5μs</td>
<td>99</td>
</tr>
<tr>
<td>6</td>
<td>ZnO</td>
<td>CVD</td>
<td>I-V characteristic, photocurrent Vs energy(eV)</td>
<td>0.4mA</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>ZnO</td>
<td>Direct Vapor Phase (DVP)</td>
<td>I-V characteristic, Responsivity</td>
<td>10nA, 50mA/W</td>
<td>101</td>
</tr>
<tr>
<td>8</td>
<td>ZnO</td>
<td>Rf sputtering</td>
<td>I-V characteristic, Responsivity, rise and fall time</td>
<td>300μA, 60A/W, 20ns, 10μs</td>
<td>120</td>
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<tr>
<td>9</td>
<td>Ga:ZnO</td>
<td>plasma-assisted molecular-beam epitaxy</td>
<td>I-V characteristic, Responsivity</td>
<td>dark current close to 19.9 mA, 1.68A/W</td>
<td>121</td>
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<tr>
<td>10</td>
<td>ZnO</td>
<td>microwave-heating</td>
<td>I-V characteristic, Spectral photoresponce,</td>
<td>60 μA, 9.6 A/W, 36 s, not applicable</td>
<td>122</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>No.</th>
<th>Material</th>
<th>Growth Method</th>
<th>Characteristic</th>
<th>Responsivity</th>
<th>Rise and Fall Time</th>
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<tr>
<td>11.</td>
<td>ZnO</td>
<td>Hydrothermal method</td>
<td>I-V characteristic, Decay time</td>
<td>8μA, 3 s</td>
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<td>12.</td>
<td>ZnO with ZnO homobuffer</td>
<td>hot filament chemical vapor deposition</td>
<td>IV characteristic</td>
<td>350nA,</td>
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<td>13.</td>
<td>Al:ZnO/n-Si</td>
<td>chemical-spray-pyrolysis</td>
<td>responsivity, quantum efficiency, rise time</td>
<td>0.1 A/W, 50 ns</td>
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<td>14.</td>
<td>ZnO</td>
<td>RF-plasma assisted MBE</td>
<td>I-V characteristic</td>
<td>6 nA,</td>
<td>-</td>
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<td>15.</td>
<td>ZnO</td>
<td>ZnO NPs dispersed in methanol were painted</td>
<td>I-V characteristic, Responsivity, rise and fall time</td>
<td>3μA, 0.1 mA/W, rise and fall time 48 s, 0.9 s</td>
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<td>16.</td>
<td>ZnO</td>
<td>sol–gel method</td>
<td>I-V characteristic, Responsivity</td>
<td>51μA, 0.011 A/W</td>
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<td>17.</td>
<td>ZnO</td>
<td>MOCVD</td>
<td>time-resolved photoresponse</td>
<td>-</td>
<td>-</td>
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<tr>
<td>18.</td>
<td>ZnO</td>
<td>CVD</td>
<td>I-V characteristic, time-resolved photoresponse</td>
<td>40μA,</td>
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<td>19.</td>
<td>Al–N-co-doped ZnO</td>
<td>RF magnetron sputtering</td>
<td>I-V characteristic, Responsivity</td>
<td>1A/W</td>
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<td>20.</td>
<td>ZnO</td>
<td>hydrothermal reactor</td>
<td>Decay time</td>
<td>2 s</td>
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<tr>
<td>21.</td>
<td>ZnO</td>
<td>Rf magnetron sputtering</td>
<td>Responsivity, UV response time</td>
<td>61 A/W resp.3s, 452 s</td>
<td>-</td>
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<tr>
<td>No.</td>
<td>Material</td>
<td>Method</td>
<td>Characteristic</td>
<td>Parameters</td>
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<td>22.</td>
<td>ZnO</td>
<td>RF magnetron sputtering</td>
<td>C-V characteristic, Responsivity, rise and fall time</td>
<td>550μA/cm², 2.6A/W, 10ns, 960ns</td>
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<td>23.</td>
<td>ZnO</td>
<td>RF magnetron sputtering</td>
<td>Responsivity, UV response time</td>
<td>166.84 A/W, 0.32 s</td>
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<td>24.</td>
<td>ZnO</td>
<td>DC sputtering</td>
<td>I-V characteristic</td>
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<td>25.</td>
<td>ZnO</td>
<td>RF magnetron sputtering</td>
<td>I-V characteristic, Responsivity</td>
<td>41.22 A/W, 2.42 s</td>
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<td>26.</td>
<td>ZnO</td>
<td>electrodeposition method</td>
<td>J-V characteristic</td>
<td>132A/cm²</td>
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<td>27.</td>
<td>ZnO</td>
<td>CVD</td>
<td>UV sensing properties</td>
<td>-</td>
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<td>ZnO</td>
<td>hydrother-mal method</td>
<td>I-V characteristic, Responsivity, I-t</td>
<td>40 A/W at 10 V</td>
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<td>ZnO</td>
<td>printing method</td>
<td>Responsivity, I-t</td>
<td>0.4 μA, 0.9 s</td>
<td>132</td>
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<td>30.</td>
<td>Ga:ZnO</td>
<td>Spray pyrolysis</td>
<td>I-V, I-t, Responsivity</td>
<td>1125A/W, 2mA</td>
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<td>31.</td>
<td>ZnO</td>
<td>RF sputtering</td>
<td>Responsivity, response time</td>
<td>0.055 A/W, 12.72ms, 447.66</td>
<td>134</td>
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<td>32.</td>
<td>ZnO</td>
<td></td>
<td>Responsivity,</td>
<td>300 a.u.</td>
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<td>Al:ZnO</td>
<td>co-sputtering method</td>
<td>I-V, I-t</td>
<td>25μA</td>
<td>136</td>
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<tr>
<td>34.</td>
<td>Ga:ZnO</td>
<td>Spray pyrolysis</td>
<td>I-V, I-t, Responsivity</td>
<td>2.4mA, 1187A/W</td>
<td>137</td>
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<tr>
<td>35.</td>
<td>Al:ZnO</td>
<td>ultrasonic-assisted sol–gel and immersion methods</td>
<td>I-V, I-t, Responsivity, I-t</td>
<td>33.6 mA/W at 10 V bias, 10.4 μA photocurrent</td>
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<td>36.</td>
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<td>pulsed laser deposition</td>
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<td>magnetron sputtering</td>
<td>I-V, I-t</td>
<td>-</td>
<td>139</td>
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<td></td>
<td>ZnO</td>
<td></td>
<td>Responsivity, response time, decay time</td>
<td></td>
<td></td>
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<tr>
<td>38.</td>
<td></td>
<td></td>
<td>3.424 A/W, 225 ms, 366 ms</td>
<td></td>
<td></td>
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<tr>
<td>39.</td>
<td>ZnO</td>
<td>RF magnetron sputtering</td>
<td>Decay time</td>
<td></td>
<td></td>
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<tr>
<td>40.</td>
<td>ZnO</td>
<td>RF magnetron sputtering</td>
<td>Decay time</td>
<td>Several seconds</td>
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<td>41.</td>
<td>ZnO</td>
<td>Electrospinning method</td>
<td>I-V, I-t, Responsivity</td>
<td>287 A/W, rise and fall time 4.87 s, 26.73 s</td>
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<tr>
<td>42.</td>
<td>ZnO</td>
<td>spin-coating</td>
<td>I-V, Responsivity</td>
<td>0.017 A/W</td>
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<td>43.</td>
<td>ZnO</td>
<td>sol-gel method</td>
<td>I-V, Responsivity, Quantum efficiency</td>
<td>0.33 A/W, 115%</td>
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<td>44.</td>
<td>ZnO</td>
<td>molecular-beam epitaxy</td>
<td>Responsivity</td>
<td>20 mA/W</td>
<td></td>
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<td>45.</td>
<td>ZnO</td>
<td>sol-gel method</td>
<td>Responsivity, external quantum efficiency</td>
<td>21.8 A/W, 88%</td>
<td></td>
</tr>
<tr>
<td>46.</td>
<td>ZnO</td>
<td>rf magnetron sputtering technique</td>
<td>I-V characteristic, Responsivity</td>
<td>0.08 μA, 1.306 A/W</td>
<td></td>
</tr>
<tr>
<td>47.</td>
<td>ZnO</td>
<td>hydrothermal growth processes</td>
<td>Responsivity, external quantum efficiency</td>
<td>7.37 A/W, 28.1%</td>
<td></td>
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</table>
1.3 Orientation and purpose of the dissertation

Now a days UV exposure on earth is biggest and pronounced issue as the size of the ozone hole in the Antarctic stratosphere increases. We know that the UV radiations are harmful for health because these radiations are carcinogenic. Due to this UV detector plays an important role in monitoring UV radiations. Rather than biological and chemical applications, UV photodetector has important application in the fields like fire detection, optical intersatellite spatial communications, the calibration of emitters, and UV imaging [42]. Therefore, development of effective UV detector that shows high UV-A sensitivity but blind towards standard visible radiation has great importance for safety of life.

Wide band gap materials are specially chosen for the application of UV photodetector as these materials are chemically and thermally more stable, which is requirement for devices operating in harsh environments [13]. ZnO is known for its wide band gap and high exciton binding energy and which has been potentially used for application of optoelectronic devices. The aim of this work is to fabricate highly sensitive and fast responses ZnO UV photodetector using simple and inexpensive spray pyrolysis deposition technique. Efforts will be focused on enhancing the photosensitivity and reducing response time of the detector.

In this proposed work it has been planned to deposit ZnO films using spray pyrolysis as deposition technique as it is very simple and relatively cost effective processing method. It offers an extremely easy technique for preparing films of any composition. The main purpose of using spray pyrolysis deposition technique is that to produces highly transparent ZnO thin film. The films will be prepared at different conditions by varying parameters like substrate temperature, solution concentration and doping concentration. It is proposed to synthesis transparent undoped and Al doped ZnO films of high photocurrent, photoresponse and maximum responsivity. In this proposed work influence of buffer layer on Al:ZnO thin film UV photodetector device will also be checked. The performance of the UV photodetector will be tested on glass. The synthesized thin films will be
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characterized by various techniques viz. XRD, EDAX, RAMAN, SEM, AFM, Optical transmission and device properties like photocurrent, photoresponse and responsivity of the thin film device will also be measured.
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