2.1 Introduction

Thin film is the layer of the material with thickness ranging from few nanometers to several micrometers. Advanced thin film technology has expertise in many fields including solar cells sensors, flat panel displays, micro/nanoelectronics, microcircuits, biomedical devices, optical instruments, microwave communications, integrated circuits etc. Thin film deposition technique is also widely applicable in the field of surface modification to change the physical properties by applying very thin layer in nanometer thickness. Thin films are used to modify the optical properties of the substrate, its electrical conductivity and to provide corrosion resistance or chemical inertness. The familiar examples of the thin films are reflective coatings on the CDs and DVDs, anti-reflective coatings on spectacles, the thin metal coating at the back side of the mirror etc.

The use of thin film technology in various fields of application includes many advantages

1. Reduction in the manufacturing cost of the material
2. Use of less amount of raw materials which are mostly easily available
3. Material can deposit on various substrates for various application with desired area

2.1.1 Thin film deposition methods

The techniques used to prepare the thin film processes differ in degree of sophistication, quality of film produced and also physical and chemical properties of the material deposited. The thin film deposition techniques are mainly divided into two parts (1) chemical deposition techniques and (2) physical deposition techniques. Again these are divided into various subclasses as shown in Fig. 2.1 below. In chemical processes a fluid precursor undergoes a chemical change at a solid substrate, leaving a solid layer on it. Physical deposition techniques involve mechanical, electromechanical or thermodynamic processes to produce a thin film of solid.
This chapter mainly deals with the various deposition techniques involved in the formation of thin films and the mainly focuses on the spray pyrolysis deposition (SP) technique. The instrumentation of the SP technique, mechanism of thin film formation and responsible factors for the growth of the thin film is discussed in detail in this chapter.

### 2.1.2 Spray pyrolysis deposition method

The spray pyrolysis technique is known for the formation of oxides like simple oxides, mixed oxides, spinal type oxides. The group I-VI, II-VI, III-VI, IV-
VI, V-VI, VIII-VI binary chalcogenides, group I-III-VI, II-II-VI, II-III-VI, II-VI-VI and V-II-VI ternary chalcogenides, adamantine copper compounds such as Cu$_2$ZnSnS$_4$/Se$_4$, Cu$_2$CdSnS$_4$/Se$_4$, CuGaSnS$_4$/Se$_4$, Cu$_2$InSnS$_4$/Se$_4$, CuIn$_3$S$_4$/Se$_4$ etc [1]. The schematic representation of the spray pyrolysis technique has been given in the Fig. 2.2 below. The main components of the instruments are glass nozzle, rotor for the motion of nozzle; a hot plate, a gas regulator valve and air tight chamber etc are discussed below.

1. Glass nozzle

The nozzle is having glass bulb with center tube through which precursor solution is sprayed on the substrate. When the carrier gas pressure is applied, vacuum is created at the tip of the nozzle and solution sucks out from the capillary tube and sprayed on the substrate.

![Diagram of spray pyrolysis technique](image)

Fig. 2.2 Schematic representation of spray pyrolysis technique
2. Rotor for the motion of nozzle

To maintain linear simple harmonic motion of the spray nozzle over the desired length to deposit the film rotor or stepper motor is used.

3. A hot plate

The hot plate is made of iron disc with diameter 16 cm and thickness 1.5 cm with 2000 W heating coil is used for heating purpose. A maximum 600 ± 5 °C temperature can be achieved with this arrangement. A chromel-alumel thermocouple is used to measure the temperature of the substrates. The temperature of the hot plate is monitored with the help of temperature controller.

4. A gas regulator valve

The gas regulator valve is used to control the pressure of the carrier gas on flowing through the spray nozzle.

5. Air tight chamber

Many toxic gases are released during the thermal decomposition of the precursor solution, so it is necessary to fix the spray system inside the airtight chamber. The exhaust fan is fitted at the outlet of the chamber to remove the gases released during thermal decomposition.

Mechanism of film formation by spray pyrolysis method

The processes involved in the decomposition of the precursor solution are (shown in Fig. 2.3) discussed below [2]:

A. Precursor solution is converted into aerosols due to applied pressure of carrier gas

B. Solvent evaporation takes places as reaches to the pre-heated substrate

C. Vaporization of the solvent leads to precipitate formation as the aerosols approaches the substrates

D. Pyrolysis of the precipitate occurs in succession before the precipitate reaches on the substrates
E. When the precipitate reaches at the substrate, nucleation and growth of metal oxide thin film takes place onto the substrate.

F. Finally, the growth of the nuclei leads to the formation of continuous thin layer of metal oxide.

Fig. 2.3 Mechanism of film formation by spray pyrolysis method

Zinc oxide thin films are the widely studied branch of the material science and extensively prepared by various deposition techniques like MOCVD [3], PLD [4], CBD [5], SILAR [6], spray pyrolysis [7] etc. ZnO is the wide band gap material absorbs mainly UV light below 380nm and transparent to the visible light. In this work spray pyrolysis method has been employed because it reproduces highly adherent and transparent films of ZnO. Transparent ZnO thin films with highest transmittance in visible region are required for the application of UV photodetectors.

2.2 Thin film characterization techniques

2.2.1 Thermo gravimetric and differential thermal analysis (TG-DTA) study

Thermogravimetry is a branch of the thermal analysis which gives the information about change in the mass of the sample as a function of temperature and time. This technique is used for the analysis of the material which shows the
change in mass (gain or mass) when heat is supplied to it. TGA provides the information about physical phenomena, like second-order phase transitions including absorption, adsorption, desorption, vaporization, sublimation etc. TGA can also give chemical information including chemisorptions, decomposition, and solid-gas reactions (e.g., oxidation or reduction) [8]. The thermal analysis is done under various ambiances like air and inert atmosphere (such as Helium or Argon). A lean oxygen atmosphere is used to slow down oxidation process. The rate of sample heating and the ambient atmosphere during analysis are the key factors to be controlled during thermal analysis. Differential thermal analysis measures the temperature difference of the sample versus the reference. The TGA and DTA give the temperature range in which material shows stable phase and do not undergo further loss in weight. It also provides the information about the temperature at which material starts decomposing and also stages involved in the decomposing process [9].

**Instrumentation**

The TGA-DTA instrument consists of [10]

1. a sensitive microbalance called thermobalance
2. a furnace
3. a gas system for providing atmosphere
4. a computer system for instrument control, data acquisition, and data processing

The various thermobalance designs are available in the market which gives the range 1 to 100 g with 0.1 μg of sensitivity. The sample holder of the balance is filled in furnace and rest of the part is thermally isolated. The furnace typically operates in the range of ambient to 1000°C. The rate of heating can be varied from 0.1°C/min to 100°C/min. The cooling system is necessary to avoid heat transfer to thermobalance. Samples are typically hold in pans made of aluminum platinum or alumina. Mostly platinum is used for inertness and cleanness [10].
2.2.2 X-ray diffraction (XRD) study

X-ray powder diffraction is an analytical technique used for phase identification of a crystalline compound by their diffraction pattern and can provide information about unit cell and its dimensions. The X-ray diffraction pattern of a material is, like a fingerprint of the material. The powder diffraction method is preferably used for characterization and identification of polycrystalline materials.

X-ray diffractometers consist of three basic elements: an X-ray tube, a sample holder, and an X-ray detector. A coherent beam of monochromatic X-rays of known wavelength is essential for X-ray diffraction. Copper (Cu) as an anode material is most commonly used target in the X-ray generating tube, for which the wavelength of the strongest radiation (Kα) is approximately 1.54 Å. Other anodic materials used in X-ray generating tubes include Cr (Kα2.29 Å), Fe (Kα1.94 Å), Co (Kα1.79 Å), and Mo (Kα0.71 Å). The radiation produced in the tube consists of the components Kα and Kβ as the highest energy X-rays. The Kα has two parts as Kα1 and Kα2. The Kα1 has a slightly shorter wavelength and twice the intensity as Kα2 [11]. Kα1 is used for analytical work. The Kβ radiation is generally removed by use of a filter or a monochromator, and the Kα2 radiation is removed from the X-ray data electronically during data processing. These X-rays are incident on the sample and when the incident X-rays striking the sample, satisfies the Bragg equation [12]

\[ 2d \sin \theta = n\lambda \]  

(2.1)

where, n is an integer  
λ is the wavelength of the X-rays  
d is the interplanar spacing  
θ is the diffraction angle

The constructive interference occurs and a peak with respective intensity is observed in the diffraction pattern. The arrangement of an X-ray diffractometer is such that the sample rotates at an angle θ while the X-ray detector is mounted on an arm to collect the diffracted X-rays and rotates at an angle of 2θ shown in Fig. 2.4
Thin film deposition methods and characterization techniques

below. The instrument used to maintain the angle and rotate the sample is termed a goniometer.

Fig. 2.4 The diagram above is from the Siemens

Applications of X-ray diffraction study

X-ray powder diffraction is commonly used for the identification of unknown crystalline materials, characterization of crystalline materials, to determination of unit cell dimensions, to measurement of sample purity etc. With specialized techniques, XRD can be used to characterize thin films samples by:

- Determining crystallite size (D) using Scherer’s formula [13]

\[
D = \frac{0.9 \lambda}{\beta \cos \theta}
\]  

(2.2)

where, \( \lambda \) is wavelength of X-rays used, \( \beta \) is full width at half maxima of the peak (FWHM) in radians, \( \theta \) is Bragg's angle

- Determining lattice mismatch between film and substrate and to calculate strain (\( \varepsilon \)) developed in the film [12]
\[ \beta = \frac{\lambda}{D \cos \theta} - \varepsilon \tan \theta \quad (2.3) \]

- Measuring textural measurements, such as the orientation of grains, in a polycrystalline sample [14]

\[
TC = \frac{\sum I_{(hkl)}/I_{0(hkl)}}{N} \quad (2.4)
\]

where, \( I_{(hkl)} \) is measured intensity, \( I_{0(hkl)} \) is JCPDS standard intensity, \( N \) is number of reflections observed in X-ray diffraction pattern.

2.2.3 Raman spectroscopy study

Raman spectroscopy is the molecular spectroscopy which is complementary technique to the infrared (IR) spectroscopy. Similar to the infrared spectroscopy in Raman spectroscopy the vibrational motion of the molecule is measured. Raman spectroscopy gives the information about the scattering of the light while IR spectroscopy is based upon the absorption of photons [15]. Raman spectroscopy is based upon the inelastic scattering of monochromatic light, usually laser source is used. The inelastic scattering is nothing but the frequency of photons in monochromatic light changes upon interaction with a sample under consideration. The photon of light from the laser source is scattered by the molecules of the sample and losses (or gain) some energy (or wavelength) during this process. The difference in energy is nothing but the change in the rotational and vibrational energy of the molecule which gives information on its energy levels. This change in energy is characteristic of a particular bond present in the molecule. The frequency of the reemitted photons is shifted up or down in comparison with original monochromatic frequency, which is called the Raman effect. This shift provides information about vibrational and rotational energy levels in the molecules. A
Raman spectrum produces a spectral fingerprint of the molecule which is unique for individual molecule.

**Origin of the Raman spectroscopy**

When the monochromatic light with frequency $\nu_0$ is incident on the molecule it excites and transform into oscillating dipoles (shown in Fig. 2.5). The three types of scattering phenomenon occurs (1) A molecule with no Raman-active modes absorbs a photon with the frequency $\nu_0$. The excited molecule returns back to the ground state with light of the same frequency $\nu_0$. This type of interaction is called an elastic Rayleigh scattering.

(2) A photon with frequency $\nu_0$ is absorbed by Raman-active molecule, the part of the photon energy is transferred to the Raman-active mode with frequency $\nu_m$ and the emitting frequency of scattered light is reduced to $\nu_0 - \nu_m$. This Raman frequency is called Stokes frequency, or “Stokes”. (3) A photon with frequency $\nu_0$ is
absorbed by a Raman-active molecule, which, is already in the excited vibrational state at the time of interaction. The excessive energy of excited Raman active mode is released, molecule returns to the ground state and the resulting frequency of scattered light is $\nu_0 + \nu_m$. This Raman frequency is called Anti-Stokes frequency, or “Anti-Stokes”.

**Instrumentation**

The block diagram of Raman spectrometer is shown in Fig. 2.6. The modern Raman spectrometer consists of three main components:

1. A laser source,
2. a sample illumination system
3. a suitable spectrometer

**Fig. 2.6 Block diagram of Raman spectrometer**

**Source**: As the Raman scattering is the weak process, the sources used in modern Raman spectrometry are lasers because high intensity is necessary to produce measurable Raman scattering of sufficient intensity. The argon and krypton ion sources that emit in the blue and green region of the spectrum are mostly used.

**A sample illumination system**: Sample holding for Raman spectroscopic analysis is easier as compared with infrared spectroscopy. In Raman spectroscopy glass can be used for windows, lenses, and other optical components while for IR it is
necessary to use crystalline halides like KBr which are more fragile and atmospherically less stable. An ordinary glass melting-point capillary is commonly used as sample holder

A **suitable spectrometer:** The detectors used in the modern Raman spectrometers are photodiode arrays (PDA) and charge coupled devices (CCD). The double grating systems are most commonly used to minimize the unwanted radiation reaching to the transducer.

**Applications of Raman spectroscopy**

1. Raman analysis of inorganic species gives information of the composition, structure, and stability of compounds
2. In organic Species, Raman spectra is used to detect functional group and to identify the specific compounds
3. Raman spectroscopy has also been widely used to the study of biological systems

**2.2.4 Scanning electron microscopy (SEM) study**

Scanning electron microscopy (SEM) is the powerful technique to study the surface properties of the material. This technique is widely used in the field of material science, metallurgy, geology, biology, medicine etc. SEM uses highly energetic electrons to generate variety of signals from the surface of the sample. These signals are generated from the interaction between the energetic electron and the sample and provide the information about the surface morphology (texture), chemical composition, crystalline structure and orientation of material.

**Principle of the SEM**

Accelerated electrons emitted from the electron gun carry large amounts of kinetic energy, and this energy is used to generate the variety of signals by electron-sample interactions when the incident electrons are slowed down on the solid sample. Generated signals shown in Fig. 2.7 include secondary electrons, backscattered electrons, diffracted backscattered electrons, photons, visible light
and heat. The secondary electrons and backscattered electrons are used to produce surface morphology or topography of the sample.

![Diagram of electron effects](image)

**Fig. 2.7** Effects produced by electron bombardment on a material

Secondary electrons are important for the morphology and the backscattered electrons for illustrating contrasts in composition of multiphase samples. The diffracted backscattered electrons are useful for the determination of the crystallographic structures and orientations of specimen under consideration. [16]. The X-rays are generated by inelastic collisions of the incident electrons with electrons in discrete shells of atoms in the specimen. As these excited electrons return to lower energy states, emits X-rays with a certain fixed wavelength (that is related to the difference in energy levels of electrons in different shells for a given element). Thus, characteristic X-rays are produced for each element present in the specimen.

**Instrumentation**

The Schematic representation of scanning electron microscope is shown in Fig. 2.8. The substantive components of the Scanning Electron Microscope are electron gun, magnetic lenses, sample Stage, display/data output devices. The electron gun produces highly energetic beam of electrons. The thermionic emission
occurs when the thin tungsten filament is heated at high temperature (about 2800K) and thermoelectrons are produced.

![Schematic representation of scanning electron microscope](image)

**Fig. 2.8 Schematic representation of scanning electron microscope [17]**

The fine electron beam is required for the analysis of SEM. The electron beam is passed through the metallic plates maintained at positive potential (1 to 30 kV). The magnetic lenses are placed below the electron gun to adjust the beam of the diameter. The specimen stage is required to support the motion and to move the specimen in various directions like horizontal movement (x-y), vertical movement (z) and rotation movement. The output signal from detector are amplified and transferred to the display unit.
2.2.5 Energy dispersive analysis by X-ray (EDAX)

Energy dispersive x-ray spectroscopy is used for the determination of the individual elemental compositional analysis of the material at individual points or to map out the lateral distribution of elements from the imaged area. When highly energetic electron beam is bombarded on the surface of the specimen, interaction of electron with specimen produces variety of signals (mentioned in section 2.2.4) including x-rays.

![Energy dispersive analysis by X-ray (EDAX)](image)

**Fig. 2.9** *Electron transfer processes occurring in an atom due to external stimulation [18]*

The Electron transfer processes occurring in an atom due to external stimulation are depicted in Fig. 2.9. An energy dispersive (EDS) detector is used to separate the characteristic x-rays of different elements into an energy spectrum. The EDS system comes with Electron Microscopy instruments like Scanning Electron Microscopy (SEM) or Transmission Electron Microscopy (TEM). The EDX analysis spectra show peaks corresponding to the elements with true composition of the sample being analyzed. Elemental mapping of a sample with image analysis is also possible simultaneously.

When the incident electron beam is bombarded on the sample it creates secondary electrons and holes in the inner shell. If the hole is in inner shells, the atoms are not in a stable state. For sack of stabilization, electrons from outer shells
will drop into the inner shells. As the outer shells are having higher energy, the atom must lose some energy in the form of X-rays. The emitted X-rays from the sample are characteristic in energy and wavelength to. This analysis provides information not only about the element present in the atom, but also the information regarding from which shells electron lost and which shell replaced them.

**2.2.6 Optical absorption spectroscopy study**

UV-vis spectroscopy is one of the widely used in molecular absorption spectroscopic technique for the quantitative determination of the organic, inorganic and biological species. UV-vis spectroscopy concerns with the absorption of electromagnetic (EM) radiations in the UV-visible spectral region by the absorbing species like atoms, molecules or ions. This molecular spectroscopy is based upon the measurement of the transmittance T or the absorbance A of solutions and/or films. In order to obtain the spectrum, the sample is irradiated with the EM radiation (a radiation of a single wavelength is employed at a time) varied over a range of the wavelength. Thus, a typical UV-vis spectrum is a plot of the amount of the radiation absorbed as a function of the wavelength or frequency.

**Principle of UV-Vis spectrometry:**

In typical absorption spectral measurement, the sample container called cuvette containing sample is irradiated with the monochromatic radiations. This radiation is partly reflected, partly absorbed and partly transmitted. Thus the intensity of the original radiation ($P_o$) is the sum of the intensities of reflected ($P_r$), absorbed ($P_a$) and transmitted ($P_t$) radiation.

$$P_o = P_r + P_a + P_t$$  \hspace{1cm} (2.5)

The effect of reflection can be compensated by passing radiations of the equal intensities through the solution and through the solvent contained in the same container. Then equation (1) becomes
The intensity of the transmitted light is found to be depending on the thickness of the absorbing medium and the concentration. The dependence on these two facts forms two fundamental laws. One is Lambert’s law, which gives the relationship between the light absorption capacity of the sample and the thickness of the absorbing medium; and the other is Beer’s law, which expresses the relationship between the light absorption capacity of the sample and its concentration. The two laws are combined together to give Beer-Lambert’s law.

**Lambert’s Law:**

Lambert stated that

1. The amount of monochromatic light absorbed by a substance is proportional to the intensity of the incident light i.e. the ratio of the intensity of the transmitted and incident light is constant.

2. The intensity of the transmitted light decreases exponentially when the thickness of the substance, through which the light is passing, increases linearly.

**Fig. 2.10 Illustration for establishing the Lambert’s Law**

Fig. 2.10 illustrates the establishment of the Lambert’s Law. If $P_o$ be the radiant power of incident light and $P$ be the radiant power of transmitted light after passing through a slab of thickness $b$, consider a small slab of thickness $dx$, then the change in power ($dP_x$), is proportional to the power of incident light ($P_x$) multiplied by the change in thickness ($dx$) of the slab through which the light is passed. That is

$$P_o = P_a + P_t \quad (2.6)$$
Thin film deposition methods and characterization techniques

\[ dP_x \propto P_x \, dx \]

or \[ dP_x = -kP_x \, dx \] \hspace{1cm} (2.7)

where \( k \) is the proportionality constant and the negative sign indicates that radiant power decreases with absorption. Equation (2.7) can be rearranged as

\[ \frac{dP_x}{P_x} = -k \, dx \]

On simplification we get,

\[ \log_{10} \frac{P'_x}{P} = \frac{k}{2.303} \, b = k' \, b \] \hspace{1cm} (2.9)

Lambert’s law is applicable to any homogeneous non-scattering medium regardless of whether it is gas, liquid or solid.

**Beer’s Law:**

Beer found that the relation between intensity of the transmitted light and concentration was exactly the same as found by Lambert for the intensity of the transmitted light and the thickness of the absorbing medium.

Suppose, a monochromatic radiation beam of intensity \( P_x \) is crossing any thickness of solution of a single absorbing substance of concentration \( c \). If \( c \) is changed by a small amount \( dc \) to \( c+dc \), the change in transmitted power \( dP_x \) is proportional to the incident intensity \( P_x \) and \( dc \). That is,

\[ dP_x \propto P_x \, dc \]

or \[ dP_x = -k'P_x \, dc \] \hspace{1cm} (2.10)

where \( k'' \) is the proportionality constant and the negative sign indicates that radiant power decreases with absorption. On rearranging we get,

\[ \frac{dP_x}{P_x} = -kd\] \hspace{1cm} (2.11)

On simplification we get,

\[ \log_{10} \frac{P'_x}{P} = \frac{k}{2.303} \, c = k'' \, c \] \hspace{1cm} (2.12)

This is the mathematical expression for Beer’s law.
The Lambert’s and Beer’s laws are combined and are expressed as,

\[
\log \frac{P_o}{P} = abc
\]  
(2.13)

In this expression, ‘a’ is a constant (where \( a = k k \)) and is called absorptivity.

The term \( \log \frac{P_o}{P} \) is called absorbance and is represented as ‘A’

\[
A = \log \frac{P_o}{P}
\]  
(2.14)

The absorbance, A is related to another important term called transmittance which is defined as,

\[
A = -\log T
\]  
(2.15)

**Instrumentation for UV-vis spectrometry:**

Varity of instruments are commercially available for measuring absorption in UV-Vis range. The five basic and essential components of UV-VIS instruments are [10]

1. Radiation source
2. Wavelength selector
3. Sample holder
4. Radiation detector
5. Signal processing and output device

**Radiation source**

It requires radiation source which provides a stable energy output over a long rang of wavelength (190nm to 800 nm). There is no any commercially available source that may provide stable output over the entire UV-visible range. For measurements in the UV region, electric discharge sources like hydrogen or a deuterium lamp are used whereas tungsten filament lamp is used as source for measurements in the visible range.
Wavelength selector

In order to enhance the selectivity and sensitivity of the instrument, one needs to use narrow band of wavelengths of light. Less expensive instruments use a filter to provide a broad band of the wavelengths. Most modern instruments use monochromators that employ a prism or diffraction grating as the dispersing medium.

Sample holder

In a typical measurement of a UV-vis spectrum, the solution of the sample is taken in a suitable cuvette and the spectrum is run in the desired range of the wavelengths. A variety of cuvettes are available in market for the spectral determination in UV-Vis range.

Radiation detector

The detectors are used to convert a light signal to an electrical signal. There are three types of detectors which are used in modern spectrophotometers,

a) Phototube
b) Photomultiplier (PM) Tube
c) Diode Array Detector

Signal processing and output device

The electrical signal from the transducer is suitably amplified before it is sent to the recorder to give an output. The resultant plot of the intensity of the absorption verses wavelength is characteristic of the absorbing species.

Film thickness was estimated using optical method utilizing R spectra using following relations

\[ R = \frac{r_1^2 + 2r_1r_2 \cos 2\delta_1 + r_2^2}{(1 + 2r_1r_2 \cos 2\delta_1 + r_1^2r_2^2)} \]  

(2.16)

Where
Thin film deposition methods and characterization techniques

\[ r_1 = \frac{n_0 - n_1}{n_0 + n_1}, \quad r_2 = \frac{n_1 - n_2}{n_1 + n_2}, \]

\[ t_1 = \frac{2n_0}{n_0 + n_1}, \quad t_2 = \frac{2n_1}{n_1 + n_2} \quad \text{and} \quad \delta = \frac{2 \pi n_1 d}{\lambda} \]

n_0 = 1 R.I. of air, n_1 = refractive index of thin film, n_2 = refractive index of the substrate, d = thickness of thin film, R = reflectance and \( \lambda \) = wavelength of incident radiation.

2.3 UV photodetector properties

ZnO thin film based MSM UV photodetector absorbs ultraviolet light emitted by the source and converts it into measurable form i.e. photoelectric current. A photodetector has some essential requirements for their commercial uses in the field of light detection are as follows.

1. **Sensitivity at the required wavelength:** Photodetector needs good sensitivity in the desired wavelength region and no/poor sensitivity elsewhere

2. **Efficient conversion of photons to electron:** The external quantum efficiency of the detector must be high (as discussed in the section no. 1.1.2).

3. **Fast response to operate high frequencies:** when the light is turned on it must show maximum rise in photocurrent and recover to original dark current as soon as light turns off.

4. **Insensitive to temperature variation:** It is necessary to operate detector in harsh environment and abundant in nature

5. **Long operating life and reasonable cost:** The cost and life time of the detector is an also important parameter.

The UV photodetector is evaluated by various measurements in order to test the performance of the device are discussed below

2.3.1 I-V characteristics of the UV detector
I-V (current–voltage) testing is most important measurement in UV detector evaluation. I-V curve represents the activities held between the metal contact electrode and the semiconductor interface. The behavior of the I-V curve depends on the type of the junction exist at the interface of the metal-semiconductor junction. There are two types of the junctions one is ohmic junction and other is Non-ohmic or Schottky type of barrier. The ohmic contacts have minimum contact resistance and no tendency to rectify signal. In n-type semiconductor $\phi_m < \phi_n$, the Fermi level is at equilibrium by transferring electrons of metal to semiconductor. In this case, the barriers to flow of electron between metal and semiconductor are small and easily overcome by the small applied voltage. In p-type semiconductor, holes flow across the junction [19].

2.3.2. The photoswitching characteristics of the UV detector

The photoswitching characteristic of the device holds the information about the photoresponse of the detector under the light modulation as function of time. This time dependent photoresponse gives the rise time and the decay time of the detector which decide the sensitivity and quality of the detector. The rise and decay time of the detector is measured by the chopping incident light using manual light chopper with constant interval of time.

2.3.3 The responsivity of the UV detector as a function of wavelength

The responsivity of the detector is measured as a function of wavelength with the help of filters of various wavelengths. The plot of the responsivity gives peak in certain wavelength region. The full width and half maximum (FWHM) of the peak and cut off wavelength shows the wavelength range of the device application [20].
2.3.4 The light intensity dependent property of the UV photodetector

The photocurrent is exponentially proportional to light intensity; the photoresponse is fitted with a power law, $I \propto P^\theta$, where $\theta$ is the non-unity exponent indicates a complex process of electron–hole generation, trapping, and recombination within the semiconductor [21-23].
References


