**UV photodetector based on ZnO thin film nanostructure**

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**Abstract:**This paper presents a modified design of Area-Efficient Low power Carry Select Adder (CSLA) Circuit. In digital adders, the speed of addition is limited by the time required to transmit a carry through the adder. Carry select adder processors and systems. In digital adders, the speed of addition is limited by the time required to propagate a carry through the adder. The sum for each bit position in an elementary adder is generated sequentially only after the previous bit position has been summed and a carry propagated into the next position. The major speed limitation in any adder is in the production of carries.

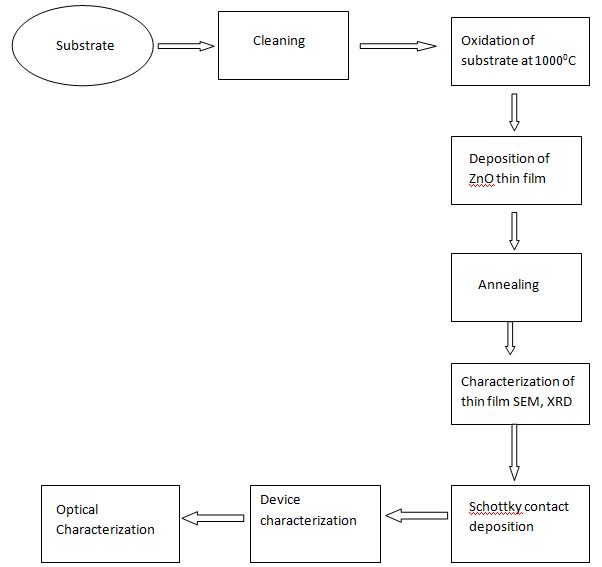
***Index******terms:***Area-efficient, Low power, CSLA, Binary to excess one converter, Multiplexer.

1. **INTRODUCTION**

In this work, we are reporting the fabrication of ZnO based nano structured UV light detector by thermal evaporation method. The applications of UV detectors are wide in military as well as civilian areas. These areas includes space communications, ozone layer monitoring, and flame detection, surface acoustic wave devices, transparent electronics [1], photo-detectors [2], dye sensitized solar cells [3], thin film transistors [4] and random lasers [5], optical communications, UV astronomy, water purification, UV radiation dosimetry, pollution monitoring, early missile threat warning, medicine, chemical/biological battlefield reagent detectors. So the need of well structured and good quality of film is highly demanded. For these applications we require those detectors that have high response and can work in harsh environment and temperature. These types of requirements can be fulfilled by the materials which have wide and direct band gap. ZnO is such a material that has super physical properties. A great deal of research shows that the optical and electrical properties of ZnO thin films have a direct connection with their crystalline quality. However, the quality of ZnO thin films is closely related to the substrate materials. Until now, ZnO thin films have been prepared on various substrates such as sapphire [6], silicon [7] and glass [8-12]. In particular, silicon is a promising candidate because of its low cost, excellent thermal conductivity, high crystallinity, availability of large size and all types of conductivity. Furthermore, silicon is the cornerstone of the current semiconductor microelectronics industry. If high-quality ZnO thin films are prepared on Si substrates, it will be beneficial for effective intergration of optoelectronic devices with Si integrated circuit (IC) technology. This chapter includes a brief description of the facilities used to fabricate and characterize the device structure investigated during the course of the work. The surface characteristics of the thin film fabricated in the device is investigated by field scanning electron microscopy (FESEM), I-V characteristics of the device are analyzed using semiconductor parameter analyzer.

1. **EXPERIMENTAL DETAILS**

Fig 1 shows the experimental procedure followed in the form of flowchart. The fabrication process includes substrate cleaning, deposition of thin film, characterization of thin film, device fabrication, and characterization of Schottky contact. After the fabrication of device different parameters were analyzed using semiconductor parameter analyzer. Subsequent sections give the detailed knowledge about the fabrication process.



**Fig. 1**: Schematic flow chart of experiment.

As a substrate, Silicon material with n type doping and orientation of <100> was taken. This substrate was cleaned by RCA-1 and RCA-2 aqueous cleaning processes. In RCA-1 procedure the cleaning agent consists of 5 parts deionized (DI) water, 1 part 27% ammonium hydroxide and 1 part 30% hydrogen peroxide while RCA-2 cleaning mixture makes use of 6 parts DI water, 1 part 27% hydrochloric acid and 1 part 30% hydrogen peroxide. Cleaning is followed by quenching of wafer in 10 parts DI water and 1 part hydrofluoric acid. RCA-1 is used as a procedure for removing organic residues and certain metals while RCA-2 is used for removing atomic and ionic contaminants. Quenching in 10 parts of DI water and 1 part of HF is used for stripping the oxide. The DI water (resistivity 18M*\_*cm) was obtained from the DI water plant of Millipore, India make (Model Milli-Q). Finally, the substrate was dried using dry nitrogen. After cleaning, the substrate was oxidized in furnace (Thermco) at 10000C in wet oxidation environment. The gaseous composition of the environment inside the furnace was 10% N2 and 30% O2. To get 200 nm of SiO2 film oxidation was performed for 20 minutes. The color obtained on the substrate was metallic blue.

1. **DEPOSITION OF DIFFERENT LAYERS**

**A. Aluminum**

After, the layer of 200 nm of SiO2 was obtained over the substrate; the substrate was put in vacuum coating unit to deposit a layer of aluminium. The pressure inside the coating unit was maintained at 10-6 mbar. The aluminium metal was put in molybdenum boat and it was vaporized. On evaporation the molecules were sticked on the substrate wich was put 18 cm above the boat. This aluminium layer acted as an ohmic contact.

**B. AZO seed layer**

Obtaining a layer of Al over the substrate, a seed layer of AZO was deposited over the aluminium after hiding some parts of Al layer. The seed layer works as catalyst for proper and aligned structure of nanostructure. Patterned AZO film, which is covered by an insulating template, was used as a nucleation site to grow ZnO nanostructure. In this approach, the AZO thin film takes on the role of metal catalyst in VLS as it serves as a buffer layer facilitating the nucleation and alignment of ZnO nanostructures. The process begins with the deposition of the AZO layer. Highly *c*-axis oriented AZO film with a thickness of 20 nm was deposited on Si substrate by vacuum coating unit. . Shadow masking technique was used to hide some part of aluminium layer and rest part was deposited with aluminium doped zinc oxide (AZO).The thickness of this film was about 20 nm. AZO was prepared by taking 98 parts of ZnO and 2 parts Al2O3.

**C. ZnO Thin film**

Over this layer of AZO thin layer of ZnO, thickness about 200 nm, was grown. Vacuum coating unit by Hindhivac,India make (Model no. 12A4D) was used for this purpose. The source and target were kept at 18 cm distance and the pressure inside the chamber was maintained at 10-6 mbar. The source material ie Ultrapure ZnO (99.99%) palate was kept in molybdenum boat for coating process. To increase the conductivity of the ZnO film it was annealed at 4500C. The environment for annealing was N2/Ar and the duration of annealing was about 20 minutes. Field emission scanning electron microscopy (FESEM) was performed to examine the surface morphology and crystal structure.

1. **THIN FILM CHARACTERIZATION**

Before fabricating the schottky contacts on the ZnO films, we investigated the surface morphology of the thin film by using a number of metrological and analytical instruments like the X-ray Diffractometer (XRD), Field Emission Scanning Electron Microscopy (FESEM), photoluminescence (PL). X-ray Diffractometer (XRD) gave the crystal orientation of the ZnO material in the film, Scanning Electron Microscope (SEM) was used to investigate the crystalline grain features of the fillm. The different measurement techniques used for the ZnO film characterization film are discussed in brief as follows.

**A. X- ray Diffraction (XRD)**

The X-ray Diffractometry (XRD) is a very convenient characterization technique for all sorts of crystalline materials. Because of the periodic structure of a crystal, every crystal is associated with a unique reciprocal space which is basically a three dimensional Fourier transformation of the real space productivity. Like all other diffraction methods XRD also measures the reciprocal space associated with the periodicity of any crystal. In addition, the very short wavelength of an X-ray photon (typically, λ = 1. 54 Å)allows it to scan the reciprocal space points corresponding to a very short crystalline period (< 5 Å)**.**  In XRD, a monochromatic X-ray beam is incident on a sample and the unique X-ray diffraction peaks are produced by conservative interference of the monochromatic beam scattered from each set of lattice planes at specific angles according to the Bragg’s law:

(1)

Where, N is the diffraction integer, λ is the wavelength of the x-ray diffraction, d is the spacing between atomic planes in the crystalline phase, and θ is the incident angle of the X-ray beam with respect to the diffraction planes. The typical intensity of the the diffracted X-rays is measured as a function of the diffraction angle 2θ and orientation of the sample.

**B. Field Emission Scanning Electron Microscopy (FESEM)**

The SEM is generally used to examine the surfaces of nano structure and crystal structure of samples. An electron beam produced by the electron gun is attracted towards the anode, condensed by condenser lens, and then focused as a very fine point on the sample by an objective lens system. A magnetic field is energized and created by the scan coils which deflect the beam back and forth in controlled manner. Once the electron beam hits the sample, a variety of signals are generated. Out of these signals, some specific signals are collected by the detectors and are then sent to a viewing screen that produces an image or an elemental composition of the sample. The greatest amount of the signal information in the SEM is provided by secondary electrons, scattered electrons and X-rays.

1. **DEVICE CHARACTERIZATION**

After examining the SEM images it was found that the prepared structure consisted 200 nm ZnO ‘nano noodles’ structure. On this Si/SiO2/Al/AZO/ZnO structure contacts of Palladium were deposited using shadow mask technique. This shadow mask gives the area of contact 1 mm X 1 mm. The thickness of contacts was 200 nm. This deposition gives the diode a schottky interface. Again annealing was done for 7 minutes in N2 environment. This palladium metal was used as front contact and back contact was taken from aluminium layer which performs as ohmic contact.

**A. Current voltage (I-V) measurements**

The DC current–voltage measurements were carried out in room temperature and illuminated conditions of the MSM detector in order to study the electrical and optical characteristics. The I–V characteristics were analyzed using the semiconductor parameter analyzer (Agilent technologies B1500A) at room temperature (270C) for applied voltage between -2 to +2 volts. The system was interfaced to a computer by interactive characterization software (ICS) version 3.7.0 of metrics technology program. A UV lamp from Benchmark, India was used along with semiconductor parameter analyzer (SPA) for the measurement under illumination.

**B. Extraction of Schottky parameters from the measured IV characteristics**:

Device fabricated for our study consist of two contacts. One is Ohmic contact which is taken from aluminium layer. The other contact is Schottky which is taken from the interface of palladium. This Schottky contact is main area of our study. The current transport through Schottky contact follows thermionic emission theory as discussed in previous chapter. Using I-V characteristics different schottky parameters such as ideality factor, Schottky barrier height, Saturation current can be calculated by following theories and formulae.

The current – voltage characteristics of a Schottky contact can be expressed as Sze [Sze, (1981)]:

 … (2)

Where, A is the contact area, A\* is the effective Richardson constant, q is the charge of an electron, k is the Boltzmann constant, φb is the barrier height, T is the operating temperature, and n is the ideality factor.

After manipulations, we can express the ideality factor as Sze [Sze (1981)]

 …(3)

Thus in order to determine the ideality factor of a schottky contact diode, we may first obtain ln(I) versus V characteristics from the measured current - voltage data of the device. We may now consider the small region over the characteristics where the ln(I) versus V characteristics are linear. Clearly, the slope of this linear region of the ln(I) versus V characteristics represents whose value can be inserted in equation (3) to estimate the value of the ideality factor of the schottky contact.

Once the value of Is is obtained, the barrier height can be estimated as :

 …(4)

1. **RESULTS AND DISCUSSION**

In this section we will discuss the important experimental results on the surface morphology of ZnO thin film fabricated by thermal evaporation method. This surface study will follow the electrical parameter analysis of the Schottky contacts obtained from I-V measurements. Further we will continue our study of device under illumination of Ultra violet light.

The surface morphology of the ZnO thin film is studied by SEM measurements. The SEM images of ZnO film grown at 5000C are shown in fig. 2. It is clearly observed from the image that the closely packed crystals of ZnO appeared like ‘nano – noodles’ structure and are distributed randomly over the entire surface of the ZnO thin film. The image also reveals that ZnO thin film has good polycrystalline structure. The diameter of a thread of fine ‘nano –noodles’ structure was about 67 nm.

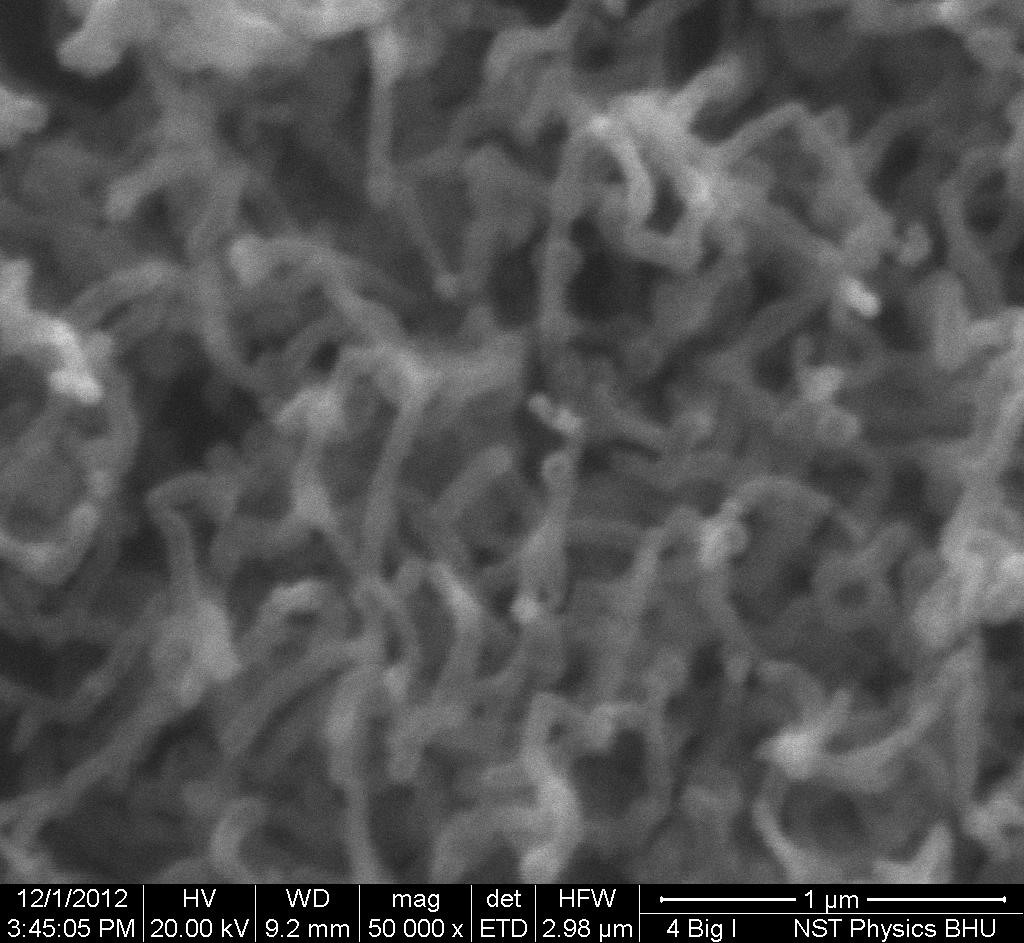


Fig. 2. SEM image of the ZnO thin film

In order to estimate the Schottky contact parameters the device was tested through a semiconductor parameter analyzer. The contacts were taken from top side of the device. The first one contact was taken from palladium interface which acted as Schottky contacts and another one contact was ohmic contact which was taken from Al layer deposited above the oxide of silicon. The measured I-V characteristics under dark conditions for single Schottky contact were used to estimate the Pd/ZnO contact parameters. The values of Saturation current (Is), ideality factor (n), and barrier height are found to be Is = 30.84 µA, ideality factor (n) = 5.68, barrier height (φb) = 0.6542 eV. The turn on voltage is found to be ̴ 0.5V. It is estimated from the measured I-V characteristics as the voltage which the current increases rapidly. It is clearly observed (Fig. 3) that the current increases significantly when the applied bias exceeds ̴ 0.5 Volts.

Graph4 Temperature variation.TIF

Fig.3 I-V characteristics at different temperature

Now we present the current–Voltage (I–V) characteristics of the Pd/ZnO Schottky contact based photodetector under UV illumination. Fig 4 shows the I-V characteristics measured in the dark and UV illumination. It is seen that for a given applied voltage, there is a significant change in the current in the presence of UV radiation.

Graph1 Comparison in dark and UV.TIF

Fig.4: I –V characteristics of photodetector under UV illumination

**CONCLUSION**

The analysis in the present work clearly demonstrates that the proposed structure can be used as potential UV detector. The device offers good contrast ratio and hence is suitable for UV detection applications. Structure modifications and growth condition alterations may be explored for improved performance in terms of efficiency and speed of response.

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