PROJECT REPORT

On

DEPOSITION OF THIN FILM BY THERMAL EVAPORATION

&

DESIGN OF GAS SENSOR ALARM

Undertaken at
DRDO, JODHPUR

CONTENTS

1. INTRODUCTION

1.1 Gas Sensor

Gas sensor has recently attracted much attention due to increasing demand of environmental monitoring and other gas detecting applications. Among different types of gas sensor, thin film gas sensor has been much of interest because of microelectronic batch-fabricated compatibility, reproducibility, and ability to form multilayer device structures. In this work, thin film based gas sensing circuit is designed for immediate applications of CO detection for environmental monitoring. Ion assisted deposition (IAD) process offers several advantages for gas sensor fabrication, including reactive deposition for gas-sensitive metal-oxide material optimization and improved thin film adhesion for better device reliability. The metal oxide layer was deposited on alumina or glass substrates. The sensors were tested with reducing gases, in the temperature range between 200^{o}C and 350 ^{o}C and the electrical change in gas sensor is detected.

Gas sensors interact with a gas to initiate the measurement of its concentration. The gas sensor then provides output to a gas instrument to display the measurements. Common gases measured by gas sensors include ammonia, aerosols, arsine, bromine, carbon dioxide, carbon monoxide, chlorine, chlorine dioxide, Diborane, dust, fluorine, germane, halocarbons or refrigerants, hydrocarbons, hydrogen, hydrogen chloride, hydrogen cyanide, hydrogen fluoride, hydrogen selenide, hydrogen sulfide, mercury vapor, nitrogen dioxide, nitrogen oxides, nitric oxide, organic solvents, oxygen, ozone, phosphine, silane, sulfur dioxide, and water vapor. Important measurement specifications to consider when looking for gas sensors include the response time, the distance, and the flow rate.

The response time is the amount of time required from the initial contact with the gas to the sensors processing of the signal. Distance is the maximum distance from the leak or gas source that the sensor can detect gases. The flow rate is the necessary flow rate of air or gas across the gas sensor to produce signal. Gas sensors can output a measurement of the gases detected in a number of ways. These include percent LEL, percent volume, trace, leakage, consumption, density, and signature or spectra. The lower explosive limit (LEL) or lower flammable limit (LFL) of a combustible gas is defined as the smallest amount of the gas that will support a self-propagating flame when mixed with air (or oxygen) and ignited. In gas-detection systems, the amount of gas present is specified in terms of % LEL: 0% LEL

being a combustible gas-free atmosphere and 100% LEL being an atmosphere in which the gas is at its lower flammable limit. The relationship between % LEL and % by volume differs from gas to gas. Also called volume percent or percent by volume, percent volume is typically only used for mixtures of liquids. Percent by volume is simply the volume of the solute divided by the sum of the volumes of the other components multiplied by 100%. Trace gas sensors given in units of concentration: ppm. Leakage is given as a flow rate like ml/min. Consumption may also be called respiration given in units of ml/L/hr. Density measurements are given in units of density: mg/m^3. A signature or spectra measurement is a spectral signature of the gases present; the output is often a chromatogram. Common outputs from gas sensors include analog voltage, pulse signals, analog currents and switch or relays. Operating parameters to consider for gas sensors include operating temperature and operating humidity.

1.1.1.APPLICATIONS OF GAS SENSORS

(i) Gas Leak Protection: - These are areas of industry where the possibility of flammable gas build-up is small, but the consequences of a gas escape could be catastrophic. These tend to be industries which by their nature have large volumes of gases piped around the works:

- Engineering companies
- Metal working plants
- Research laboratories

(ii) Confined Space Entry

The most prominent application for portable gas detection instruments. The instrument is used to check the atmosphere of sewers, tanks and other vessels prior to entry for maintenance purposes. These instruments invariably are 'multi-gas'. They have 3 or even 4 sensors included in the package. Large volumes of these instruments are purchased by:

- Public utilities - especially water and telecoms
- Chemical and petrochemical - for entry into vessels
- Cabling contractors
- Piling contractors

- Tunnelling contractors
- Civil engineers
- Landfill operators

(iii) Hazardous Area: Working Areas of industry where the build-up of flammable gas or vapour is an ever present danger. These instruments are very often the same multi-gas instruments used for confined space entry, but there are areas where single gas monitors ('explosimeters') are used. Typical industrial sectors here are:

- Chemical and petrochemical industries
- Oil/gas exploration
- Mining

1.1.2 TYPES OF GAS SENSOR

(I) The Pellistor Catalytic Gas Detector

Pellistors are miniature calorimeters used to measure the energy liberated by the burning of a combustible (flammable) gas or vapour. A pellistor consists of a coil of small-diameter platinum wire supported in a refractory bead on which is deposited a layer of catalytic material, on which the gas is burnt. The coil serves two purposes. Firstly, it is used to heat the bead electrically to its operating temperature, about 500°C, and secondly it is used to detect changes in temperature produced by the oxidation of the flammable gas. The earliest forms of catalytic gas sensors consisted solely of bare coils of platinum wire, operating at 800-1000°C. At such temperatures, platinum wire evaporates extremely quickly causing signal drifts resulting from a reduction in the wire diameter. The specification for such a sensor, which is still produced commercially, requires that the sensor has a life of 100 hours. The majority of present day devices, as stated earlier, have the coil cloaked in a porous ceramic onto which is deposited the precious metal catalyst. The enhanced catalytic activity resulting from the much larger surface area of catalyst available permits much lower operating temperatures of around 500°C, resulting in lower power drain and longer device lifetime.

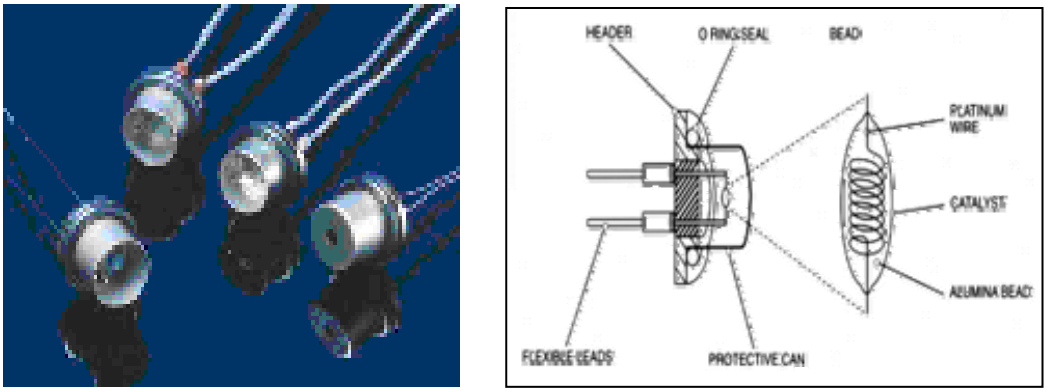


Fig 1.2 Pellistor gas sensor

The concept of the pellistor is based on the fact that the most foolproof way to determine whether a flammable gas is present in air is to test a sample by trying to burn it! A pellistor consists of a very fine coil of wire suspended between two posts. The coil is embedded in a pellet of a ceramic material, and on the surface of the pellet (or 'bead') there is a special catalyst layer.

In operation, a current is passed through the coil, which heats up the bead to a high temperature. When a flammable gas molecule comes into contact with the catalyst layer, the gas 'burns'. The reaction occurs without a flame since the level is below the Lower Explosive Limit (or LEL) of the gas. However, just as in a burning reaction, heat is released which increases the temperature of the bead. This rise in temperature causes the electrical resistance of the coil to rise. There is another bead in the circuit which is identical to the detector bead, but does not contain any catalyst.

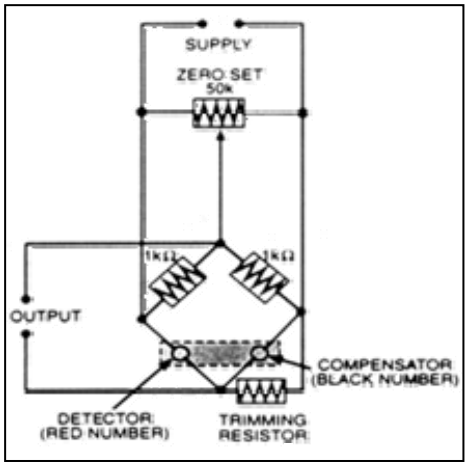


Fig 1.3 bridge circuit

This bead will react to changes in humidity, ambient temperature etc, but will not react to flammable gas. All that is required is a comparison of the resistance of one bead against another in a Wheatstone bridge type circuit in order to obtain a meaningful signal.

(ii) Thermal Conductivity Gas Sensors: Pellistors measure the flammability of a gas; they cannot be used to measure levels of gas above the Lower Explosive Limit (LEL), since the reducing level of oxygen will result in a fall-off of signal. However, a similar device can be used to monitor these high levels of gas. We have a range of thermal conductivity sensors, which are designed to complement the pellistor range in terms of electrical characteristics, so that they can be used in the same Wheatstone Bridge circuits. They are supplied with a compensator bead which is in a sealed enclosure of air. This enclosure acts as the thermal conductivity reference in exactly the same way as it acts as the reference for a pellistor.

Thermal conductivity measurements do not rely on the flammability of the gas, the technique can be used to analyze a whole range of gas mixtures, provided that there are only two gases present and that the two gases have significantly different thermal conductivities. Examples includes

- 0 - 100% Hydrogen in Air
- 0 - 100% Methane in Air
- 0 - 100% Carbon Dioxide in Air
- 0 - 100% Carbon Dioxide in Methane
- 0 - 100% Helium in Air

Thermal conductivity cannot be used for gas mixtures where the thermal conductivities of the two gases are similar. The best example of this is oxygen levels in air, as the thermal conductivities of oxygen and nitrogen are too close to give a meaningful signal.Our pellistors and thermal conductivity sensors can be obtained already packaged as complete, flameproof gas detection heads for use in fixed gas detection systems.

(iii)Infrared gas sensor

Infrared Gas Sensors exploit the property that many gases absorb radiation in the 2-14 micron, infrared region of the spectrum. These spectral absorbance show features which may be regarded as 'fingerprints' to identify the gases and enable their concentrations to be

deduced. The sensor bodies contain an infrared source and infrared detectors inside a compact and combined gas cavity/ optical cell. The detectors have infrared band pass filters placed in front, which tune them to the specific gases to be sensed. When the specific gas enters the cavity it is registered as a change in detector signal. The magnitude of this change is related to the concentration of that gas via a simple exponential formula.By utilizing different infrared filters a range of gases can be sensed and discriminated with these devices.

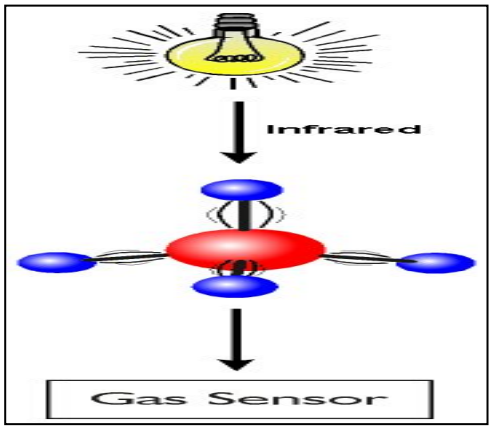


Fig 1.5 Vibrating molecules in Infrared frequency

In cases where spectral lines overlap, then an individual sensor may show cross sensitivities to a gas range. Infrared gas sensors are very robust devices not affected by contact with a harsh chemical environment. Any changes in ambient conditions such as temperature are compensated for in software. Their dimensions and power requirements are compatible with and complementary to pellistor gas sensors. After over thirty years of successful manufacture of pellistor-based flammable gas sensors, the range of Non-Dispersive Infra-red (NDIR) gas sensors represents the first of many diversifications into other areas of gas sensor technology.

In a molecule, absorption or emission of energy can occur in transitions between different energy levels. These transitions can be associated with changes in the vibrational energy and changes in the rotational energy of the molecule. Such internal energies are quantized, so that the molecule can exist only in certain discrete vibrational and rotational energy levels. The energy related to transitions between vibrational energy levels is equivalent to radiation in the near infra-red region of the electromagnetic spectrum. Each vibrational level is associated with a set of rotational levels, which results in several closely

spaced energy levels existing within a frequency band in the infra-red spectrum of the molecule. The fundamental frequencies at which the bands exist are functions of the particular bond and the mode of vibration, e.g. stretching or bending. When a molecule is exposed to infra-red radiation with an energy equivalent to a vibrational transition, the radiation is absorbed and the molecule undergoes the transition. This absorption is used as the means to determine the amount of target gas molecules present.

The NDIR technique uses a broad-spectrum source, such as a filament lamp, to expose the gas to a wide range of infra-red frequencies. An associated detector is fitted with an optical filter such that it can only monitor the intensity of a certain narrow frequency band. This frequency band is selected to match a frequency band within the absorption spectrum of the target gas and the detector output is therefore affected by the concentration of the target gas. The frequency of radiation, for our purposes, is more often expressed in terms of its wavelength, as the two terms are directly related

(iv) **CO_2 Gas Sensor**

The CO_2 Gas Sensor measures gaseous carbon dioxide levels in the range of 0 to 5000 ppm. This probe is great for measuring changes in CO_2 levels during plant photosynthesis and respiration. With this sensor, one can easily monitor changes in CO_2 levels occurring in respiration of organisms as small as crickets or beans! The CO_2 Gas Sensor is easily calibrated using a calibration button. A chamber with probe attachment is included for running controlled experiments with small plants and animals.

Fig. 1.6 CO_2 Gas Sensor

1.2 VACUUM COATING UNIT

It is a versatile laboratory model coating unit for thin film application with facilities for evaporation, Optional accessories like Substrate Heating, Rotary Drive, Flash

Evaporation, EB Gun evaporation etc. It is an ideal unit for thin film coatings in Research, Educational institutions, semiconductor, optics the Vacuum coating unit & chamber gadgetries are manufactured using high vacuum compatible materials.

Fig 1.2.1 Vacuum coating unit

Salient Features

- Versatile coating unit.
- Compact and elegant.
- Can accommodate wide range of accessories.
- Highly reliable and proven.
- Suitable for mounting a 3 KW Electron Beam Gun.

Optional Accessories:

Rotary Drive, Radiant Heaters, Cold Fingers, Thickness Monitor, Flash Evaporations, Multi Filament Turrets, Liquid Nitrogen Trap(LNT), substrate heater, Electron Beam Gun 3KW Single Source/4 Source.

Technical Specification

1. Vacuum Chamber …….Beljar Type
2. Chamber Size ……300 mm Dia x 350 mm height (nominal)
3. Material ……Stainless Steel - SS 304.
4. Base Plate ……SS304, 330mm dia, with 11 Nos. ports for Various feed through
5. Chamber Lifting……Manual lifting with spring & ball cage assembly
6. CHAMBER GADGETORIES: (STD.)
   a. Work holder Size …… 225 mm Dia.
   b. LT Evaporation …… 10 V A.C(Sequential)
   c. Ion Bombardment …… 1 set, 3.5 KV, 50 MA D.C
   d. Source Shutter (manual)…… 1 set
7. VACUUM PUMPING SYSTEM
   a. Diffusion pump type & speed…… ……OD-114D, 280 Lit/Sec
   b. Rotary Vacuum Pump type & speed…… ED-15, 250 Lit/Min
   c. High Vacuum Valve…….100mm Butterfly Valve
   d. Roughing, Backing Valve……25mm size(CV-25)
   e. Vacuum Gauges……Analog, Pirani, Penning Gauge with sensors to measure Vacuum in the range of 0.5 mbar to 1 x 10^{-3} mbar and 10^{-3} to 10^{-6} mbar)
8. Ultimate Vacuum with DC-704 oil…… 6.5 x 10^{-6} mbar. without LN2 & 1 x 10^{-6} m.bar. With LNT
9. Utilities Required
   a. Power…… 230V AC, 50Hz, Single Phase, - 15 Amps.
   b. Water at 25 C …… .. 2 Lit/min at a pressure of 1.5 - 2 Kg/cm^2

1.3 Physical Vapor Deposition:-

Vapor deposited physically on the glass/metal substrate with the help of Vacuum Coating Unit .In this Unit we have several methods to Evaporate the metal .These methods are as follows:

1.3.1 **Vacuum Thermal Evaporation**

The vacuum thermal evaporation deposition technique consists in heating until evaporation of the material to be deposited. The material vapor finally condenses in form of thin film on the cold substrate surface and on the vacuum chamber walls. Usually low pressures are used, about 10^{-6} or 10^{-5} Torr, to avoid reaction between the vapor and atmosphere. At these low pressures, the mean free path of vapor atoms is the same order as the vacuum chamber dimensions, so these particles travel in straight lines from the evaporation source towards the substrate. This originates 'shadowing' phenomena with 3D objects, especially in those regions not directly accessible from the evaporation source (crucible). Besides, in thermal evaporation techniques the average energy of vapor atoms reaching the substrate surface is generally low (order of kT, i.e. tenths of eV). This affects seriously the morpholgy of the films, often resulting in a porous and little adherent material.

In thermal evaporation techniques, different methods can be applied to heat the material. The equipments available in the laboratory use either resistance heating (Joule effect) or bombardment with a high energy electron beam, usually several KeV, from an electron beam gun (electron beam heating)

(i). E-Beam Evaporation

- In this probleThermal emission of electrons from a filament source (usually tungsten) is used to heat samples to high temperatures.
- Typically, electron beams are used when required temperatures are too high for thermal evaporation.
- Magnetic field and restring used to steer beam by 270^{o} into metal source. (This is done to allow shielding of tungsten filament and prevent contamination. as shown in fig 1.3.1.)

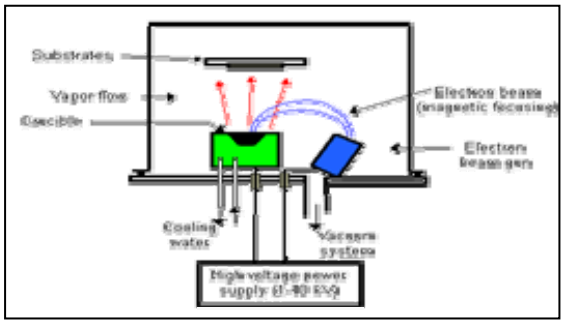


Fig 1.3.1 e-beam Evaporation

(ii) Thermal Evaporation or Filament Evaporation

- Metal sources (i.e. pellets) are placed on filaments (Tungsten, Molybdenum, Quartz, graphite, etc.).
- Metals are heated via a resistive filament under vacuum to their melting point.
- Metal pellets give off a vapor the atoms of which have some kinetic energy dependant on temperature.
- Metal atoms travel in a straight line from the source to a sample.
- Deposition rates on order of 1 nm/sec are standard.
- Some contamination may result from the filament being at least the same temperature as the source.

1.3.2. Sputtering

- Parallel plate system accelerates ions bombarding source material
- If ion energy high enough (typically 4x bond energy of source) atoms will be kicked lose (sputtered). Typical bond energies ~5 eV.
- Gas providing ions must be inert (i.e. do not react with sample substrate).
- Obviously low pressures are incompatible with sputtering, thus the sample must be located close to target source.
- Insulating materials must use RF energy source.
- Sputtering works well for materials with extremely high melting points (carbon, silicon) and alloys.

1.3.3. THIN FILM DEPOSITION OF ALLOYS

- Multiple layers of metals can easily be deposited using either filament or e-beam evaporation.
- Because alloys contain materials with different vapor pressures, it is difficult to deposit an alloy by evaporation.
- One method of evaporating alloys is to melt two sources simultaneously in separate crucibles, and control each evaporation rate separately. This can be difficult a second possibility is to sputter the material.

1.3.4. Uniformity and Deposition Rate

Semicircular symmetry allows multiple wafers to be evaporated simultaneously. For liftoff applications, a planar configuration is preferred. Rotating planetary can help with uniformity.

- Maintaining a lower deposition rate will yield greater uniformity.
- Placing samples far from the source will help uniformity, but will also lower deposition rate.
- The deposition rate depends on the position and orientation of the wafer in the chamber.
- An evaporation rate is the rate at which a material will vaporize (evaporate, change from liquid to vapor) compared to the rate of vaporization of a specific known material. This quantity is a ratio, therefore it is unit less.
- The vapor pressure of a liquid is the pressure exerted by its vapor when the liquid and vapor are in dynamic equilibrium. A substance in an evacuated, closed container will vaporize a finite amount. The pressure in the space above the substance will increase from zero and eventually stabilize at a constant value, the vapor pressure. Vapor pressures increase with temperature. The boiling point is the temperature at which the vapor pressure of a liquid equals the external pressure. In general, the higher the vapor pressures of a material at a given temperature, the lower the boiling point. In other words, compounds with high vapor pressures form a high concentration of vapor above the liquid. When the vapor source is heated, the vapor pressure of the metal to be evaporated becomes substantial, hence, atoms are sent out into the vacuum chamber, some of which reach the substrate to form a metal film
- Mean Free Path, for purposes of evaporation, is the distance a molecule travels in a straight line (in vacuum) before its velocity vector is randomized by a collision.

1.3.5. Step Coverage

- Step coverage describes the conformity of a thin film grown over a feature. Step coverage can be improved by

  (i). Planetary with two dimensions of rotation.

(ii) By heating the sample substrates. Heating the substrate to ~ 60% of the melting temperature promotes atom mobility after adhesion. This method improves step coverage by making use of surface diffusion. Surface diffusion follows Arrhenius Behavior: With a high enough temperature, the diffusion length can be made larger than the feature size. In some instances, such as for lift off, it is desirable to achieve zero step coverage.

Sputtering will in general have superior step coverage (for aspect ratios < .5) as sputtered atoms have random velocities. Evaporated substances tend to be collimated. For high aspect ratios, CVD processes may be used.

1.3.6. Quartz Thickness Monitor

Quartz crystals are used to monitor deposition rates. The quartz oscillates at a resonance frequency that is dependant on the thickness and atomic mass of the film deposited onto it. When a voltage is applied across the faces of a properly shaped piezoelectric crystal, the crystal is distorted and changes shape in proportion to the applied voltage. At certain discrete frequencies of applied voltage, a condition of very sharp and repeatable electro-mechanical resonance is seen. Quartz monitors are capable of measuring thickness of less than a single atomic layer with 0.5% accuracy.

Quartz deposition meter must be programmed for each material it is used to measure. The monitor's position in the evaporation chamber is also relative. The tooling factor is used to calibrate the meter to its position in the evaporation chamber. The Quartz crystal must be replaced frequently to provide consistent results. If the deposition rate is oscillating during a controlled deposition, it is a sign that the crystal needs to be replaced. Crystal life is highly dependant on process conditions of rate, power radiated from the source, location, material, and residual gas composition.

To measure deposition thickness precisely, a deposition meter must have knowledge of the material being evaporated, specifically its density and Z-ratio. The Z-ratio is a parameter that corrects the frequency change to thickness transfer

function for the effects of acoustic impedance mismatch between the crystal and the coated material. A table of Z-ratios for common materials is available here.

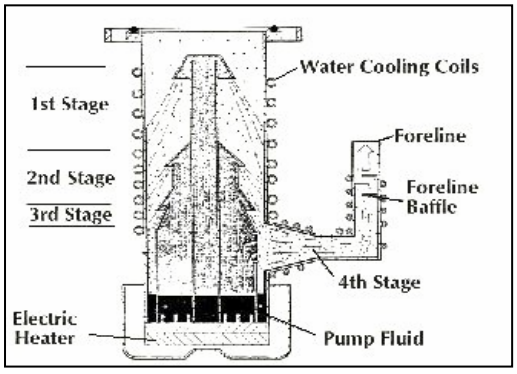
The flow of material from a deposition is not uniform so it is necessary to account for flux differences between the deposition meter's sensor and any samples. This is accounted for by the tooling factor, which can be experimentally established.

1.3.7. Vacuum Pumps

(i) Rotary Pump-

The rotary pump is a device which is for creating vacuum in chamber upto 10^{-3} Torr. In this two dumbbell shape rotary fans are creating the vacuum by sucking the air the chamber and the air is forwarded toward the outlet valve.

(ii) Diffusion Pump - High vacuum pump operating in the ranges from 10^{-5} Torr to10^{-6} Torr featuring relatively high pumping speed; Diffusion pumps operate by boiling a fluid, often silicon oil, and forcing the dense vapor stream through central jets angled downward to give a conical curtain of vapor. Gas molecules from the chamber that randomly enter the curtain are pushed toward the boiler by momentum transfer from the more massive fluid molecules removed from high-end applications because of the oil vapor back streaming into the vacuum system and contaminating the chamber. Pressure 10^{-6} Torr or better is referred to as high vacuum (HV). They tolerate operating conditions (e.g. excess particulates or reactive gases) that would destroy other pumps; they have often very high pumping speeds relatively low cost, and are vibration- and noise-free. Fig 1.3.2 shows this schematic diagram of diffusion pump.



.3.1 Diffusion pump

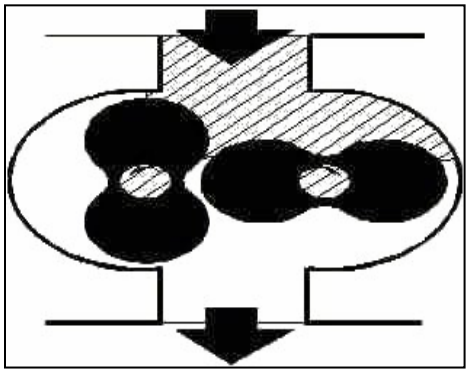


Fig 1.3.2 Rotary pump

The jet assembly consists of metallic nozzles aimed downwards facing the pump inner body so as to cool the vapor molecules emerging from these nozzles. The oil boiler, with external flat type heating coil for burst free evaporation, is located at the bottom of the pump and it holds specified quantity of oil for efficient working of the pump. An ultimate vacuum in the range of 5 x 10^{-7} m.bar can be achieved by using Dow Corning 704 Silicon Fluid, as this fluid does not oxidize by air and is chemical resistance which eliminates Frequent replacements. These pumps are built in with water cooled cap over the jet assembly so as to trap the back streamed oil vapors thus producing clean and better ultimate vacuum over conventional Diffusion pump. Other features is, pump is built in with High vacuum valve such that it can be used asAre wrapped around the body.

High Pressure Pirani Gauge - Analog

Change of pressure in vacuum systems brings about a rise or fall in number of gas molecules present and hence a rise (or) fall in the thermal conductivity of the gas. Thus the heat loss of constant voltage The pirani gauge head filament has high temperature co-efficient of resistance. So a slight change in System pressure brings about useful change in filament resistance resulting in an out of balance of the This electrically heated filament is an arm of a self balancing wheat stone bridge circuit. An automatic control amplifier corrects bridge voltage automatically. Thus the required bridge voltage (which varies depending upon the pressure at the sensor head filament) is a measure of the pressure which afterElectrically heated filament in the system varies with the pressure.

Salient Features:

- Compact solid state electronics
- Two gauge head capability
- Factory calibrated
- Reliable and repeatable

  Pressure indications
- Excellent Zero stability

2. EXPERIMENTAL WORK

2.1 Thin Film deposition:-

The Thin Film have been deposited by using thermal evaporating Vacuum Coating. Thin film of Al and Fe was deposited on glass substrate. The fabrication process is explained here in following steps.

Opening of the chamber

First of all thermal evaporator unit was installed in vacuum chamber the chamber should be cleaned to avoid contamination the required material to be deposited was kept in filament or boat with stand assembly

Closing of bell jar and vacuum pumping

1. Close the chamber. We can use the Vacuum grease to tightly attach the bell jar with chamber.
2. Now, turn on power supply and Water flow. Start the rotary pump by using puss button switch.
3. Open back pump and turn on pirani gauge power. Wait until pressure drops to 0. 5 torr. Open the chamber in the backing mode.
4. When pirani gauge shows pressure drops above 0.05 torr. Initiate the roughing pump and start the heater of the diffusion pump. Keep the chamber in this mode until the pressure drops to more than 0.05 torr .It will take approx. 30 min.

Evaporation of material

1. Turn on heater power.
2. Rotate current dial slowly increasing current.
3. The amount of current required varies for different metals.
4. When you begin to get a deposition, press open shutter on deposition meter and open shutter inside bell jar by flipping shutter switch down.
5. Adjust current up or down to maintain ideal deposition rate for specific metal.
6. At desired thickness, close shutter.
7. Slowly ramp down current when finished.

Opening of chamber

1. Turn off high vacuum switch.
2. Wait 10 minute for everything to cool down.
3. Open the Chamber.
4. Take out the glass substrate.
5. Find the V-I characteristics of the film.

Thermal evaporation in vacuum

In the evaporation deposition technique, the material is heated until fusion by means of an electrical current passing through a filament or metal plate where the material is deposited (Joule effect). The evaporated material is then condensed on the substrate. Other ways of heating are used, such as a RF coil surrounding a graphite or BN crucible, where the material to be evaporated is fused. The assembly of the technique is simple and results appropriate for depositing metals and some compounds with low fusion temperature (Al, Ag, Au, SiO, etc.).

Typical metals used as heating resistance are tantalum (Ta), molybdenum (Mo) and wolfram (W), with vapor pressure practically zero at the evaporation temperature (T_{evap} = 1000-2000 °C). When a helical filament surrounds the material it is convenient that the evaporant material wets the metal. A scheme of the deposition equipment used in the laboratory is showed in the Fig 2.1 The thermal evaporator uses resistive energy to evaporate thin films onto a given substrate. The thickness is controlled by the use of a quartz crystal monitor

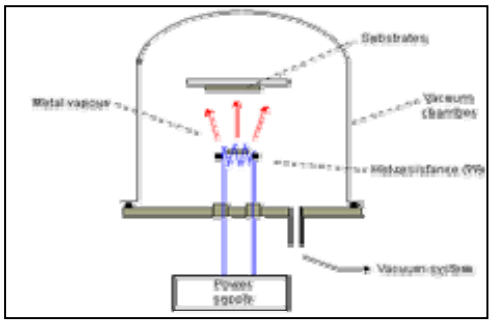


Fig 2.1 Thermal evaporation

Fig 2.2 Thermal Evaporator

2.2 Design for Circuit:-

2.2.1 The block diagram of gas sensor:-

The block diagram of thin film gas sensor is based on the fact that when sensor sense the gas there is a change in the internal resistance, so we use a versatile continuity tester attached with thin film .As there is a change in the internal resistance of the film the continuity tester will check the resistance and start the Buzzer. And we can find the leakage of the gas.

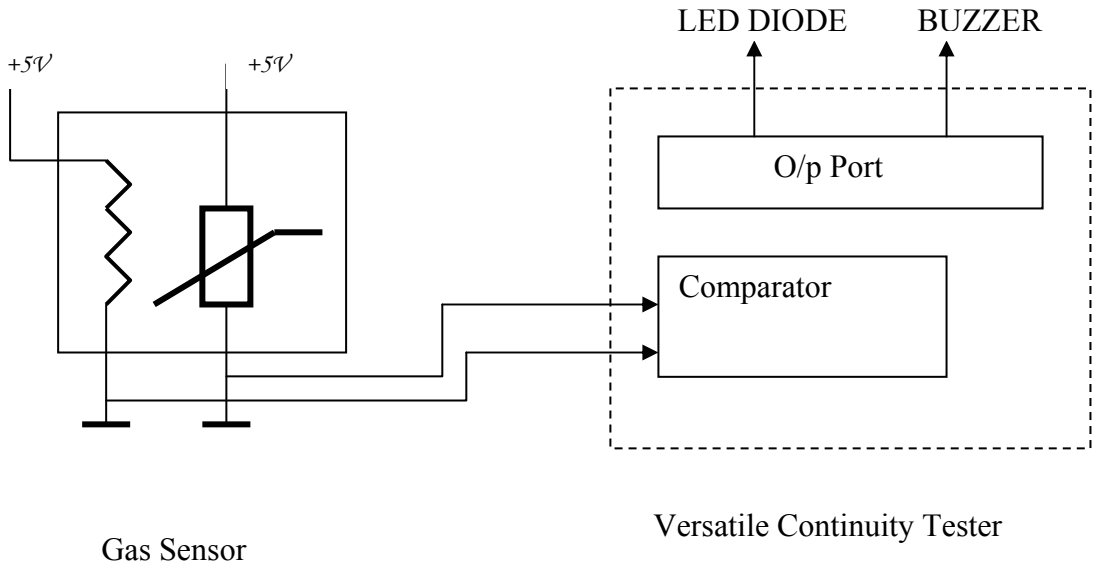


Fig 2.3 GAS SENSOR BLOCK DIAGRAM

2.2.2Circuit Description:-This circuit is used to measure the resistance changes in the metal thin film when the gas is passed through it. In this circuit LM324 IC is use as a comparator to compare the voltage across the film with different reference voltages. Comparator gives negative or positive voltage at the output and according to this the LED are glow and we can able to find out the concentration of gas in air. Four LEDs are use to detect whether the gas concentration is high / low \very high\very low.

2.2.3Continuity Tester:-

The continuity tester is a widely used in the electronic circuits for the purpose of checking and testing of continuity of various electronic components. The versatile continuity tester works according to the indication of LED to different resistances ranges. When a component is placed between test lead A and B, one of the four LEDs will glow depending upon of resistance of given component. The simple continuity tester has four resistance ranges for quick and reliable fault finding in electronics equipment.

The four resistance ranges indicated by LEDs button:

- VLO: - Very Low resistance= resistance between test clips is smaller than 5Ω.Buzzer sound.
- LO: - Low resistance= resistance ranges between test clips is 5Ω and 100K Ω.
- HO: - High resistance= resistance ranges between test clips is 100K Ω and 15M Ω.
- VHO: - Very High Resistance= resistance ranges between test clips is higher than 15M Ω.

Explanation to Circuit:-

The circuit shows that three Operation Amplifiers compares the drop across the test lead to a fixed voltage and indicate which of the two is highest by switching their output to the positively supply level or ground- see the accompanying table.

	VLO	LO	HO	VHO
A1	0	1	1	1
A2	0	0	1	1
A3	0	0	0	1
LED	D4	D3	D2	D1

The fourth OP-AMP output, (A4), function as a rectangular wave generator for driving the buzzer. The generator is switched on by diode D7, because it is allowed to operate when the output of A1 is low and D1 lights (VLO).After completion of the continuity tester on the PCB shown, ranges VLO and LO are adjusted with P1 and P2. Clip the test lead to a 5Ω resistor, and adjust for adjusting P2 until D2 and D3 go out and light respectively.

Current consumption of the tester is less than 20mA. The tester can, of course, also be powered from mains adaptor. It is recommended to a decouple R8 with a 22uF electrolyte capacitor when the supply voltage is relatively low. To boost the sound output of the buzzer, R16 can be replaced with a preset-adjust this until the buzzer resonates.

2.2.4 Circuit diagram

(i) Regulated power supply

The Regulated power supply is consisting of the 9-0-9volt, 250mA step down transformer takes 220V 50Hz A. C. Input in the primary winding and convert it into 9 volt A.C supply. The secondary winding of the transformer is center tapped, and it is used in full wave rectifier circuit. At the first and third nodes of the transformer, two 1N4007 diodes are employed to rectify A. C.; both the outputs of diodes are made one terminal by shorting them. This single terminal is used as positive terminal. The second node is used as negative or ground terminal. A capacitor valued 2200 microfarad is connected in parallel with output of transformer as a shunt capacitor filter. After this capacitor, a regulator IC 7808 is employed which gives 9V regulated output. Then a capacitor of value 10 microfarad is connected to remove the remaining ripples from the D.C. output. Thus the 9V output is get, which can now be used wherever required, as +V and ground.

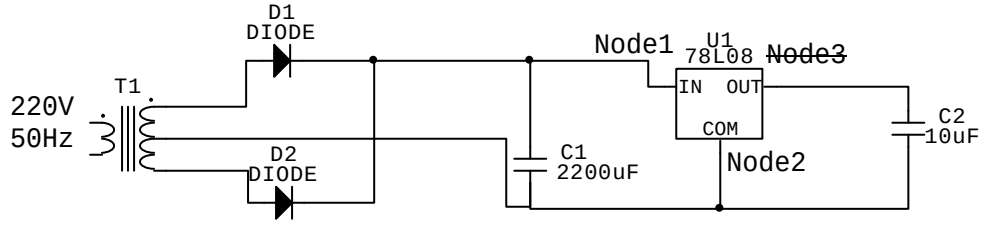


Fig 2.4 regulated power supply

(ii) Gas sensor circuit diagram

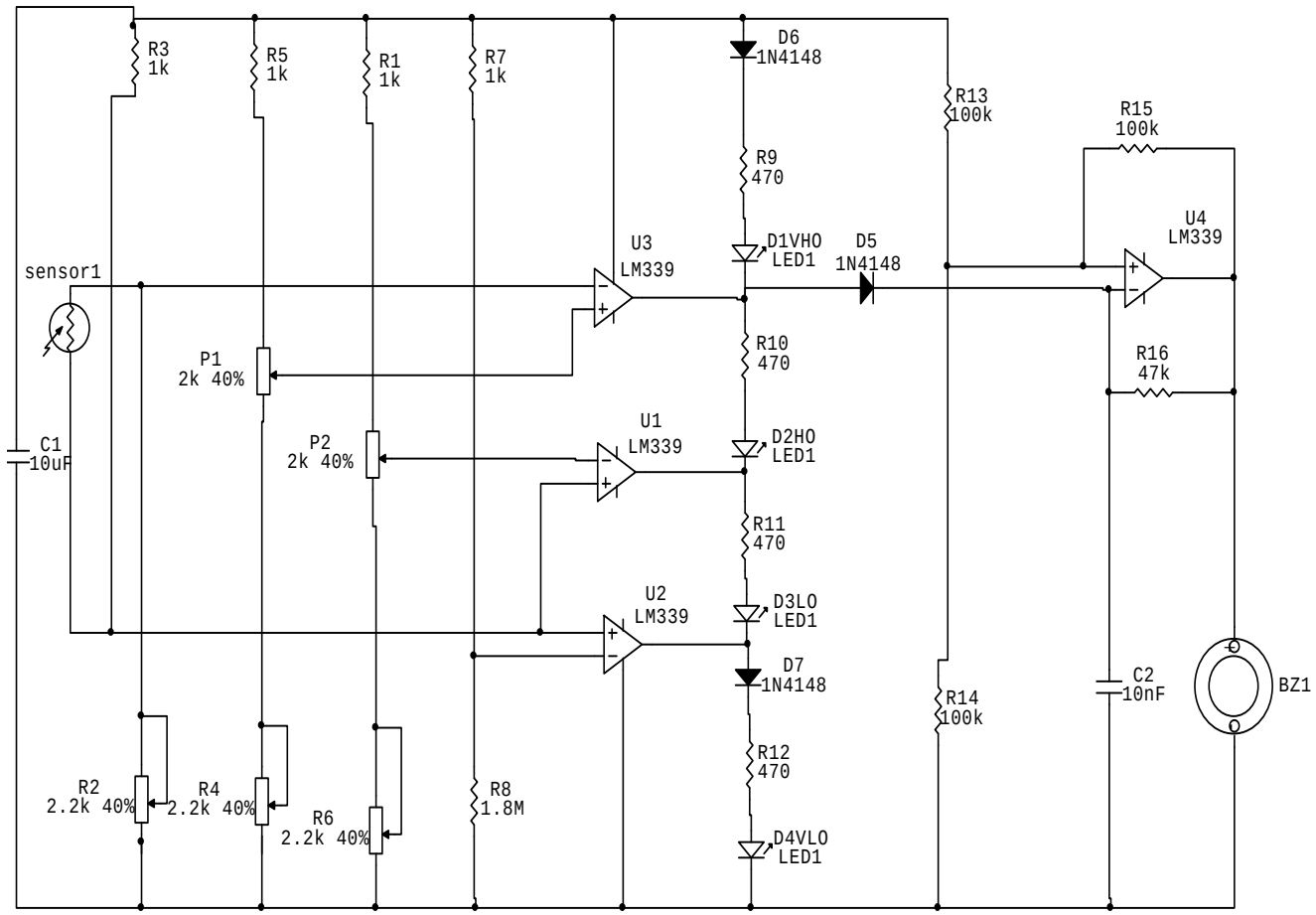


Fig 2.5CIRCUIT DIAGRAM OF VERSATILE CONTINUITY TESTER

2.2.5 Explanation for Operation Amplifier:-

Operational Amplifier

An Operational Amplifier most commonly referred as Op-Amp. It is a very high gain Differential amplifier with high input resistance and low output resistance. OP-AMP can amplify signal having frequency ranges from 0Hz to a little beyond 1MHz. In other words the OP-AMP can be used to amplify not only DC signal (0 frequency) but also AC signals (high frequency signals).

The name Operational amplifier has been given because it was originally design to perform mathematical operation. By proper selection of external components, OP-AMP can be configured to perform a variety of operation such as summation, subtraction, multiplication, integration & differentiation.

The IC version of OP-Amp (741 IC) was introduced in between 1964 and 1968.with the IC OP-AMP, the circuit design becomes very simple; moreover it has the advantage of low cost, take up less space & powers then the discrete components.

Typical uses of OP-AMP are to provide Voltage amplitude changes (amplitude & polarity), oscillators, filter circuit & many types of instrumentation circuits.

An operational amplifier contains a number of differential amplifier stages to achieve a very high voltage gain.

OP-AMP as a Comparator

A comparator compares a signal voltage on one input terminal of the OP-AMP with a reference voltage applied to other input terminal. The comparator circuit has only two possible output voltages, which indicate whether the applied input voltage is greater than or less than the reference voltage. The simplest type of comparator is the basic non inverting comparator as shown in fig. given below.

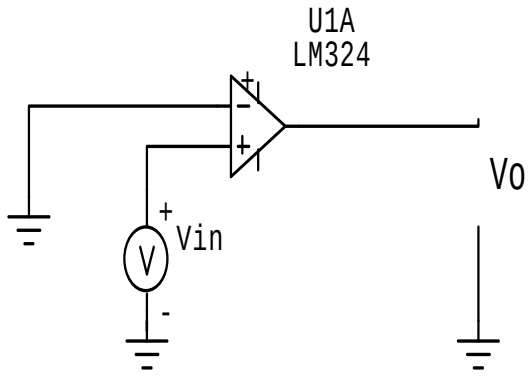


Fig 2.6 Comparator

To construct the comparator OP-AMP is operated in open loop condition. Since the open loop gain of the OP-AMP goes in to saturation. Thus the two possible output levels of this comparator are Vsat and – Vsat.

The inverting input terminal is grounded. Hence the reference voltage becomes ground potential for this comparator. The input voltage Vin is applied to the non-inverting input terminal. The comparator compares the input voltage Vin with the ground potential and indicates at the output, by the output voltage level, whether the input voltage is positive (above ground potential) or negative (below ground potential).

As long as Vin is positive the output voltage is +Vsat .This is shown in the transfer characteristics of comparator

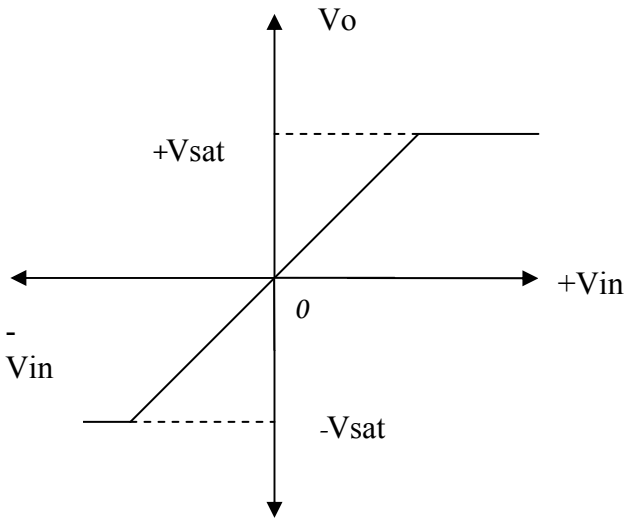


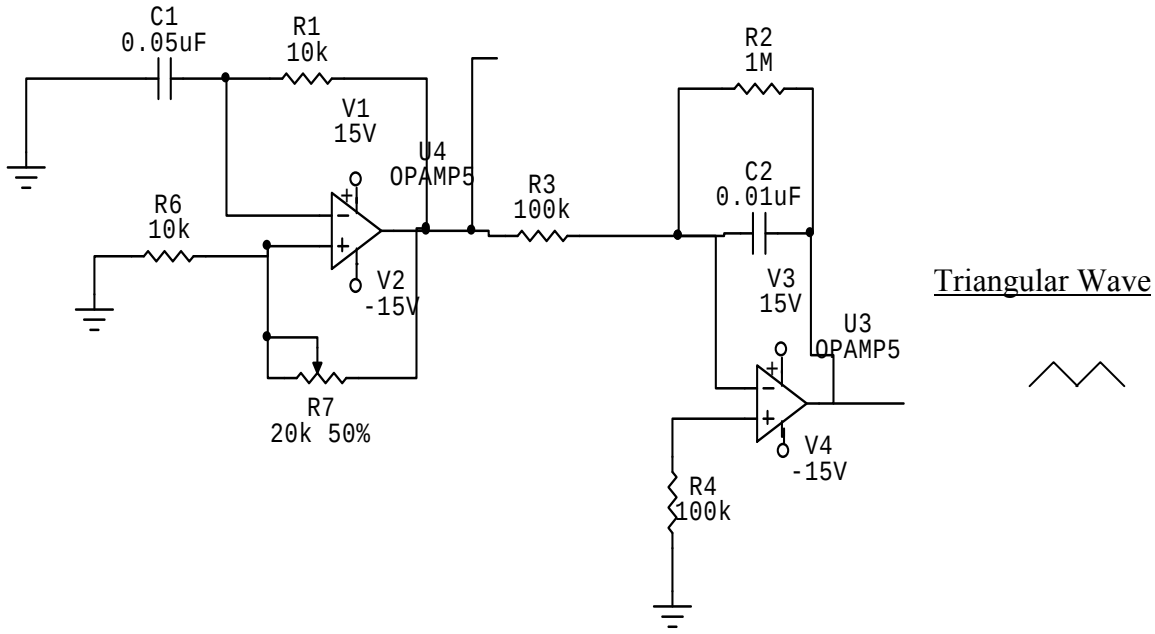
Fig2.7 Transfer characteristics of comparator

The switching of Vo from +Vsat to –Vsat or vice-versa occurs when the input voltage Vin crosses the zero level. The circuit is therefore also known as zero crossing detectors.

The various applications of comparators arte zero crossing detectors, level detector and window detectors.

Triangular wave Generator

The triangular wave generator can be formed by simply connecting an integrator to the square wave generator. The resultant circuit is shown in fig. This circuit requires a dual OP-AMP, two capacitors, and at least five resistors. The frequency of the square wave and triangular wave are the same. For the fixed R1, R2 and C values, the frequencies of the square wave as well as triangular wave depends on the resistance R. As R is increased or decreased, the frequencies of the triangular wave will decrease or increase, respectively. Although the amplitude of the square wave is constant (+/- V sat), the amplitude of the triangular wave decreases with an increase in its frequency and vice-versa.



3. FUNCTIONAL REQUIREMENTS OF THE CIRCUIT

3.1Parts specification

a. Resistors:

R1,R3,R5,R7=1KΩ

R2,R4,R6=2.2KΩ(trim)

R8=1.8KΩ

R9,R10,R11,R12=470Ω

R13,R14,R15=100KΩ

R16=47KΩ

P1, P2=2KΩ ten turn pot (trim)

b. Capacitor:

C1=10μF

C2=10nF

c. IC

LM324

d. LED FOUR

e. Diode

1N4148 TWO

f. Buzzer ONE

3.2 Components require for regulated power supply

a. IC

7809

b. CAPACITOR

C1=0.1uF

C2=2200uF

c. TRANSEFORMER

909 One

d. DIODE

IN4007 Two

4. CHARACTERISTIC OF THIN FILMS

V-I characteristics is measure with the use of for probe technique in which voltage is given to the film with the help of voltage source and voltage is measure with voltmeter and current is measure from another two probe with the help of ammeter

4.1 FORMULA USED

the formula used for calculation of conductivity is

$\sigma = I / 2\Pi SV$

where

S=Separation between the electrodes, 0.3 c.m

4.2 V-I Characteristic

4.2.1 Aluminum

Thickness=145 KA°

VOLTAGE (mV)	CURRENT (mA)
1.0	1.0
1.4.	54.2
1.6	73.6
2.0	115.0
2.2	128.5
2.4	136.6
2.8	154.0
3.0	168.5
3.2	179
3.4	195.6
3.6	200.1

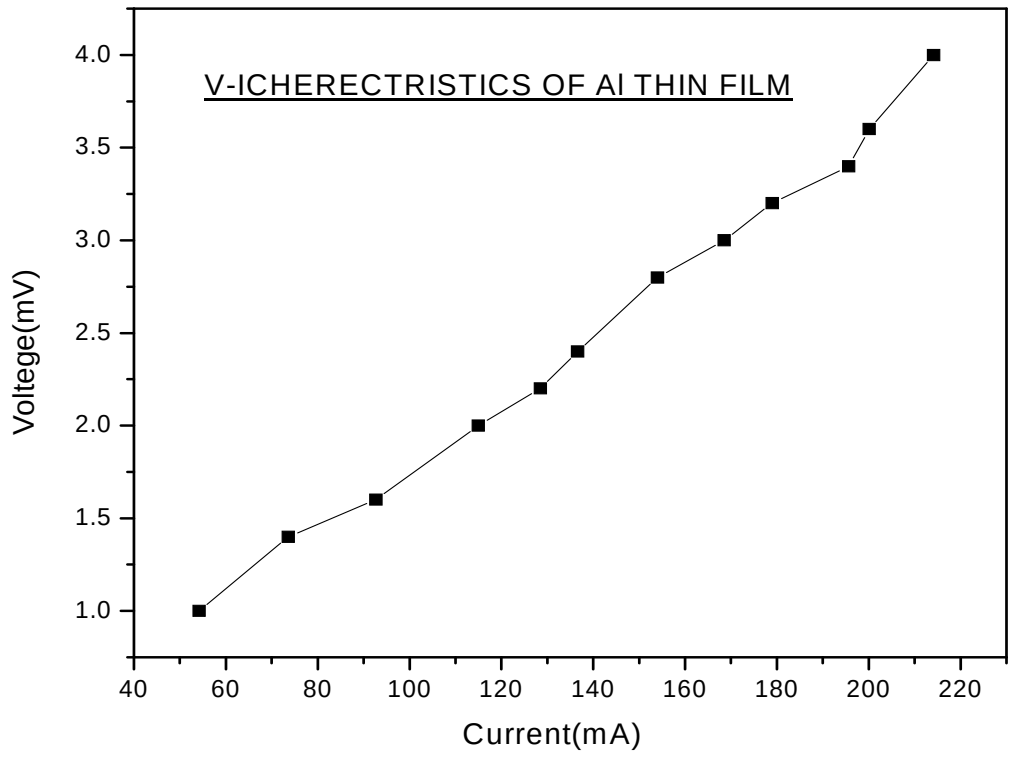


Fig 4.1 V-I CHARACTERISTICS OF AL THIN FILM

Conductivity= 55.17241siemans per c.m.

4.2.2 Iron Oxide Thin Film

a. thickness of film = 1623 A°

b. width of film =1.4 c.m

c. length of film = 2.2c.m

d. Resistance =14 K ohm

e. Resistivity =0.1549 Ω.cm

f. conductivity =6.4548 s / c.m

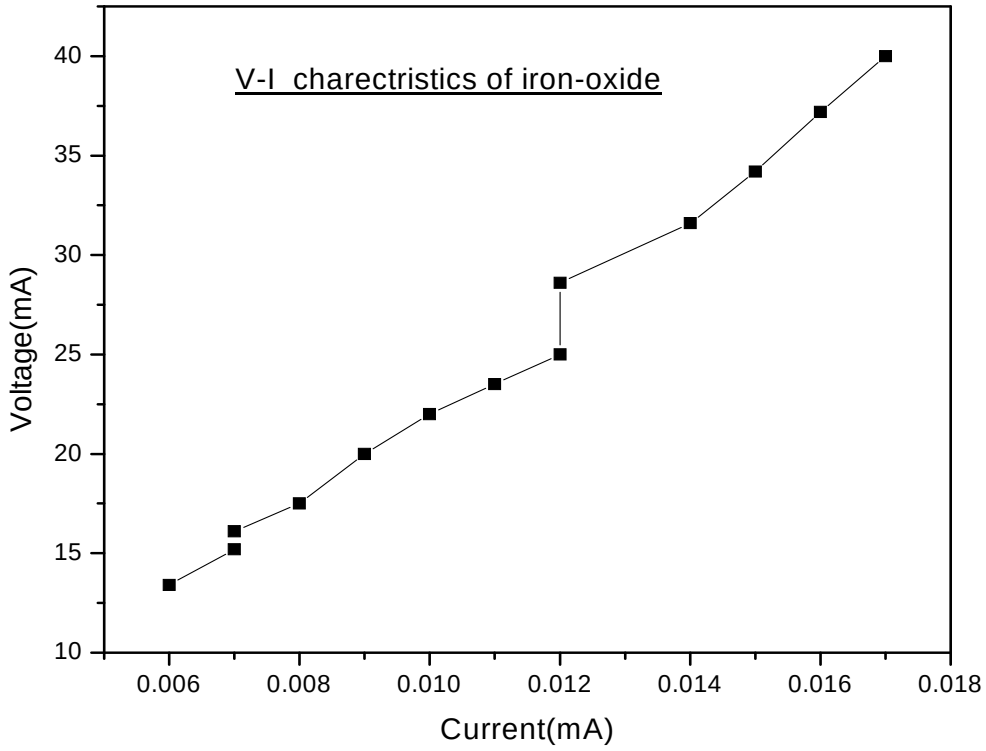


Fig 4.2 V-I characteristics of iron oxide

5 CONCLUSIONS

* Thin film of Aluminum of thickness 145 kA was deposited with thermal evaporation technique .

V-I characteristics of film was studied with four probe technique.

* The conductivity of Al thin film was found 55.17241 siemens per c.m.

* Thin film of Iron Oxide of thickness 1.623 kA was deposited with thermal evaporation technique .

V-I characteristics of film was studied with four probe technique.

* The conductivity of Iron Oxide thin film was found 6.4548 siemens per c.m.

* The resistivity of Al and Iron Oxide was measure with the help of the formula

$$\rho = RA/L$$

WHERE

R=Resistance of the film

A=Cross sectional area of film

L=Length of the film

* The oxide thin films are best materials for gas sensing applications.

* The circuit for gas sensing device was successfully design.

* With passage of gas through the thin film the resistance of the thin film changes & corresponding LED is glow