FABRICATION AND CHARACTERIATION OF SCHOTTKY DIODE.

INTRODUCTION

There are various types of diodes depending upon the doping profile of P-N Junction. But the storage charge in the junction capacitor gives rise to delay when they operate at high frequency. To eleminate this charge storage, P type material can be replaced with metal forming a metal semiconductor diode. As there is no charge storage in metal semiconductor diode, so no reverse current can exist for a while which observed in other P-N junction diode and no delay time(REVERSE RECOVERY TIME). So this type of diode can be easily used for rectifier at high frequency such as 300MHz.

Another important criteria of schottky diode is the low offset voltage of about 0.2-0.25 volt than other P-N junction diodes having 0.7 volt. So this type of diode can be used for rectifying low magnitude (Peak<.7Volt) signals. Now a days low power schottky diodes become the backbone of low power schottky TTL, which is very popular only for it's high speed,

Fabrication steps of this diode is similar to P-N junction diode without diffusion and diffusion related steps.

BASIC MATERIALS, CHEMICALS AND EQUIPMENTS FOR THE PROCESS :-

a) **Silicon Wafer :**appropriately designed silicon wafers have been procured from abroad. Wafers of 4 inch diameter and 350 μm thickness with resistivity 0.5 Ωcm orientation <100> is given for Semiconductor Diode Fabrication.

b) **The TemPress diffusion Furnace:** The diffusion furnace has been fitted with quartz tubes in the stacks. The temperature rise and fall upto 1200 ^{O}C have been tested using the microprocessor based temperature controller.

c) **Oxygen and Nitrogen Gas :**Highly pure oxygen and nitrogen gas together with cylinders, valves and gas flow control have been used.

d) **De–ionized water plant :** De–ionized water plant has been required for production of 18 MΩ water using doubled distilled water as the input.

e) **Chemicals :**Other necessary electronic grade chemicals is required.

f) **A diamond cutter :** A Diamond cutter is required for chip seperation.

g) **Masks :** Masks is required to maintain appropriate size of the device.

h) **Ultra-Sonic vibrator :** The ultra-sonic vibratior is required for cleaning purpose.

i) **The vaccume coating unit :** The vaccume coating unit with 5 X 10^{-6} mm of Hg Pr. vaccume with electron beam evaporation facility is used.

j) **Dryer :** A dryer is required.

k) **Temperature controlled heater :**A chemical bench temperature controlled heater is required

l) **Voltmeter and Ammeter :** voltmeter and ammeter is required for device performance measurement.

m) **Others essential items :** Some other general purpose things is requires such as tweezer, Safety Goggles, Covering dress for lab etc.

THE VARIOUS PROCESS STEPS FOR REALIZATION OF SCHOTTKY DIODES ARE GIVEN BELOW :-

A) Testing of dopant by hot probe method.
B) Etching and polishing of Silicon wafer.
C) Cleaning of silicon wafer.
D) Metalization.
E) Photolithography
F) Device separation
G) Soldering or bonding for lead contact

DETAILS STEPS FOR THE FABRICATION OF THE SCHOTTKY DIODE.

A) Testing the type of dopant by hot probe methode.

At first the probes of the voltmeter is touched on the silicon surface. Then the positive terminal of the voltmeter is heated (with a soldering iron) and the reading is checked. If the reading is positive then the wafer is of N type and if the voltage is negative then the wafer is P type.

In our case the voltmeter shows positive reading and so it is concluded that the silicon wafer is of N-type.

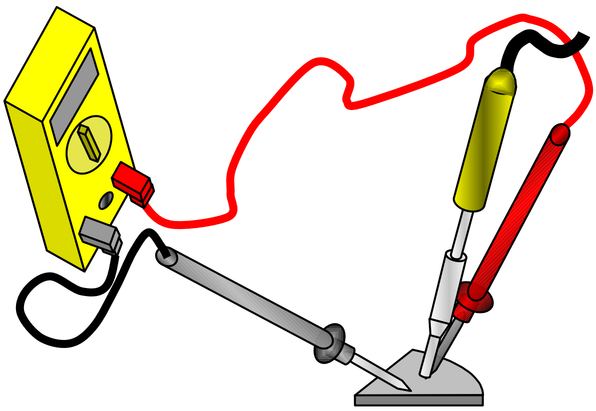


Fig. 1 : (Hot probe testing to determine the wafer is P type or N type)

B) Chemical Etching or Polishing

The given n type silicon wafer is a unpolished one. So polishing is required and is done by 20 % NAOH solution at temperature 85^{O} C for 3 to 5 minutes.

C) Wafer Cleaning

Wafer cleaning is a very important step in device fabrication process because of the variety of organic and inorganic contaminants of unknown origin, which are present on the semiconductor surface which detoriate the performance of the device. The cleaning process is done by i) Acid cleaning process and ii) dry plasma cleaning process. Here we have done the acid cleaning process.

i) Acid cleaning process.

1)**Removing Dust Particle:** The wafer is kept in a clean beaker containing hot (85 ^{O}C) Tri-Chloro-Ethelyn (TCE) and boiled for 5 minutes followed by 3 minute ultrasonic cleaning to remove dust particle.
2)**Removing Oil and Grease:**The wafer is then transferred to a beaker containing hot (85 ^{O}C) Acetone and again boiled for 5 minutes and followed by ultrasonic cleaning for 3 minute.
3)**Removing inorganic compound :**The wafer is then transferred in a beaker containing solution of H_2SO_4 : H_2O_2 at ratio 1:1 and is heated at 85 ^{O}C till the reaction stop then cleaned into DI water to remove inorganic compounds.
4)**Removing Silicon Di Oxide Layer :** Then the wafer is dipped into 10% HF solution for for 2 to 3 minutes and again cleaned into DI water to remove SiO_2 layer.
5)**Removing Acidic Organic Compound :**The wafer is then immersed in a beaker containing solution of H_2O : H_2O_2 : NH_4OH at ratio 5:1:1 and is heated at 70^{O}C for 10 minutes and then passed into cold DI water to remove acidic organic compound.
6)**Removing Alkaline Organic Compound :**The wafer is then immersed in a beaker containing solution of H_2O : H_2O_2 : HCl at ratio 6:1:1 and heated at 70^{O}C for 10 minute and then cleaned into DI water to remove alkaline organic compound.
7)**Rinsing and Drying :**The wafer is rinsed in running DI water. The wafer is then dried with a wafer dryer. Now the wafer is ready to oxidation.

D)Metalization

Metalization is one of the most important steps of device fabrication. Better adhesion gives always better performance of the fabricated device. The substrate is placed on the substrate holder. The vaccume level achieved upto 5 x 10^{-6} mm of Hg with the help of rotary (RP) and diffusion pump (DP). High vaccume region is required for metalization to achieve grater mean free path from source of metal (which to be deposited) to the substrate (wafer have to be metalised) because to avoid the collisions with other gas particles. Metalization has done by different techniques such as (i) Thermal Evaporation for low melting point of metal (ii) Electron beam technique when melting point of metal is high. (iii) RF sputtering when metal oxide or bi-metals are used. (iv) plasma technique when both are gas. Here the Electron beam technique is used.

The schematic diagram of Vaccume coating unit is given below:

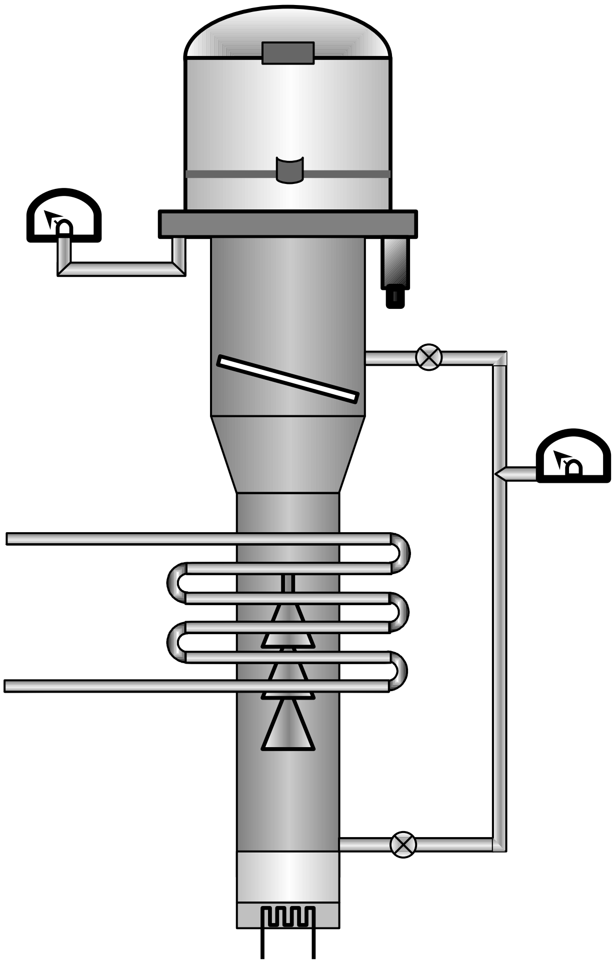


Fig. 2 (Vaccume coating unit)

Density of silicon is very low so it condenses easily and also evaporated quickly. Silicon can capture air particles.

Operation Steps of vaccume coating unit:

i)Loading of the wafer.
ii)Rotary pump (RP) on, baking valve open, when vaccume reached at 10^{-2} torr then backing closed.
iii)Roughing valve open, when vaccume level 10^{-2} Torr then roughing valve closed.
iv)Again backing valve opened.
v)Water circulation on . Diffussion pump (DP) on, Baffel open and achieved high vaccume.
vi)Then power switch on . After deposition (Here aluminium deposition for ohmic contact) power switch off, baffel closed, DP off.
vii)After 20 minutes water circulation off.
viii)Backing closed, RP off.

Back side metalisation: Back side of the wafer Ag metalized same as above or coating a silver paste with paint brush. After that heat treatment is required at 110 ^{O}C for 10 minute and 700 ^{O}C for 45 second. If the backside coating is silver paste then it is happened before the Al metalization because heat treatment is required for Al at 450 ^{O}C to 500 ^{O}C for 45 Second.

E)Photolithography

Photolithography is required for device isolation many deices can be fabricated in a single wafer. It is done by the same process as stated earlier photolithography process.

Etching
Aluminum etching is done on the selective portion.

Hard-photoresist removal
Hard photoresist is removed by acetone.

F) Device-separation :

It is the process by which we can separate single device from the wafer (single P-N junction diode from the wafer of many P-N junction diode). In our case the diamond scriber is used for the separation of P-N junction diode.

G) Lead contact :

It is done with the help of bonding technique or otherwise soldering is required. Here the soldering technique is used. A thin metallic ware is soldered on both side of the device in our case. During soldering, it should be remember that the temperature of the metallic film is very thin and therefore the temperature and the soldering time should be kept as low as possible.

Characterization of the fabricated Schottky diode

Circuit Diagram

The basic circuit diagram of the voltage current characteristic of the P-N junction diode is given below:

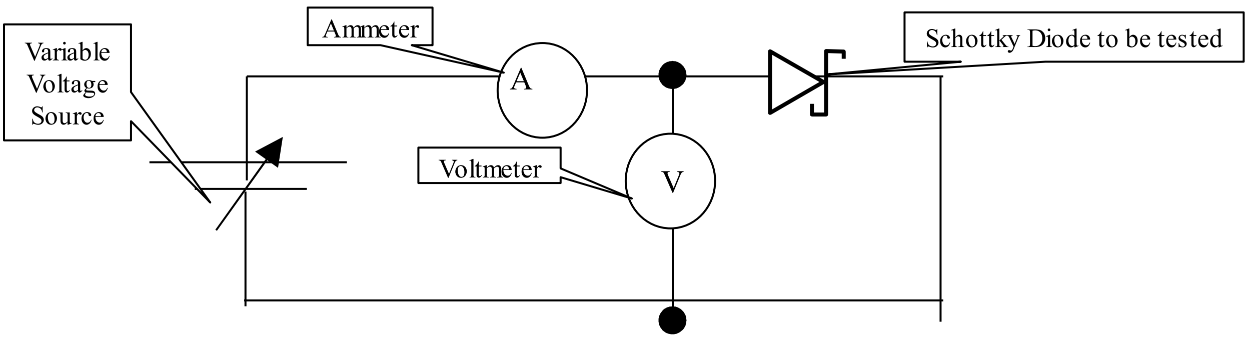


Fig. 5 (Circuit Diagram for performance test)

Connection Diagram

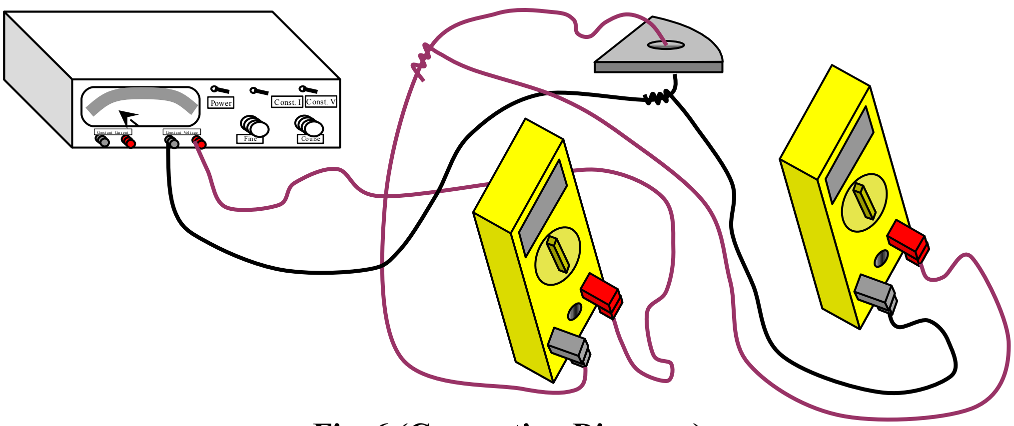


Fig. 6 (Connection Diagram)

Apparatus required for measurement:

i. Digital Multimeter as Ammeter. (Min step 1 µA in 200 µA range)
ii. Digital Multimeter as Voltmeter. (Min step 1 mV, Range 200 V DC)
iii. Variable voltage source (0-40 Volt with course and fine control).

Results:

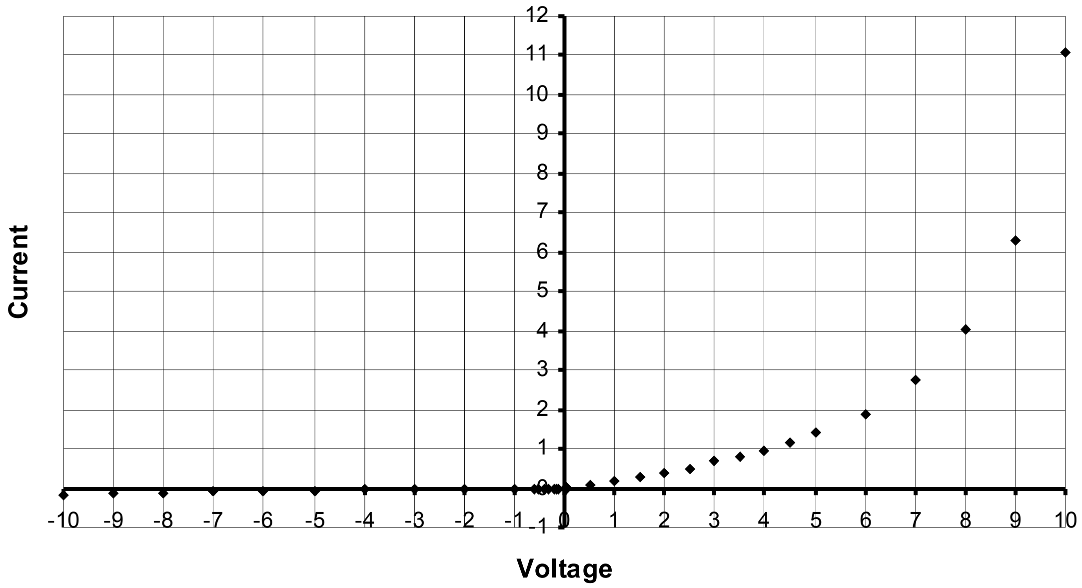
Reverse Bias Result

Voltage (V)	Current (mA)
-10.0000	-.1760
-9.0000	-.1400
-8.0000	-.1100
-7.0000	-.0890
-6.0000	-.0710
-5.0000	-.0550
-4.0000	-.0410
-3.0000	-.0298
-2.0000	-.0200
-1.0000	-.0120
-.6000	-.0095
-.5000	-.0087
-.4000	-.0083
-.3000	-.0074
-.2000	-.0070
-.1500	-.0060
-.1000	-.0050

Forward Bias Results

Voltage (V)	Current (mA)
.0203	.0015
.0460	.0020
.5000	.0700
1.0000	.1800
1.5000	.2800
2.0000	.3800
2.5000	.5000
3.0000	.6900
3.5000	.8200
4.0000	.9700
4.5000	1.1800
5.0000	1.4000
6.0000	1.8900
7.0000	2.7400
8.0000	4.0300
9.0000	6.3000
10.0000	11.1000

V-I Charasterics of Schottkey Diode



Remarks:

The device though gives reading of a schottky diode but still this diode cannot be used for commercial application as the performance is very poor. So, entire process for device fabrication needs much more attention on cleanliness. The polishing time should be increased for better device performance and fabrication.