LAB REPORT – VI

IV characteristics of Metal-Semiconductor (MS) contacts

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Objective : IV characteristics of Metal-Semiconductor (MS) contacts

Theory :

A silicon wafer is a material essential for manufacturing semiconductors, which are found in all kinds of electronic devices that enrich our lives.Few of us have a chance to encounter an actual silicon wafer in daily life. This ultra-flat disk is polished to a mirror-like surface, and made as free as possible of tiny surface irregularities, making it the flattest object in the world. It is also ultra-clean, virtually free of microparticles and other impurities. These qualities are necessary so it can be used as the substrate material of today's state-of-the-art semiconductors.You can find high purity wafers from Czochralski (CZ) and Float Zone (FZ) growth method.

Metal- Semiconductor contact

The principle of forming different types of the metal-semiconductor contact is the mismatch of the Fermi energy between metal and semiconductor material, which is due to the difference in work functions.

The metal-semiconductor (MS) contact is an important component in the performance of most semiconductor devices in the solid state. As the name implies, the MS junction is that a metal and a semiconductor material are contacted closely.

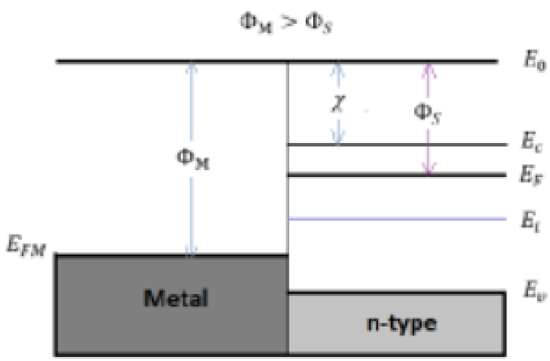
1. Rectifying Schottky Diodes
2. Non-rectifying Ohmic contact

Schottky junction

In the Schottky contacts or diodes, it has IV characteristics like normal pn junction diode.

The Schottky barrier contact refers to the MS contact having a large potential barrier height formed when the Fermi energy of the metal and the semiconductor are aligned together. The barrier height Φ_B is defined as the energy difference between the band edge with majority carriers and the Fermi energy of the metal. Since the Schottky barriers could lead to rectifying characteristics, it is normally used as a diode, which is a single MS junction with rectifying characteristics. Both n-type and p-type semiconductors can be formed the Schottky contact, such as Titanium Silicide, and Platinum Silicide.

$\Phi_S=\chi+(E_C-E_F)_{FB}$



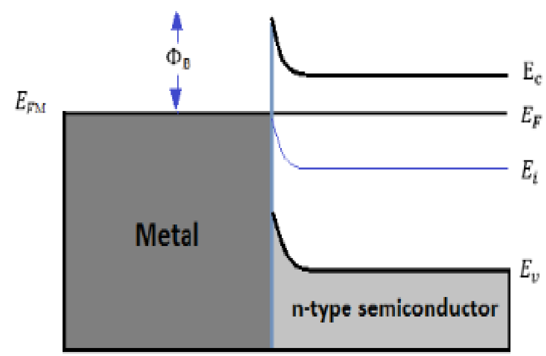
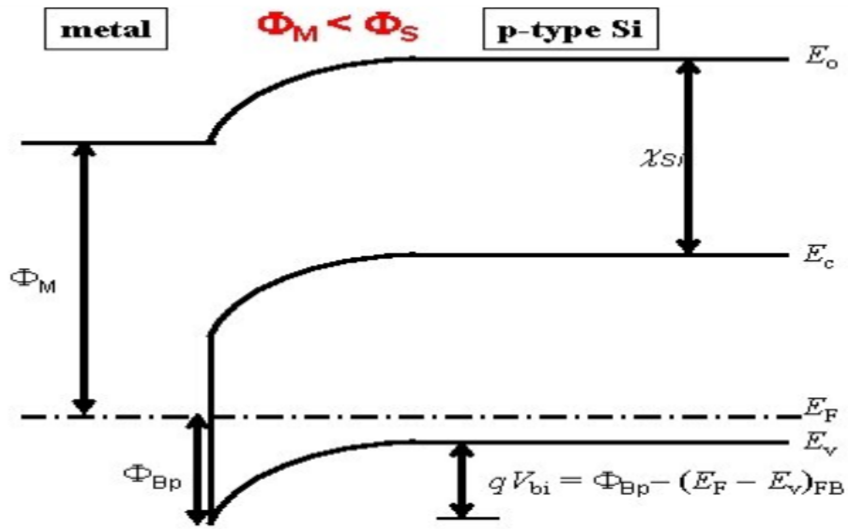


Fig.2: MS contact with n-type s/c **Fig.2b: MS contact with same level of fermi level**

MS contact with n-type semiconductor with $\Phi_M>\Phi_S$ make Schottky junction.The surface potential-energy barrier Φ_B, the primary characteristics of the Schottky barrier, is characterized by the Schottky barrier height, which is a function of the metal and the semiconductor

$$\Phi_B=\Phi_M-\chi, \quad \text{for n-type semiconductor}$$



Schottky contact with p-type semiconductor

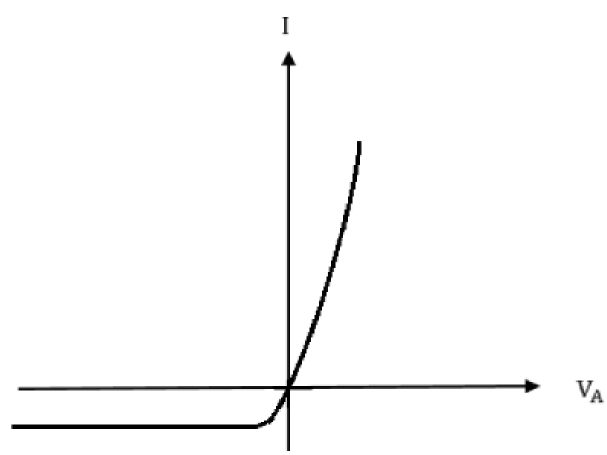
MS contact with p-type semiconductor with $\Phi_M<\Phi_S$ make Schottky junction. The surface potential-energy barrier Φ_B, the primary characteristics of the Schottky barrier, is characterized by the Schottky barrier height, which is a function of the metal and the semiconductor

$$\Phi_B=Eg/q+\chi-\Phi_M,\text{for p-type semiconductor}$$

The IV characteristics of Schottky diode is given below-

$I=I_0(e^{qVA/kT}-1)$

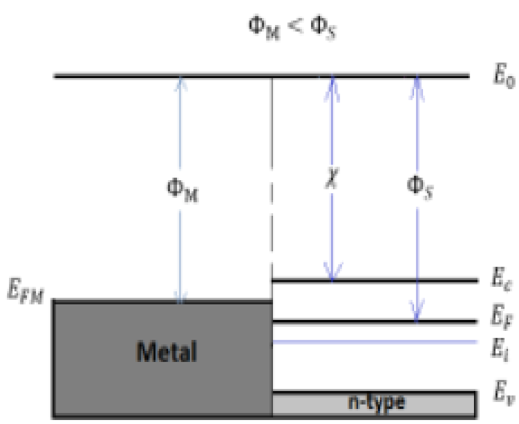
where I0 is a saturation current



IV characteristics of Schottky diode

Ohmic contact

Not all MS contact can perform as the rectifying Schottky diode, since there is no potential barrier formed. Under this situation, when the current can be conducted in both directions of the MS contact, the contact is defined as the Ohmic contact. An ideal Ohmic contact is a low resistance, and non-rectifying junction with no potential exists between themetal-semiconductor interface.The MS contact with $\Phi_M<\Phi_S$ in an n-type semiconductor electrons will transfer from the metal to the semiconductor due to their low energy, which will cause the Fermi level in semiconductor move up until the equilibrium state is established.



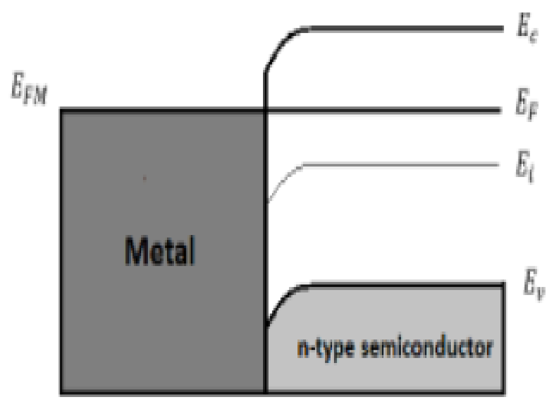


Fig.5a: Ohmic contact with n-type s/c

Fig.5b:Ohmic contact with same fermi level

Since there is no barrier structure for electron flow from the semiconductor to metal, even a very small forward bias voltage (V_A>0) will rise a large forward bias current. When there is an applied reverse bias voltage, a small potential barrier is formed for electron flow from metal to semiconductor. However, the small barrier will eventually vanish when the reverse bias voltage becomes larger. Consequently, there is a large reverse current flow when V<0. The I−V characteristic is shown in Figure 6.

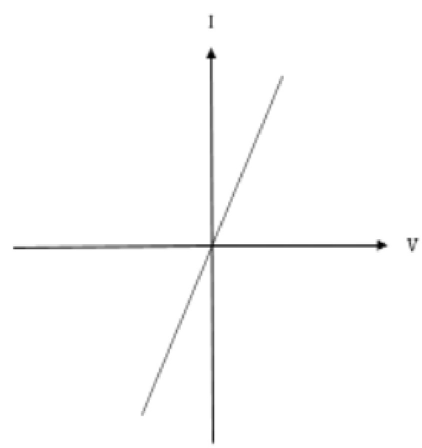


Fig.6: IV characteristics of ohmic contact

Triax cable

Triaxial cable, often referred to as triax for short, is a type of electrical cable similar to coaxial cable, but with the addition of an extra layer of insulation and a second conducting sheath. It provides greater bandwidth and rejection of interference than coax, but is more expensive. Application of triaxial cables is for probes taking precision low-current measurements where the leakage current through the insulator between the core and shield would normally alter the measurements.

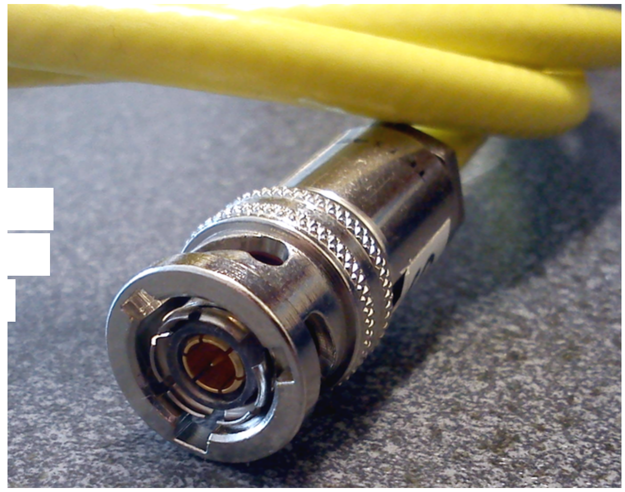


Fig.7: Triax cable

Four probes station

This is most important IV characteristic measurements instruments which is very costly used to measure IV characteristics of semiconductor, MS contact etc. it has vacuum lock of opening plate and it also have facilities of optical illumination system if required for any experiments. Sample under test we need to put it on the chuck inside the chamber. We can move all four probes in 3 directions as per our requirement.

Fig.8: Four probes station

Keithley 4200

The 4200A-SCS Parameter Analyzer reduces the time from setup to running characterization tests by up to 50%, allowing uncompromised measurement and analysis capability. Plus, embedded measurement expertise provides unparalleled test guidance and gives supreme confidence in the resulting measurements.Advanced measurement hardware for DC I-V, C-V, and pulsed I-V measurement types.

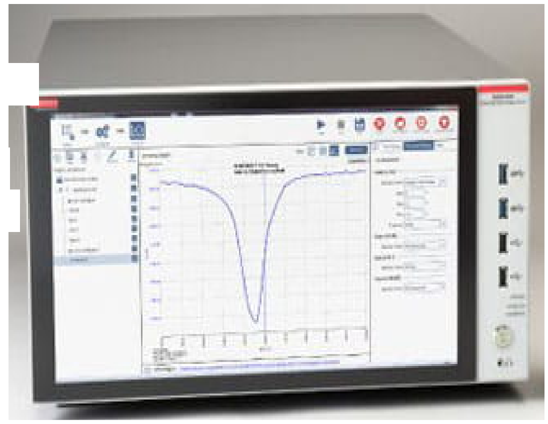


Fig.9: Keithley 4200

Begin testing immediately with hundreds of user-modifiable application tests included in theClariussoftware.Automated real-time parameter extraction, data graphing, analysis functions.

Following steps are there for this experiment:

1. We Si sample and deposited Au(gold) metal on top of the Si sample using deposition technique and put this sample on the chuck.
2. Then we connect the sample with probes to keithley 4200 using triax cable and measured the IV characteristics.
3. Create the vacuum in four probes chamber using rotary pump andcreating vacuum remove the contaminations from the chamber. So that exact IV Characteristics we get.
4. Connection to metal with one of probe we can check with electrical microscope by adjusting X Y and Z directions in microscope.
5. After connecting above set up. We have given a constant sweep voltage i.e -5 v to 5 v in keithley 4200.
6. Initially, we plotted the IV Characteristics at room temperature 300Kand we increased the temperature to 303K and observed the IV Characteristics of MS Junction.
7. We can observe the follow in metal semiconductor work function for p and n type.

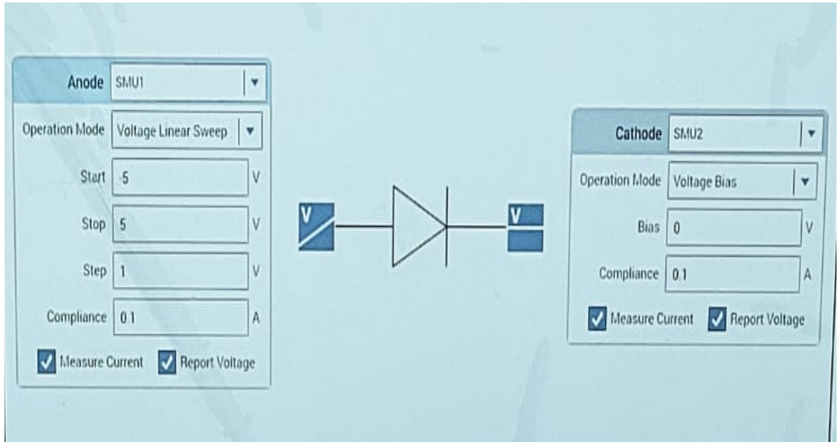


Fig.10: Input icon

Results

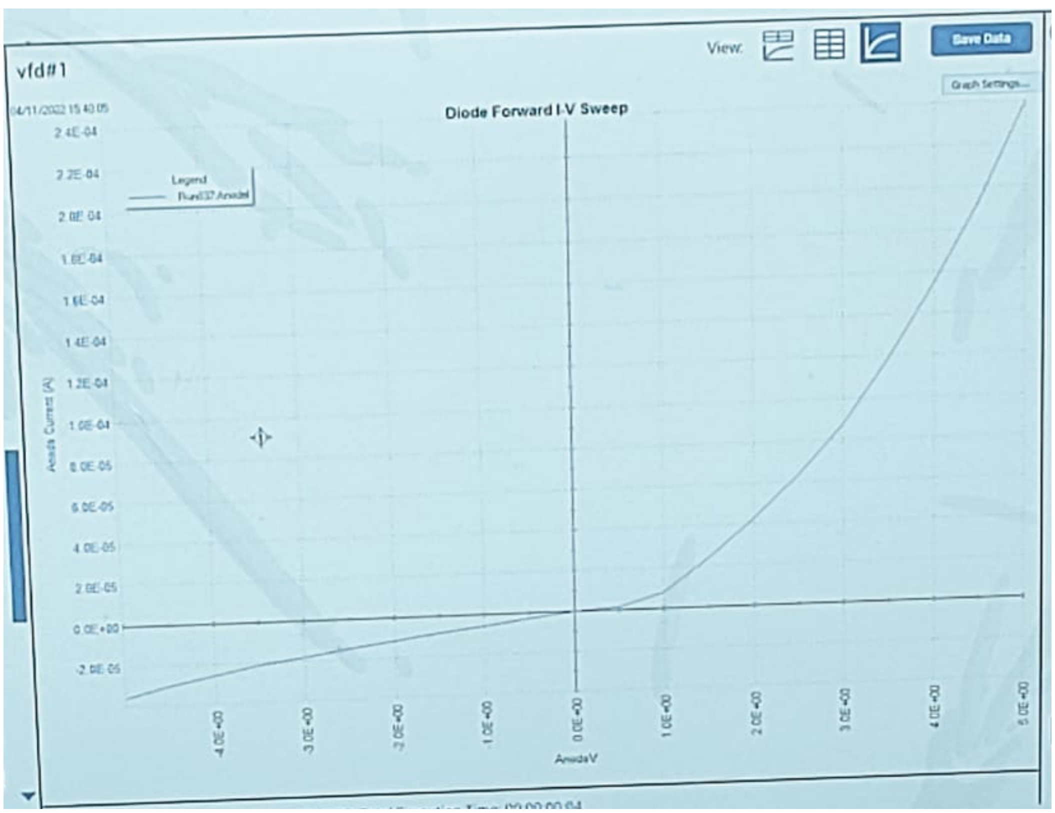


Fig.11: IV characteristics of Schottky diode at 300K

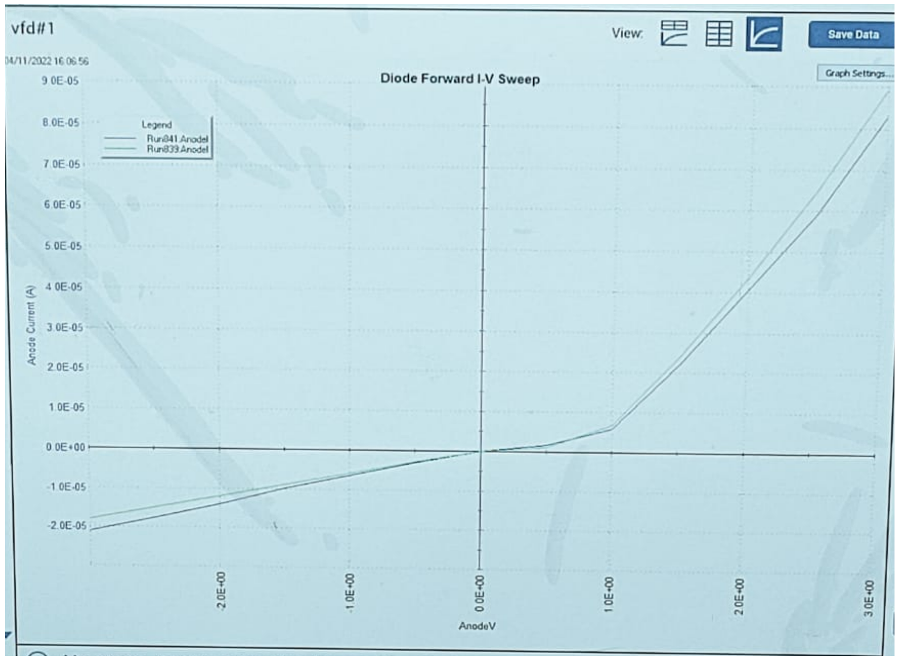


Fig.12: IV characteristics of Schottky diode at 300K and 303K

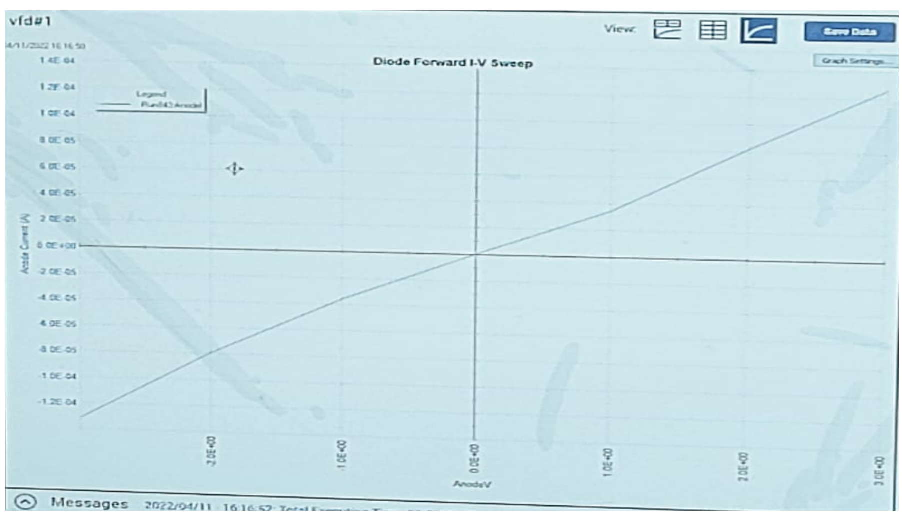


Fig.13: IV characteristics of Ohmic contact at 300K