Silicon Controlled Rectifier (SCR)
Lecture – 3

TDC PART – I
Paper - II (Group - B)
Chapter - 5

by:

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SCR / Thyristor Construction Materials

- A **Silicon Controlled Rectifier** is so called because "**Silicon" is used for its construction**; its called **"Controlled"** because it **can Controlled (turn it "ON") the current passes through SCR using Gate (G) terminal and** its called **"Rectifier"** because once it's **"ON", it behaves like** a **"Rectifier"** and its o**peration similar as a Rectifier diode** (very low resistance in the forward conduction and very high resistance in the reverse direction).

- Like the ordinary junction diode, an SCR is a unidirectional device that blocks the current flow from Cathode (K) to Anode (A). Unlike the ordinary junction diode, a thyristor (SCR) also blocks the current flow from Anode (A) to Cathode (K) until it is triggered into conduction by a proper Positive Gate (G) signal between Gate (G) and Cathode (K) terminals. As the terminology indicates, the **SCR** is a controlled rectifier and construction of a silicon semiconductor material with a third terminal for control purposes.

- The basic material used for fabrication of an SCR is N-Type Silicon. Silicon was chosen because it has a specific resistance of about 6 ohm-mm. Although it is possible to use a variety of different materials for SCR (thyristors), Silicon is the most popular. The trade name for this type of device - Silicon Controlled Rectifier - also indicates that Silicon is the most popular material. Silicon provides good thermal conductivity as well as a high voltage and current capability.

- Another advantage is that the manufacturing processes for Silicon are more mature, and hence cheaper to run, than those for other materials. However, other materials including Silicon Carbide (SiC); Gallium Nitride (GaN); diamond; Carbon (C); and Semi-Wide-Gap Semiconductor material Gallium Arsenide (GaAs) as well, have been investigated and according to the research they demonstrated promising properties under extreme conditions of high power, high temperature and high frequency. Nevertheless silicon still remains the most popular substance. Silicon is the natural choice as base material for manufacturing SCR devices. SCR device is made of Silicon only because of the following advantages :-

- **(1)** Ability to withstand high junction temperature of the order of 150° C,
- **(2)** Less variations in characteristics with temperature,
- **(3)** High thermal conductivity,
- **(4)** High voltage and current capability and
- **(5)** Leakage current in silicon is much smaller then that in Germanium and it is necessary that leakage current should be minimum as possible as, this device is used as a switch.

Construction of Silicon Controlled Rectifier (SCR)

- The **fabrication/ construction** of the particular SCR depend upon service expected from that type. It consists, essentially, of a four layer (multi layer P-N-P-N) pellet of P and N type silicon semiconductor materials. The semiconductor material is always silicon (Intrinsic semiconductor) in which proper impurities are added. The junctions are either **Planer Diffused (All Diffused) or Alloyed Diffused.** The material which may be used for P - type diffusion is **Aluminium** and for N - type diffusion is **Phosphorous.** The contact with Anode can be made with an Aluminium foil and through Cathode and Gate by Metal-sheet. Diffusion must be carried out at a proper temperature and for necessary duration to provide correct concentration because this decides the properties of the device.

- To manufacture the SCR, three types of constructions are used, namely the **Planar Diffused type, Alloyed Diffused** or **Mesa type** and **Press pack type.** According to the power rating, there are three types of construction of SCR which is as follow :-

- **(1) Planer Diffused (All Diffused) type construction** - For low-power rating,

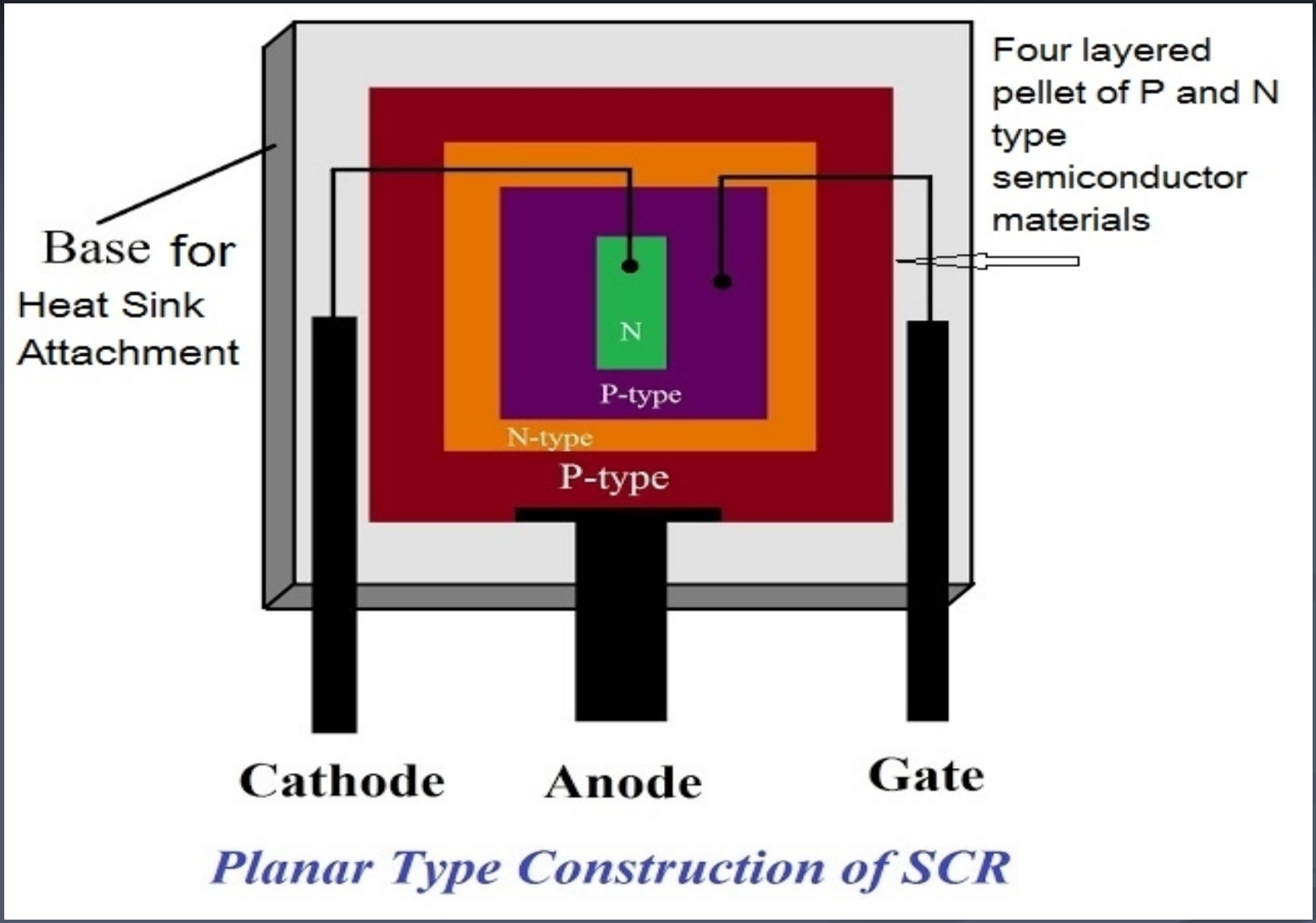
- **(2) Alloyed Diffused Mesa type construction** - For high-power rating,

- **(3) Press Pack type construction –** For used in higher current applications.

- For understanding the basic construction of SCR, only Planner Diffused type and Alloyed Diffused (Mesa type) construction of SCR is given and discussed below.

(1) Planer Diffused (All Diffused) Type Construction

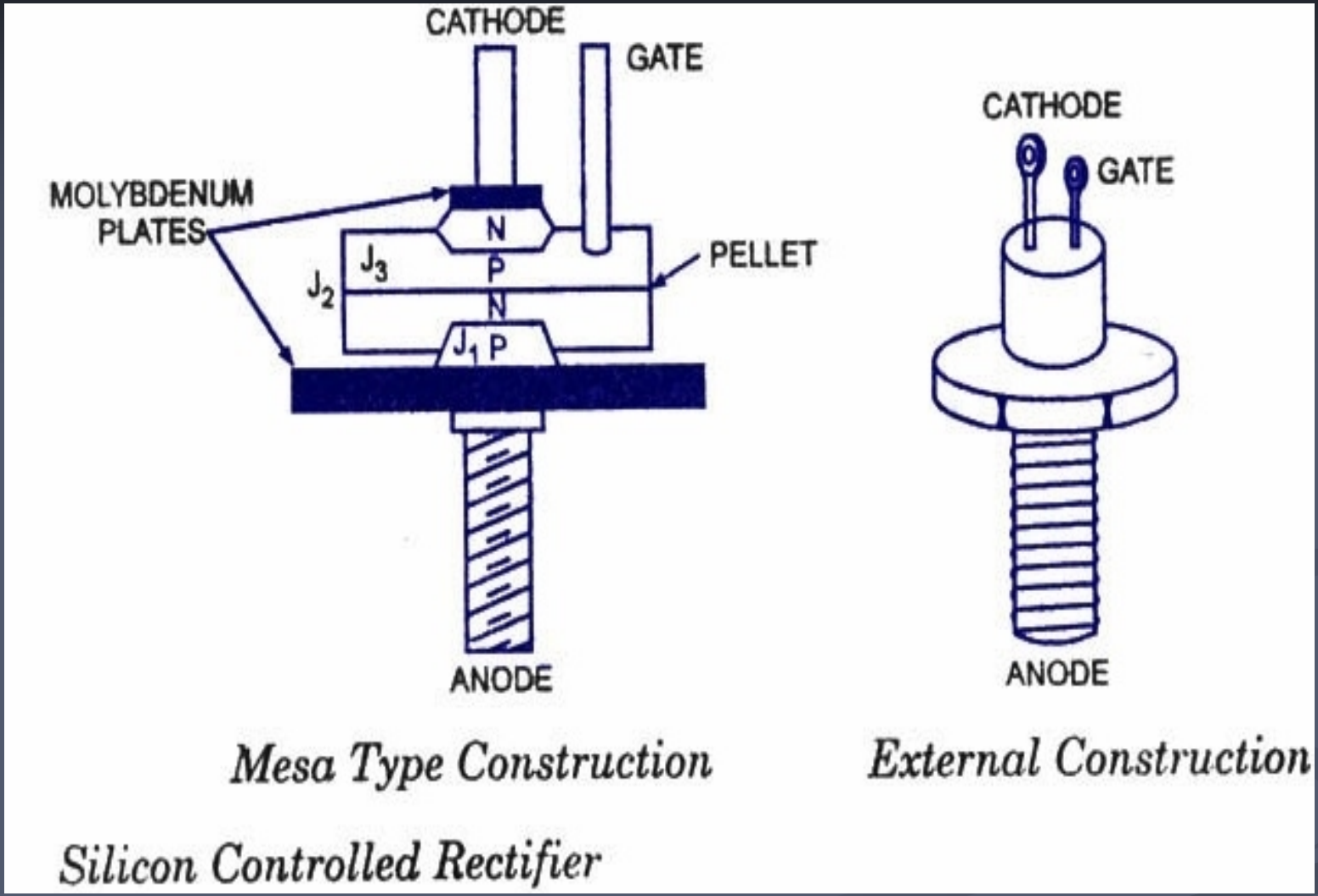
- Low power SCRs employs the planar construction technique. The cross section of the Planer Diffused type construction SCR is shown in **Fig (14)** below. It consists of four layered pellet of P and N type semiconductor materials. Planar construction is useful for making a number of units from a silicon wafer. Here, all the junctions are diffused. The planer Diffused construction is best suitable for low power SCRs. The main disadvantage of the planer structure is that it requires more silicon per ampere current capacity.



- **Fig (14)** Shown Planer Diffused Type Construction of a SCR.

(2) Alloyed Diffused or Mesa Type Construction

- The other technique is the Alloyed Diffused type construction also called Mesa type construction. High power SCRs employs the Alloyed Diffused type construction also called Mesa type construction. The cross section of the Alloyed Diffused type construction is shown in **Fig (15) below.** This technique is used for high power SCRs. In this technique, the inner junction J2 is obtained by diffusion, and then the outer two layers are alloyed to it. The P-N-P-N pellet is properly braced with tungsten or molybdenum plates to provide greater mechanical strength and make it capable of handling large currents. Here, the bottom-most P-type region represents the Anode (A) and the top-most N-type region shows the Cathode (K) terminal. The two regions form a connection with the Cathode (K) and Anode (A) terminal with the help of molybdenum plates.



- **Fig (15)** Shown Alloyed Diffused or Mesa Type Construction of a SCR.

- One of these plates is hard soldered to a copper or an aluminium stud, which is threaded for attachment to a heat sink. This provides an efficient thermal path for conducting the internal losses (Heat) to the surrounding medium. The uses of hard solder between the pellet and back-up plates minimises thermal fatigue, when the SCRs are subjected to temperature induced stresses. For medium and low power SCRs, the pellet is mounted directly on the copper stud or casing, using a soft solder which absorbs the thermal stresses **set up by Differential Expansion** and provides a good thermal path for heat transfer.

(3) Press Pack Type Construction

- Higher current SCRs employ the Press-Pack type construction also called Hockey-Pack type construction. The Press Pack construction style is an assembly that has essentially the same physical shape as a hockey pack. The Press-Pack or Hockey-Pack type construction SCR is shown in **Fig (16)** below. Modern SCR generally use Press-Pack or Hockey Pack construction. For a larger cooling arrangement, which is required for Higher Current SCRs, the Press-Pack or Hockey-Pack construction is employed, which provides for double-sided air for cooling. The construction provides excellent cooling of the semiconductor material and is generally used in higher current applications.

- **Fig (16)** Shown Press-Pack or Hockey-Pack type construction of a SCR .

- The salient features to be considered, while designing and construction of a SCRs, are the diameter and thickness of wafer, composition of the base material, type and amount of the material to be diffused into the wafer, shape, position and contact area of the gate, shape and size of the SCR, type of heat sink etc.

- Fabrication technology determines various properties of the device. The voltage rating of a device can be increased by lightly doping the inner two layers and increasing their thickness. But due to this increased resistance, forward voltage drop increases and large triggering currents are required causing greater power dissipation accompanied by smaller current ratings. The energy emit by silicon falls from 1.5 W/cm2 at 25° C to 1.25 W/ cm2 at 125° C. A high voltage power device can seldom be used beyond 125° C.

- The current carrying capacity and voltage rating of the device can be increased by irradiating silicon with neutrons. The current rating of the device can also be increased by reducing the current density at the junction but this result in a bulky device with large turn-on time.

- Today SCRs of voltage rating up to 10KV and an RMS current rating up to 3000A with corresponding power-handling capacity up to 30MW (10KV × 3000A) are available. SCR's emit about 1.5 watt's of energy in the form of heat, per ampere current conducted. Failure to dissipate this energy is perhaps one of the main sources of SCR failure. The reliability of SCR's decreases about 50% for every 10°C increase of semiconductor temperature. Other critical parameters such as the dv/dt rating and the blocking voltage rating also decrease rapidly with increase in temperature. The heat generated by the SCR must be dissipated, thus, all SCR controllers have some means (arrangements) to cool the SCR's.

- Since, SCR handling and conduct large current; junction areas of SCRs are very large. Hence SCR dissipate large amount of heat. For large current applications, thyristors need better cooling then we have to use a heat sink. Better cooling is achieved to a great extent by threaded portion (stud) of SCRs are tightening onto frame or mounting them onto heat sinks with the help of nut. The stud type SCR with threaded portion is for the purpose of tightening the SCR (thyristor) to the frame or heat sink with the help of nut. Typically an aluminium heat sink, with fins to increase the surface area, is used to dissipate this energy to air. Controllers with relatively small current capacities rely on natural convection. Higher current capacity SCR (thyristor) uses a fan to force air past the fins in order to increase heat dissipation. Occasionally, water cooled heat sinks are used on SCR (thyristor) with very high current ratings.

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