Silicon Controlled Rectifier (SCR)

Lecture – 10

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

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SCR Triggering Methods

- The **SCR or Thyristor** is one kind of **Semiconductor Device** and it is specially designed to utilize in **High-Power Switching Applications.** The operating of this device can be done in a **Switching Mode** only and acts as a switch. When the SCR is **Triggered** by its **Gate (G) Terminal** into the circuit, then **it will supply the current constantly.** When designing an SCR based circuit, special concentration should require for activating the circuit. The working of the entire region of the **SCR** circuit mainly depends on the way of its triggering. Here we will discuss **different methods** of SCR triggering or **SCR Turn-ON Methods or Triggering of Thyristors.** There are different **Triggering Methods** are available based on various entities which include **temperature, voltage supply, gate current etc.** We will discuss some of them which are frequently used in SCR triggering.

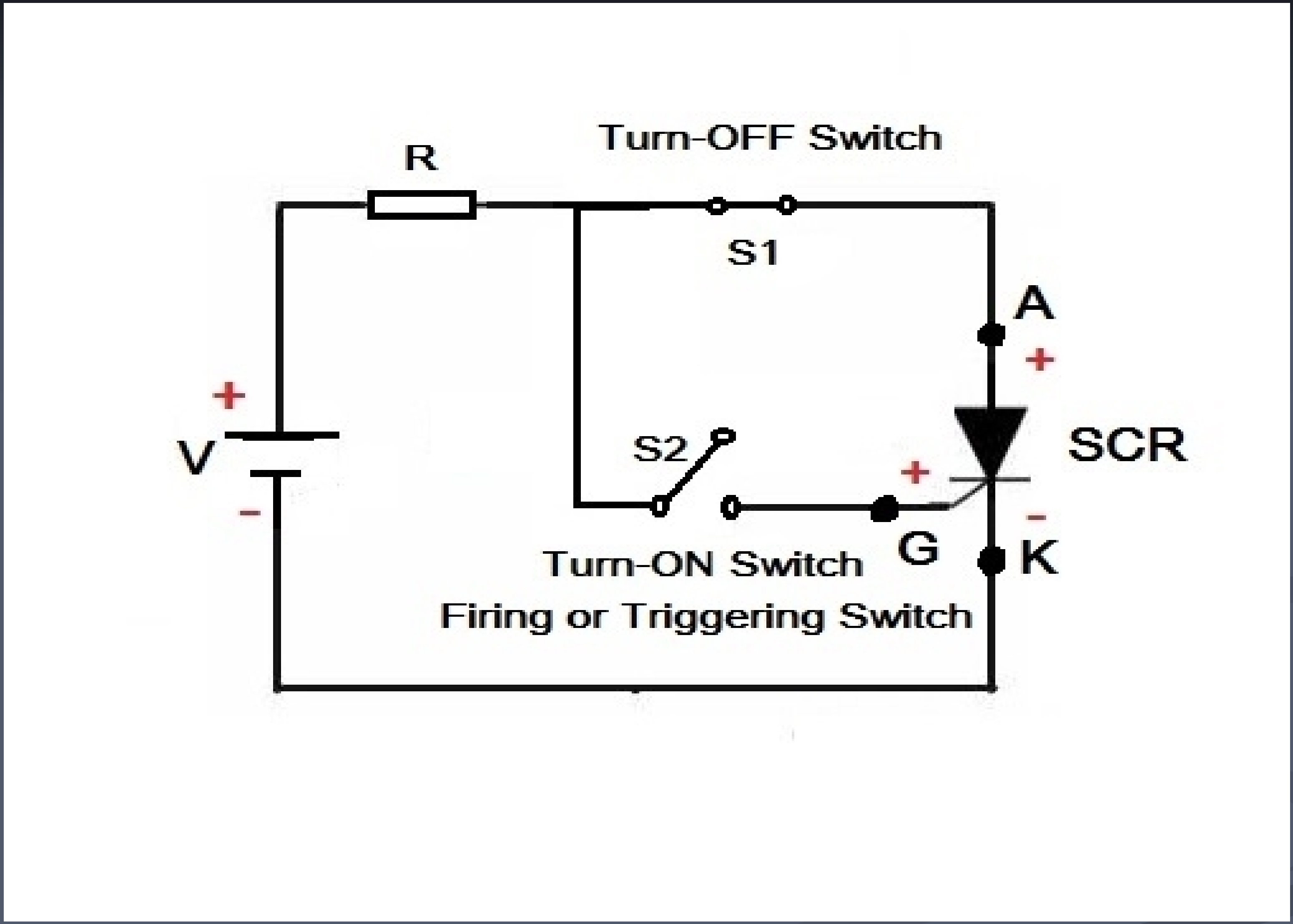
What is SCR Triggering?

- We know that **Silicon Controlled Rectifier (SCR)** or thyristor includes two stable states namely **Forward Conduction State** and **Forward Blocking State. SCR triggering method can be defined as, when the SCR is switching in Forward Blocking State to Forward Conduction State which means OFF-State to ON-State,** then it is termed as **SCR Turn-ON methods or SCR Triggering.**

- The **Turning-ON Process** of the SCR is known as **Triggering.** SCR **Turn-ON** methods are the techniques to bring an SCR in **Forward Conduction Mode (ON-State)** from **Forward Blocking Mode (OFF-State).** In other words, turning the SCR from **Forward Blocking State (OFF-State)** to **Forward Conduction State (ON-State)** is **known as Triggering.** An SCR in **Forward Conduction Mode (ON-State)** is characterized by **Low Impedance, Low Voltage Drop across Anode & Cathode** and **High Anode Current.** The value of **Anode Current** is determined by the load. Thus it allows for the flow of Current. Therefore, an SCR in **Forward Conduction Mode** is called its **ON-State** and may be treated as a **Close Switch.** In fact, triggering itself means to bring the SCR or thyristor to **ON-State** from its **OFF-State**.

SCR Triggering Methods

- The SCR triggering mainly depends on different variables such as **temperature, voltage supply, gate current, etc.** When the **Voltage (V)** is applied to the **Silicon Controlled Rectifier (SCR) and** if the **Anode (A) Terminal** can be made **Positive (+)** relating to the **Cathode (K),** then the SCR turn into **Forward Biased.** Therefore this SCR or thyristor enters into the **Forward Blocking State (OFF-State). This can be made to activate into Forward Conduction Mode and it performs by using any type of the SCR Turn-ON methods listed below.** **Fig (38)** Shown Basic SCR Triggering Circuit Arrangement.



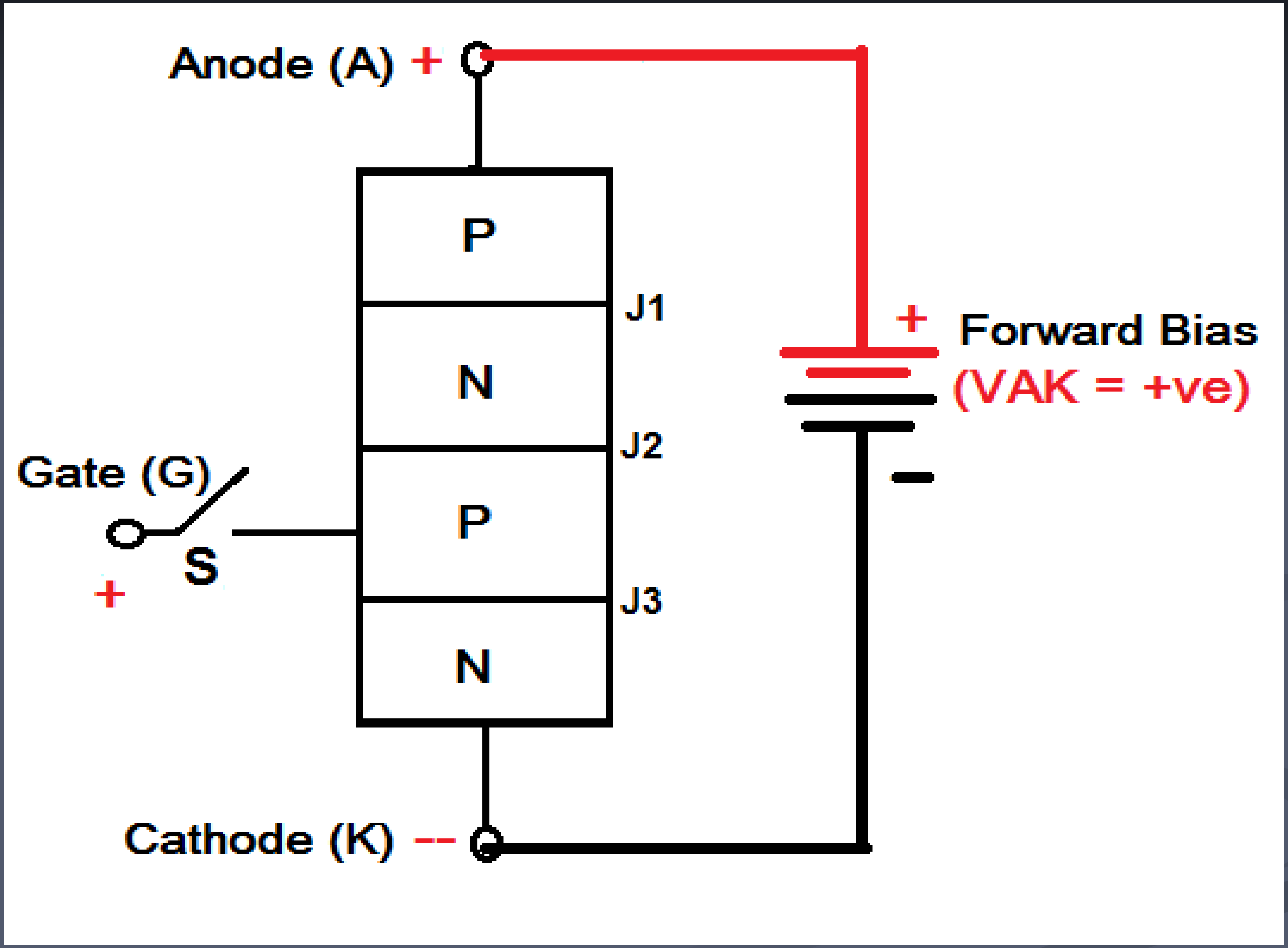
- **Fig (38)** Shown Basic SCR Triggering Circuit Arrangement.

- There are **different methods** for **activating (Turning -ON) or Triggering the SCR** which include the following below. The various methods of SCR **Triggering or Turning-ON** are discussed here one by one. The various SCR **Triggering Methods** are,

- **(1) Forward Voltage Triggering**
- **(2) Gate Triggering**
- **(3) dv/dt Triggering**
- **(4) Thermal or Temperature Triggering**
- **(5) Radiation or Light Triggering**

(1) Forward Voltage Triggering

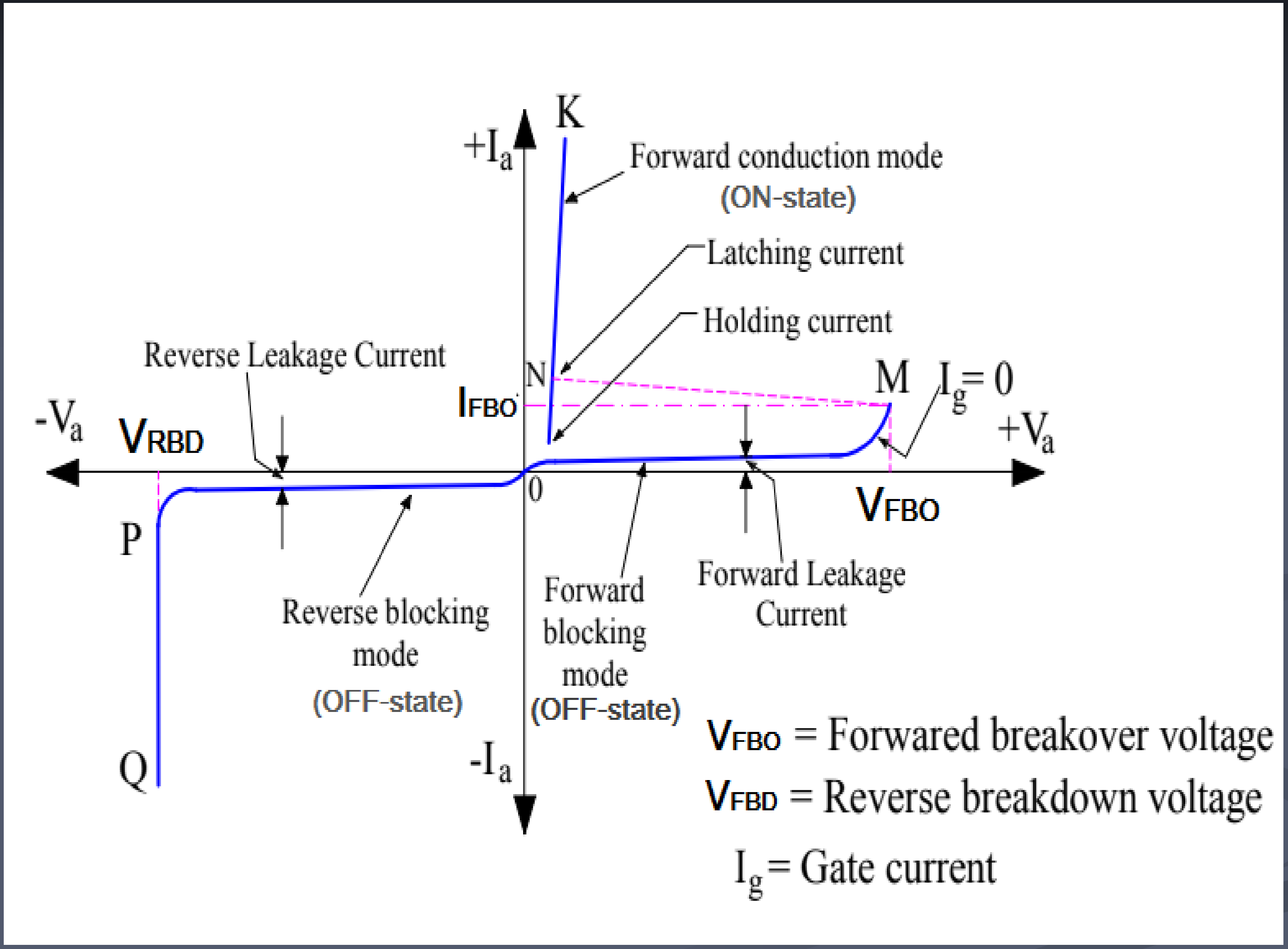
- Carefully read the name of this method. It says **"Forward Voltage Triggering".** This means we will make **SCR ON** by applying **Forward Voltage** across its terminals as shown in **Fig (39).** What does this mean? This simply means that we will make it **Forward Biased** and will **increase** this bias voltage till **SCR gets ON**. Lets us now see how increasing forward bias voltage make **SCR Turn-ON.**



- **Fig (39)** Shown Forward Voltage Triggering method to make SCR Turn-ON.

- In a **Forward Biased SCR** or **thyristor, junction J1 and J3** are **Forward Biased** whereas **junction J2** is **Reversed Bias.** This kind of triggering method is mainly used to increase the voltage among the **Anode (A) and Cathode (K)** terminal. So that the **width** of the **depletion layer** can be **increased** and makes to **increases the accelerating voltage of minority charge carriers** at **J2 junction.** Further, this can be lead to an **Avalanche Breakdown of J2 junction** at a **Forward Breakover Voltage.**

- Therefore, increasing this **Forward Bias Voltage** will **narrow down the width of the depletion region** of **junction J2** and at a particular voltage, **this depletion region will vanish.** At this stage, **Reversed Biased junction J2** is said to have **Avalanche Breakdown** and this voltage is called the **Forward Breakover Voltage (V_{FBO}).** The name **Forward Breakover Voltage** is given as at this voltage the **V-I characteristics of SCR** breaks and shifts to its **ON Position.** Refer the **V-I characteristics of SCR** shown in **Fig (40)** below.



- **Fig (40)** Shown V-I characteristics of SCR.

- You may notice that at **Forward Breakover Voltage (V_{FBO})**, the V-I curve breaks at **Point M** and shift to its **ON Position at Point N** with **Forward Breakover Current (I_{FBO}).** This is the reason; this critical voltage is called **Forward Breakover Voltage (V_{FBO}).**

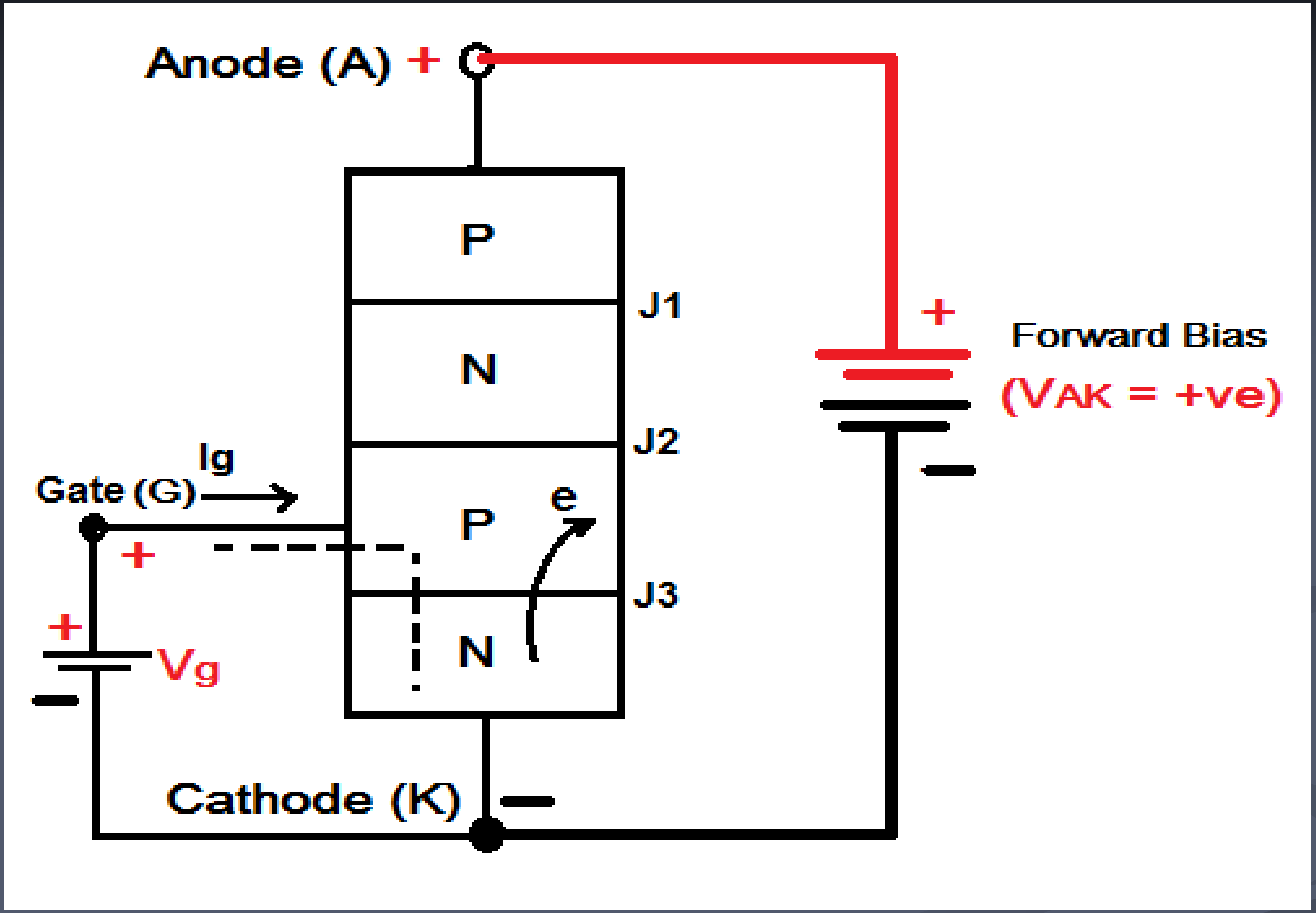
- As soon as **Avalanche Breakdown at junction J2 occurs**, a huge current (anode current) with a less drop of voltage, starts flowing from **Anode (A) to Cathode (K) terminal of SCR.** The value of this **Anode Current (Ia)** is only limited by the **External Load Resistance.** Thus SCR is now in its **Conduction Mode in Forward Direction i.e. from Anode to Cathode.** This is **Forward Triggering Method of turning SCR ON.**

- **In practical,** this method cannot be used as it requires an **extremely large anode voltage to the cathode.** Once the **voltage is higher** than the **Forward Breakover Voltage**, then it offers extremely **huge currents. This may cause harm to the SCR or thyristor.** So, in **most of the situations,** this kind of SCR triggering method **cannot be used.**

- Normally this method is not used to **Turn-ON SCR** as it may damage it. Generally the **Forward Breakover Voltage (V_{FBO})** is less than **Reverse Breakdown Voltage (V_{RBD})** and hence **Reverse Breakdown Voltage (V_{RBD})** is considered as final voltage rating while **designing SCR.** It must also be noted and bear in mind that, once **Avalanche Breakdown** takes place at **junction J2**, the blocking capability of **junction J2 is lost.** Therefore if **Anode Voltage (Va)** is reduced below **Forward Breakover Voltage (V_{FBO})**, the SCR will continue to conduct. The SCR can now be **Turned -OFF** by bringing its **Anode Current (Ia)** below a certain value called the **Holding Current (I_H).**

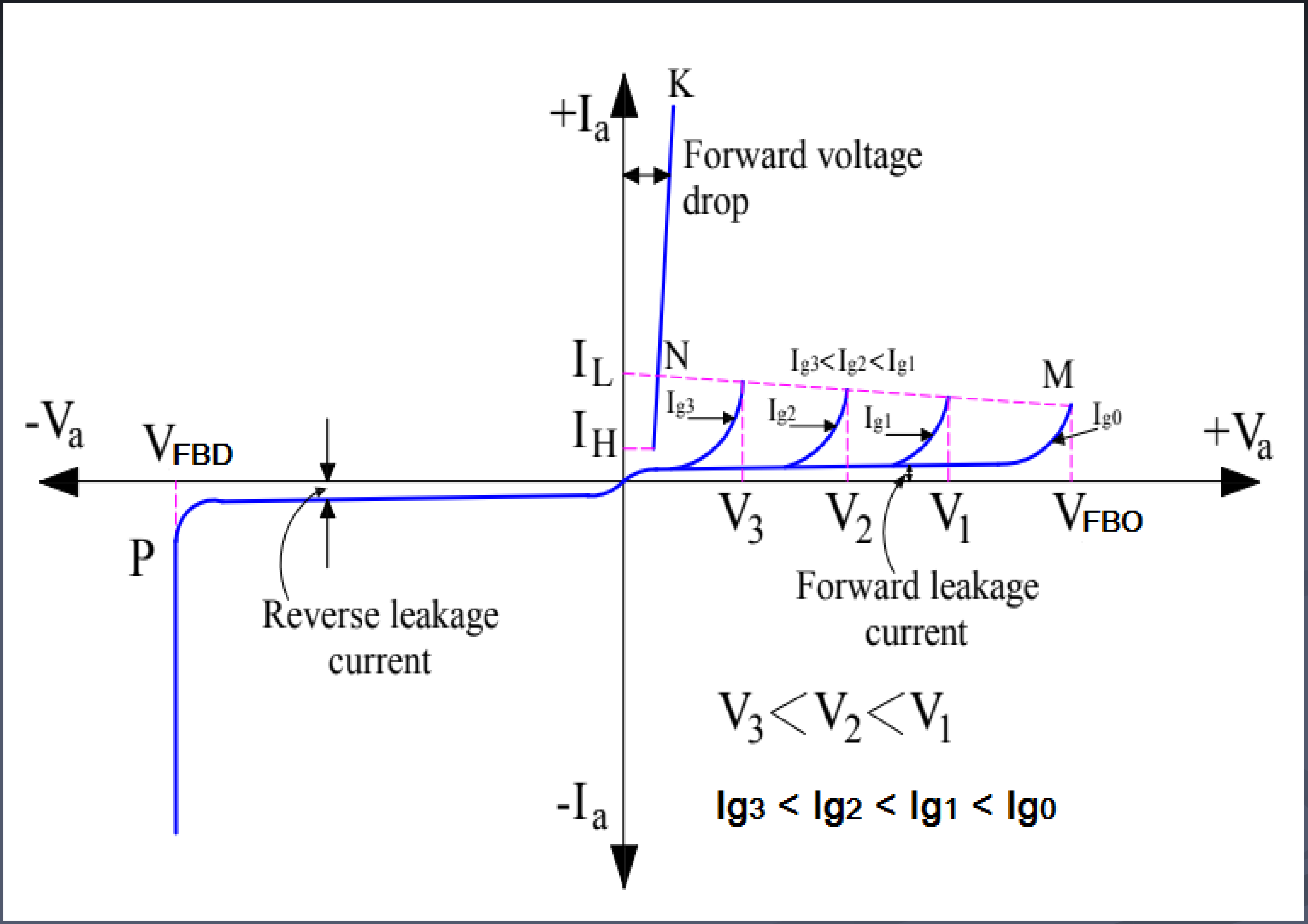
(2) Gate Triggering

- Gate triggering is the method in which **Positive Gate Current** is flown in **Forward Biased SCR** to make it ON. **Gate triggering** is in fact the most reliable, simple and efficient way to **Turn-ON SCR.** In this method, **Positive Gate Voltage** between **Gate (G) and Cathode (K) terminals** are applied in **Forward Biased SCR** which establishes **Gate Current** from **Gate (G) terminal to Cathode (K) as** shown in **Fig (41)** below.



- **Fig (41)** Shown Gate Triggering method in which **Positive Gate Current** is flown in **Forward Biased SCR** to make it ON.

- When **Positive Gate Current** is applied, **Gate P-type layer** is flooded with **Electrons** from the **Cathode (N-type side).** This is because the **Cathode N-type layer** is **heavily doped** as compared to **Gate P-type layer.** Since **junction J1 and J3** are already **Forward Biased,** the injected **Electrons** in **Gate P-type layer** may reach **junction J2** and hence **reduces the width of depletion region.** This result is reduction of **Forward Breakover Voltage (V_{FBO}).** In fact, the **more the injected Electrons** in **Gate P-type layer,** the more will be chance of **Electrons** reaching **junction J2.** This means the more the value of **Gate Current,** the more will be reduction in **Forward Breakover Voltage (V_{FBO}). Thus Gate Current and Forward Breakover Voltage are inversely proportional.** Please refer the **Figure (42) below. Fig (42)** Shown below the **V-I characteristics of a SCR** for different values of **Gate Current Ig.**



- **Fig (42)** Shown the **V-I characteristics of a SCR** for different values of **Gate Current Ig.**

- Following points can be observed and noted from the above **Figure (42) shown the V-I characteristics** curve **of a SCR.**

- **(1)** When **the Gate Current Ig** is **zero**, the **Forward Breakover Voltage is V_{FBO}.**

- **(2)** As **Gate Current increases** from **zero to Ig1,** the **Forward Breakover Voltage reduces** from **V_{FBO} to V1.** Similarly, its value reduces from **V1 to V3** as the **Gate Current** increases from **Ig1 to Ig3. The reason behind this is that** the current which is applied to the **Gate (G) terminal** is high then additional electrons will be inserted into the **J2 junction** & consequences to approach into the **Conduction position** at **Less applied Voltage.**

- Thus the **SCR** may be **Turned-ON** by applying **Gate Current.** It should be noted that **SCR** is **Turned-ON** due to **Forward Breakover Voltage (V_{FBO})** though this voltage is reduced considerably due to **Positive Gate Current.**

- Once **SCR Starts Conducting** in **Forward direction**, **reversed bias Junction J2** no **longer exists**. Therefore, no **Gate Current** is required for **SCR or thyristor** to remain in **ON-State.** Therefore if **Gate Current** is removed, the conduction of current from **Anode to Cathode** is not affected. However, if **Gate Current** is reduced to zero before the rising of **Anode Current** to a specific value called the **Latching Current (I_L) the SCR or thyristor will Turn-OFF again.** This means we should not make **Gate current OFF** until **Anode Current (Ia)** has crossed **Latching Current**.

- **Latching Current (I_L) is defined as the minimum value of anode current which must be attained during turn on process of SCR to main the conduction even when gate current is removed.**

- Once SCR or thyristor starts conducting, gate losses its control. The SCR or thyristor can now be **Turned-OFF** only if the **Anode current** reaches below a specified value of **Anode current.** This value of **Anode current** below which **SCR gets Turned-OFF** is called **Holding Current (I_H).** As can be seen from the V**-I characteristics of SCR,** the value of **Latching Current (I_L)** is more than the **Holding Current (I_H).**

- **Holding Current (I_H) is defined as the minimum value of anode current below which it must fall for Turning-OFF the SCR or thyristor.**

- While designing the gate SCR triggering circuit, the following important points must be kept in your mind.

- **When the SCR is triggered, then the Gate signal must be detached instantly, otherwise, the power loss will be there within the Gate junction.**

- **As an SCR is in Reverse Biased, then Gate signal shouldn’t be applied to this.**

- **The Gate signal’s pulse width must longer than the required time used for the Anode Current for increasing to the value of Holding current.**

(3) dv/dt Triggering

- **dv/dt** Triggering is the technique in which **SCR** is **Turned-ON** by changing the **Forward Bias Voltage** with respect to time. **dv/dt** itself means rate of change of voltage w.r.t time.

- As we have discussed earlier, in a **Forward Blocking Mode** when the SCR device is in Forward Biased, **junction J1 and J3** is in forward biased and **junction J2** will be in reverse biased. A **Reversed Biased junction J2** may be treated as a **Capacitor** due to presence of **Space Charges** in the vicinity of **Reversed Biased** junction. Let us assume its **Capacitance** to be **'C' farad**. The **Charge** on capacitor **Q, Voltage** across the capacitor **V** and **Capacitance C** are related as **below :-**

- The charge on capacitor Q, voltage across the capacitor V and capacitance C are related as below :-

- **$Q = C V$**
- **Differentiating both sides w.r.t time, we get**
- **$dQ / dt = C (dV / dt)$**
- **But Current $I_c = dQ / dt$**
- **$\Rightarrow I_c = C.(dV / dt)$**

- **In other way we can illustrate the whole process as,** If V**oltage** across the device is **V**, the C**harge** by **Q** and C**apacitance** by **C** then,

- $I_C = dQ / dt$
- $Q = C V$
- $I_C = d(CV) / dt$
- $= C. dV/dt + V. dC/dt$
- as $dC / dt = 0$
- $I_C = C.(dV / dt)$

- Thus the current through the **Reversed Biased junction J2** is directly proportional to **(dv/dt). Therefore if the rate of rise (change) of forward voltage i.e. (dv/dt) across the device is high, the charging current IC will also be high. This charging current acts like gate current** and this may **Turns-ON the SCR or thyristor** even though the **Gate Current is zero (I_g = 0).** It should be noted that, it is rate of rise of voltage which is responsible for turning the **SCR-ON.** It is independent of magnitude of voltage. The voltage may be low, but the rate of its rise should be high enough to **Turn-ON the SCR.**

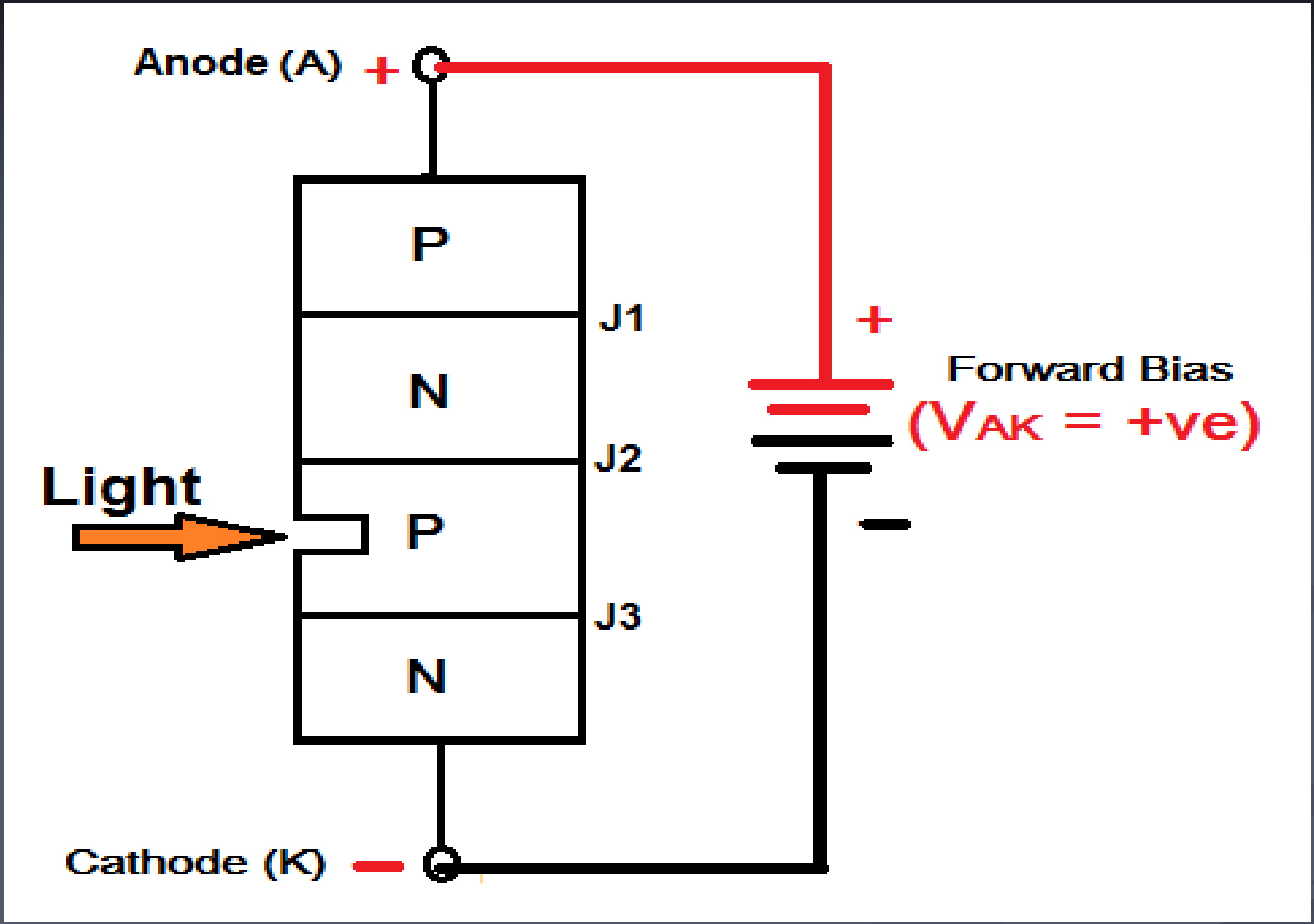
(4) Thermal or Temperature Triggering

- Temperature triggering is also called **thermal triggering.** During **Forward Blocking Mode** operation of **SCR,** when **Forward Voltage** applied then **Anode (A)** made P**ositive (+)** with respect to **Cathode (k)** terminal, this will be make **junction J1** and **J3** become **Forward Biased** whereas **Junction J2** become **Reverse Biased.** From the above biasing rule most of the applied voltage appears across **Reverse Biased Junction J2.** As we know that in reversed biased **junction J2** a **Reverse Saturation Current also known as Reverse Leakage Current** flows whose value depends on the temperature of the junction.

- This means, in Forward Blocking Mode of SCR or thyristor, there will be a flow of **Reverse Leakage Current (Reverse Saturation Current)** across the **junction J2.** This current will **increase the temperature** of the **junction J2 which in turn will result in further increase in Reverse Leakage Current.** This increased **Reverse Leakage Current** will again **increase the junction J2 temperature** and hence **will further increase the Reverse Leakage Current. Thus, this process is Cumulative** and will **eventually lead to vanishing of depletion region** of Reversed Biased **junction J2** at some temperature. At this temperature, the **SCR** will get **Turn-ON.**

(5) Radiation or Light Triggering

- In light triggering, **a pulse of light** of **suitable wavelength** guided by **optical fibers** is irradiated to turn SCR ON. A Special Terminal **"Recess" or "Niche" is made in the inner P layer** instead of gate terminal **for light triggered SCR** as shown in **Fig (43)** below.



- **Fig (43)** Shown a **Recess or Niche is made in the inner P-type layer for light triggered SCR.**

- When this "**Recess" or "Niche"** is **irradiated,** free **charge carriers** i.e. **Electron and Hole Pairs** are generated just like when **Forward Voltage** applied on the **Anode (A) to Cathode (k)** terminal of **SCR.** Again when **light** is thrown on **silicon material** and if the **intensity of irradiated light** is **exceeds a certain** value, the **Electron-Hole Pairs increase.** When the pulse of light of appropriate **Wavelength** is guided by **Optical Fibers** for **irradiation** and if the **intensity** of this **light thrown** on the "**Recess" or "Niche" exceeds a certain value,** the **Electron-Hole Pairs increase** then **Forward Biased SCR** is **Turned-ON.** Note there that, irradiated light produces free charge carries which is just like in case of gate current. There charge carries move near the reversed biased **junction J2** and reduces the **Forward Breakover Voltage (VFBO).** This is the reason, the **SCR** gets **Turned-ON**. The **SCR** which is **Turned-ON** by **using light** is called **Light Activated SCR or LASCR.**

to be continued ....