BE1M13VES

Manufacturing of Electrical Components

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Overview

TOPIC

Semiconductor Components

Basic properties

- Nonlinear characteristics - used for rectifying, sensing, saturation etc.
- VA characteristics are quite dependent on ambient factors - temperature, light.
- Some components are able to amplify the input signal - transistors

Doping

Intrinsic semiconductors (semiconductors without impurities):

- The free charge is excited via temperature or light.
- Quite small conductivity dependent on ambient factors.

Extrinsic semiconductors (semiconductors with doped material):

- Most of the free charge is excited at room temperature from impurities.
- Similar behavior as metal conductors (rising resistance with temperature).
- Two types of doped materials (dopants): **donors & acceptors**

Doping

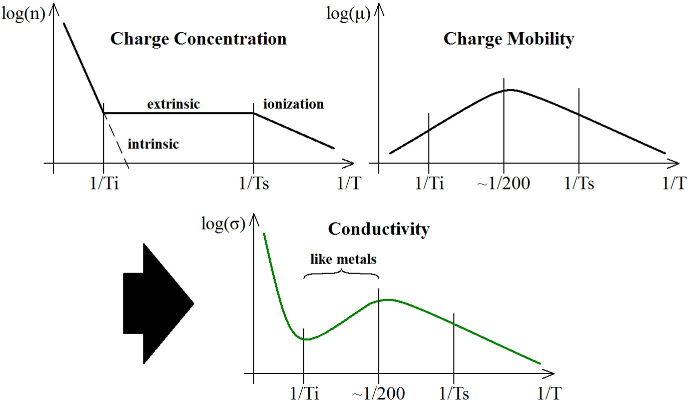
Degenerate semiconductors

- High level of dopant.
- Almost the same behaviour as metal conductors.
- Their are used to create contact layer between metal wire and semiconductor.

Type of conduction

- Adding donors (5 valence electrons) $\Rightarrow$ electrons conduction, type N (negative).
- Adding acceptors (3 valence electrons) $\Rightarrow$ holes conduction, type P (positive).

Temperature dependency



Semiconductor Materials

Element Materials:	Si, Ge (old but still used in specific applications), ...(C, Sn ⇒ IV. element group)
Compound materials:	SiC (varistors and early LEDs), GaAs (LEDs), CdS (Photoresistors)
Donors:	(V. element group) P, As
Acceptors:	(III. element group) B, Al

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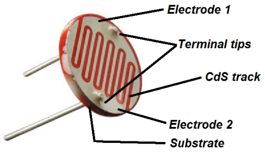
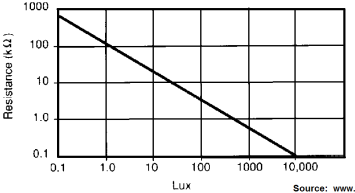
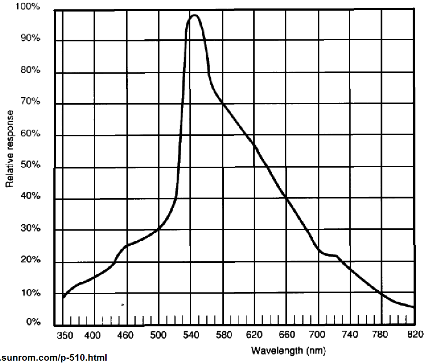
LDR, Photoresistor - Basic properties

- The resistance decreases with illumination.
- The spectral light sensitivity depends on semiconductor material.

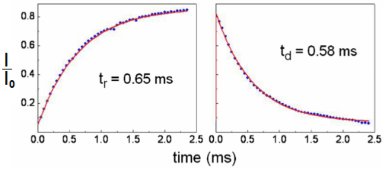


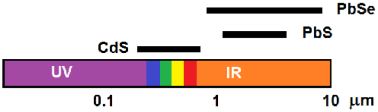




Source: www.sunrom.com/p-510.html

LDR Materials and dynamic features





- Materials: CdS, CdSe, PbS, PbSe, and others;
- **No PN junction** - one type of conductivity:
  - intrinsic - high resistance, sensitive to short wavelengths of light
  - extrinsic - smaller resistance, sensitive to longer wavelengths of light (IR)
- Dynamic response is exponential: **miliseconds**

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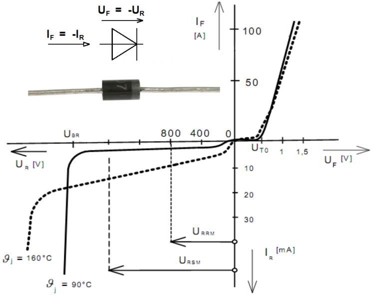
Diode

The construction contain one junction between different types of semiconductor conductivity $\Rightarrow$ PN junction.



Shockley diode equation

$$I = I_0 \cdot \left(e^{\frac{U}{n \cdot U_T}} - 1 \right)$$

I_0 ... saturation current,

U_T ...thermal voltage $= kT/e$,

n ...emission coefficient $= \langle 1, 2 \rangle$.

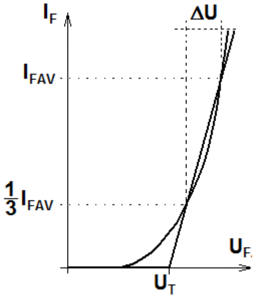
Diode - Forward Orientation

$$U_F \approx U_T + I \cdot r_T$$

U_T threshold voltage, for Si diode ≈ 0.6 V,

r_T dynamic resistance.

$$r_T \approx \frac{\Delta U}{\Delta I} = \frac{3 \cdot \Delta U}{2 \cdot \Delta I_{FAV}}$$

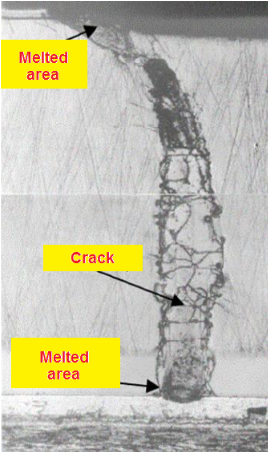


Very small forward voltage and high reverse (breakdown) voltage are good properties for rectifying.

Diode - Reverse Orientation

Breakdowns:

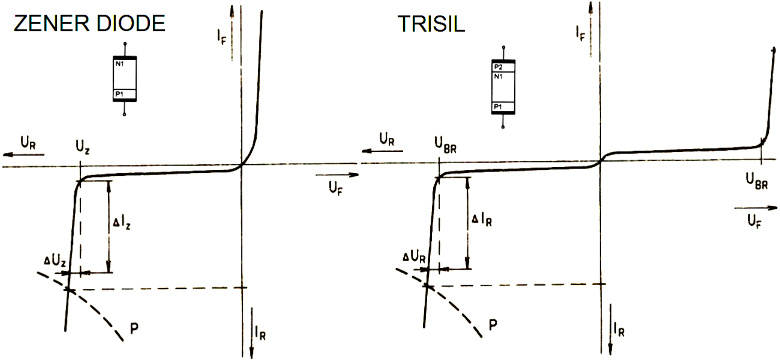
1. **electrical**... nondestructive, component handles the power loss (Zener diode and trisils).
2. **thermal**... destructive, the power loss melts the semiconductor layer.



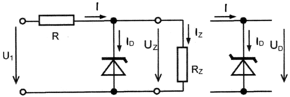
Breakdown Mechanisms:

1. Avalanche - U_{BR} icreases with temperature, in case $U_{BR} < 6$ V
2. Quantum tunnelling - U_{BR} decreases with temperature

Zener Diode and Trisil



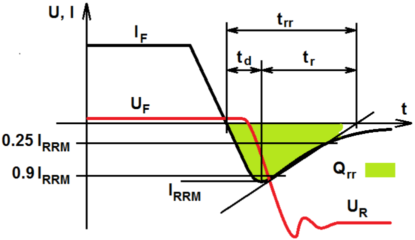
They are used as voltage reference or protection (common voltages $\langle 2\ V, 200\ V\rangle$).



Dynamic Behavior

Reverse Recovery:

- t_{rr} reverse recovery time
- t_d time of delay
- t_f time of fall

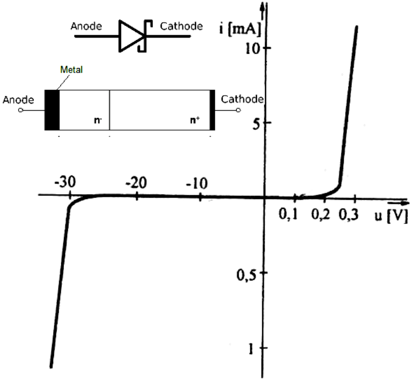


There is stored charge in the diode. The charge must be remove during the change of voltage polarity to recover reverse state of the diode.
After approximation by a triangle:

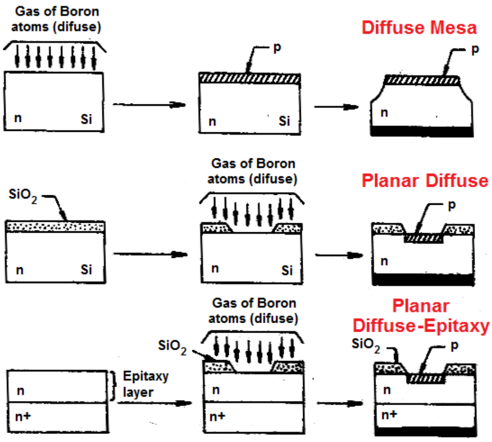
$$Q_{rr} = \frac{1}{2} \cdot I_{RRM} \cdot t_{rr}$$

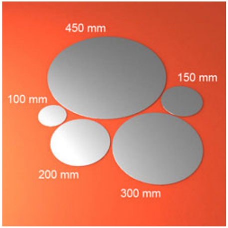
Schottky diode

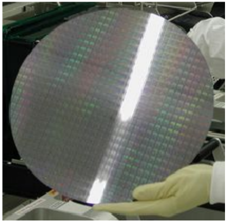
- Junction between semiconductor and metal.
- Smaller threshold voltage (0.3 V).
- Smaller recovery charge Q_{rr} (fast).
- Smaller breakdown voltages (common max 50 V, rare up to 200 V)



Diodes - Technology







TOPIC

Bipolar Transistors - Basic Properties

Component with two PN junction and three electrodes:

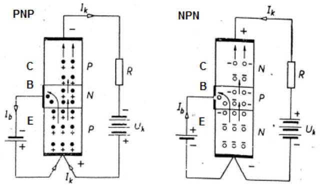
BASE ... affect, control the current flow between COLLETOR and EMITTER

COLECTOR ... collects the electrons flowing through BASE.

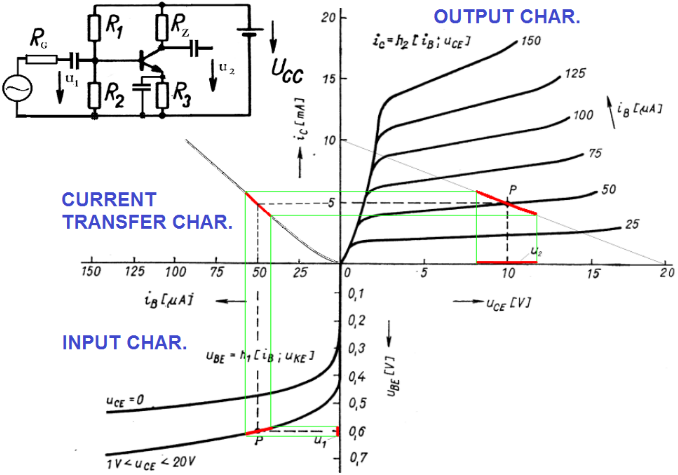
EMITTER ... emits the electrons to the base.

Arrangements: NPN, PNP

Applications: Amplifiers, switches

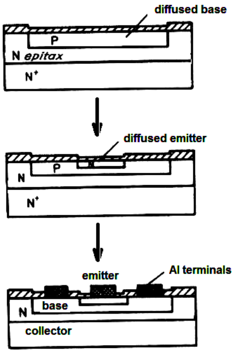


Transistors - Characteristics



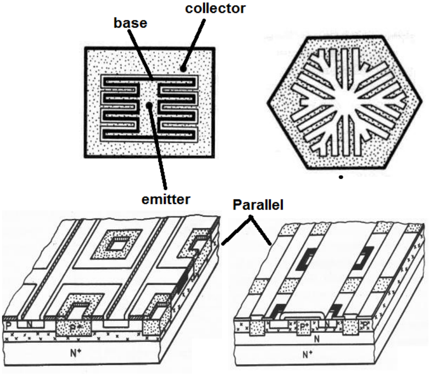
Technology

Planar diffuse-epitaxy: epitaxy layer has thickness 10 μm and it is created on degenerated semiconductor (similar to diodes technology).



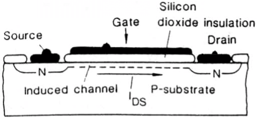
1. Creating the epitaxy N layer,
2. diffuse of boron,
3. creating of SiO_2 layer,
4. mask etching,
5. diffuse phosphor,
6. another SiO_2 layer and etching,
7. creating terminals.

Structures

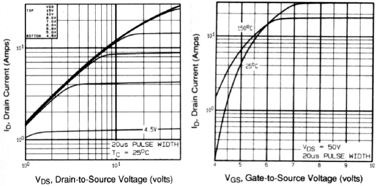


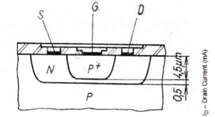
The large emitter area is needed to get high current capability. The current density is the highest at the edge of emitter layer. Therefore the structures with long edge are preferred.

Unipolar types

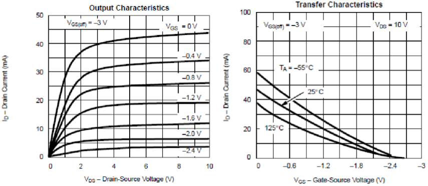


MOSFET



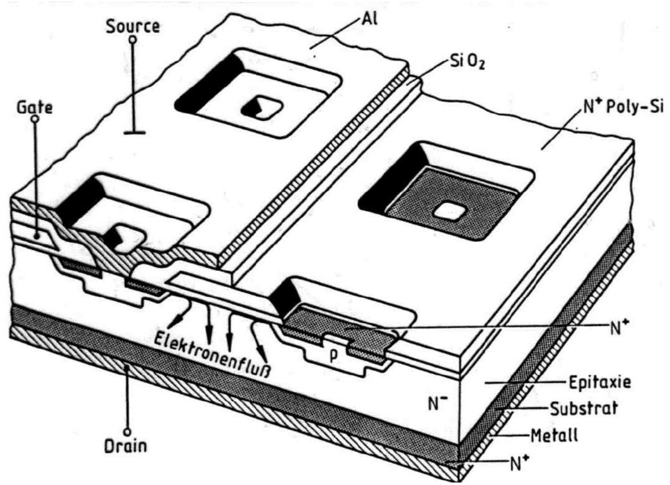


JFET



The flow of the current is controlled via electric field $\Rightarrow$ gate with low consumption.

SIPMOS Technology



HEXFET Technology