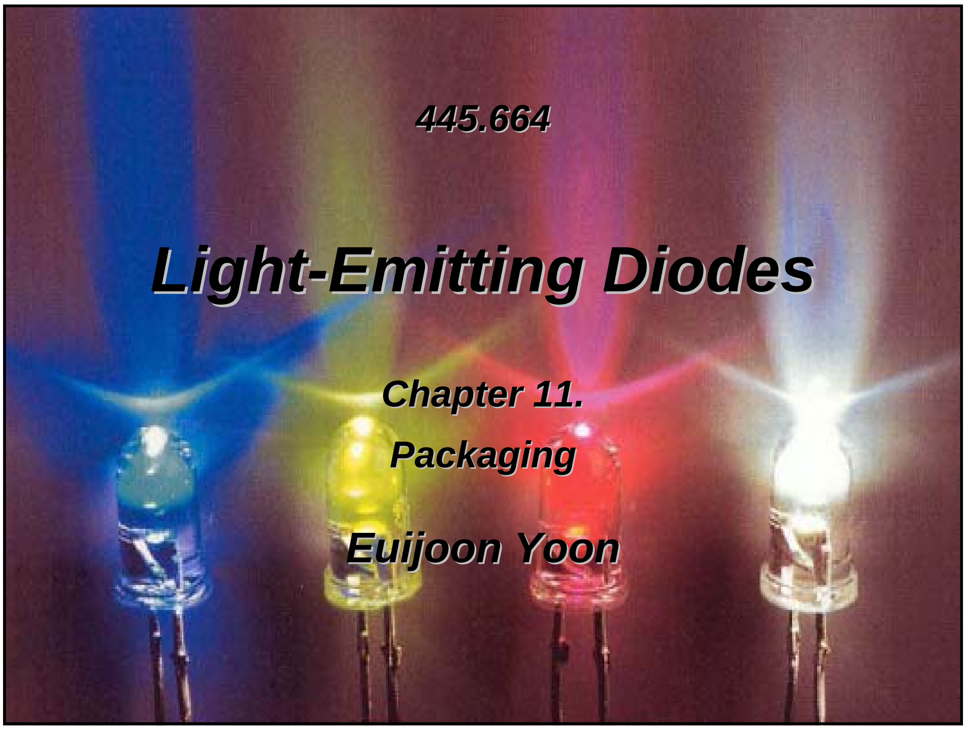

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Light-Emitting Diodes

Chapter 11.
Packaging

Euijoon Yoon

Typical LED package

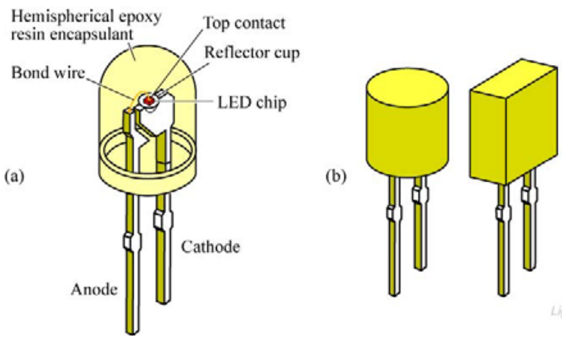


Fig. 11.1. Typical packages; (a) LED with hemispherical encapsulant; (b) LEDs with cylindrical and rectangular encapsulant.

E. F. Schubert
Light-Emitting Diodes (Cambridge Univ. Press)
www.LightEmittingDiodes.org

- ***Virtually all LEDs are mounted in a package.***
- ***The chip-encapsulating material advantageously possesses high optical transparency, a high refractive index, chemical inertness, high-temperature stability***
- ***The refractive index contrast between the semiconductor and air is reduced by epoxy dome (n~1.5).***

LED leadframes & power package

Low-power package

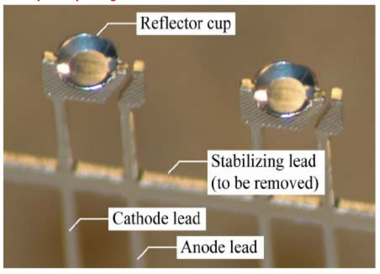
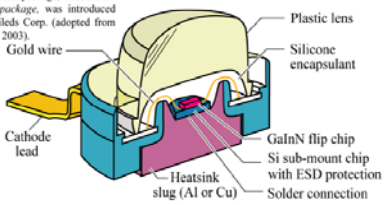


Fig. 11.2. Leadframe of a conventional 5 mm package for mounting and connecting LED chips. The stabilizing lead is cut off, once mechanical stability between the anode and cathode lead has been established by the epoxy encapsulant.

- *The individual leadframes are connected via a temporary stabilizing lead*
- *The LED chip is die-bonded to the flat bottom of the reflector cup*

Fig. 11.3. Cross section through high-power package. The heatsink slug can be soldered to a printed circuit board for efficient heat removal. This package, called *Barracuda package*, was introduced by Lumileds Corp. (adopted from Krames, 2003).

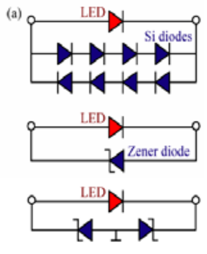
Power package



- *Power packages have a direct, thermally conductive path from the LED chip, through the package, to a heat sink (PCB)*
- *Al/Cu heatsink slug with low thermal resistivity*
- *Silicone encapsulant : mechanical softness in its cured state*
- *Direct mount on a Si submount : electrostatic discharge protection (ESD)*

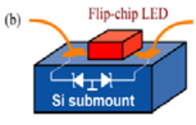
Protection against electrostatic discharge (ESD)

- *Electrostatic discharge (ESD)*
  : one of the major failure mechanism for electronic and optoelectronic components
- *Charge +Q is brought into contact and discharged uniformly over a time*
  - *I. When charge is brought into contact with cathode*
    - *Reverse discharge*
    - *Equivalent circuit of C and a parallel resistor R_p*
    - *Energy dissipation : $I^2R_p\Delta t$*
  - *2. When charge is brought into contact with anode*
    - *Forward discharge*
    - *Equivalent circuit of V_{th} and a serial resistor R_s*
    - *$V_{th}+IR_s \approx IR_s$ (high current)*
    - *Energy dissipation : $I^2R_s\Delta t$*



- *$I^2R_p\Delta t >> I^2R_s\Delta t$*
  : Reverse discharges are more damaging than forward discharge event

Fig. 11.5. (a) Electrostatic discharge (ESD) protection circuits using multiple Si pn junctions, one Zener diode, and two Zener diodes. (b) ESD protection integrated into a Si submount (two-Zender diode circuit after Lumileds, 2004).



Thermal resistance of packages

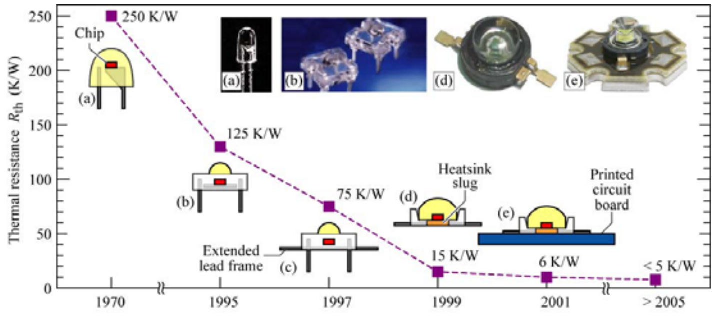


Fig. 11.5. Thermal resistance of LED packages: (a) 5mm (b) low-profile (c) low-profile with extended lead frame (d) heatsink slug (e) heatsink slug mounted on printed circuit board (PCB). Trade names for these packages are "Piranha" (b and c, Hewlett Packard Corp.), "Barracuda" (d and e, Lumileds Corp.), and "Dragon" (d and e, Osram Opto Semiconductors Corp.) (adopted from Arik *et al.*, 2002).

- ***The maximum temperature of operation may be determined by,***
  1. ***Reliability consideration***
  2. ***Degradation of encapsulant***
  3. ***Internal-quantum-efficiency consideration***

Chemistry of encapsulants

- ***Requirements for excapsulants***
  : high transparency, high refractive index, chemical stability, high temperature stability, hermeticity

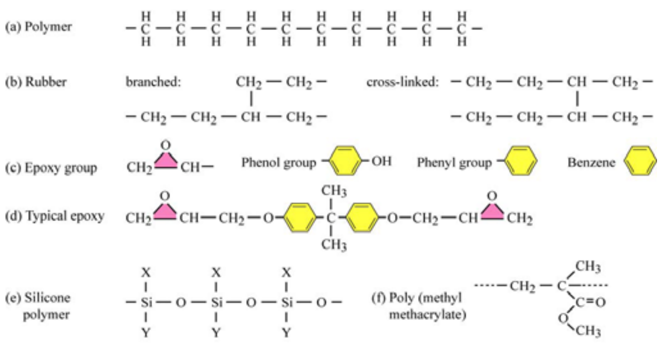


Fig. 11.6. Chemical structures of polymers. Epoxy resins, silicone polymers, and poly methyl methacrylate (PMMA) are used as LED encapsulants. In the silicone structure, X and Y represent atoms or molecules such as H, CH_3 (methyl), C_6H_5 (phenyl).

- ***Epoxy resin***
  - ***Common capsulant***
  - ***Transparent for long-wavelength LED***
  - ***Chemically stable up to 120 °C***
- ***Silicone encapsulant***
  - ***Thermally stable up to 190 °C***
- ***PMMA***
  - ***Relatively low refractive index***

Advanced encapsulant structures

- **Graded-index encapsulant**
  - The layer of highest refractive index is in contact with the semiconductor chip. The outer layers of the encapsulant have lower refractive indices.
- **Mineral diffuser: causes light to reflect, refract, and scatter, thereby randomizing the propagation direction and isotropizing the far-field distribution. TiO_2, CaF_2, SiO_2, $CaCO_3$, $BaSO_4$.**
- **Nanoparticles: titania, magnesia, yttria, zirconia, alumina, GaN, AlN, ZnO, ZnSe.**
  - When the size is smaller than the wavelength, the nanoparticles do not scatter light. Index changes.