Comparison of Bulb and LED Adhesive Curing Systems

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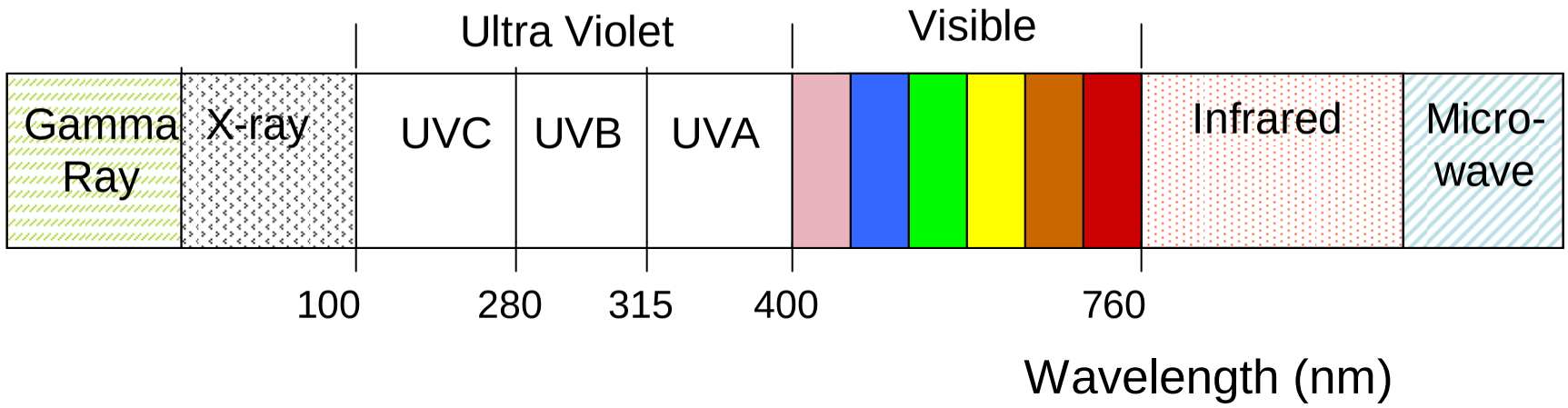
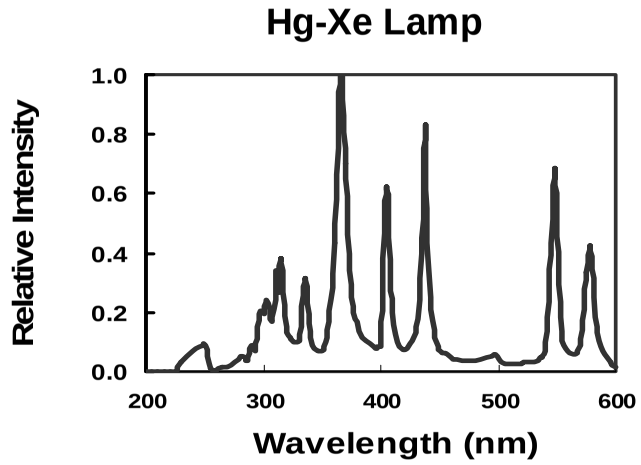
UV Spectrum



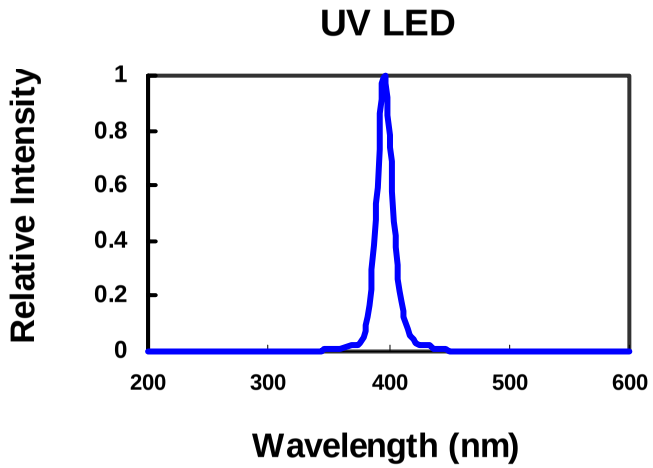
Ultra Violet radiation is divided into UVA, UVB and UVC

Optical Spectrum

- Bulb systems generate a broad spectrum from UV to IR with many emission lines.
- Emission lines in the UVC range, e.g. at 250 nm, surface cure acrylate adhesives and inks.
- Only one or a few of the emission lines are used for curing a particular adhesive.
- The other emission lines cause excessive heating, uncontrolled rates and shrinkage.
- Narrow filtering of the UV bulb output is therefore required, which reduces power in-light out efficiency and leads to additional heating.



- LEDs generate a narrow spectrum (10-15 nm wide) so all of its power is concentrated in one narrow band.
- UV-C LEDs are underdevelopment in labs.
- LEDs produce a narrow spectrum that can be matched to the wavelength needed for curing.
- This avoids the effect of excessive heating.



Operating Life

- Power output of UV bulbs drop with operating life.
- Power drops to about 75% after 2,000 hours.
- This may cause uneven adhesive curing.
- *Optical detectors* to monitor output power, or
- *Hour meters* to record number of hours bulb is used, are
- Methods *to live with* drop in power output of UV bulbs.
- Bulb inventory, Production down time, Replacement Complexity, Bulb monitoring.

- Life span of LEDs is in the order of 15,000 – 100, 000 hours.
- Power output of LED is constant throughout its long life

Warm Up Time

- UV bulb systems have a “warm-up” time.
- Depending on the type of UV bulb and other factors, warm-up time can be 30 minutes, 5 minutes, 90 seconds or other values.
- To avoid the nuisance of warm-up, many UV bulbs are turned on for the full shift.

- LEDs have instantaneous on/off.
- LED only accumulate time when turned on.

Energy Conversion Ratio

- Bulb systems produce wide band optical energy with many emission lines.
- Only a fraction of it is useful for curing a particular adhesive.
- Bulb systems have conversion ratio from electrical to useful optical energy of about 5-15%.

- LED systems produce a narrow band optical energy focused on a specific wavelength.
- LED systems have conversion ratio from electrical to useful optical energy of about 10%.
- The efficiency of LEDs are still improving.
- (Infrared and deep-red LEDs have achieved 50% efficiencies.)

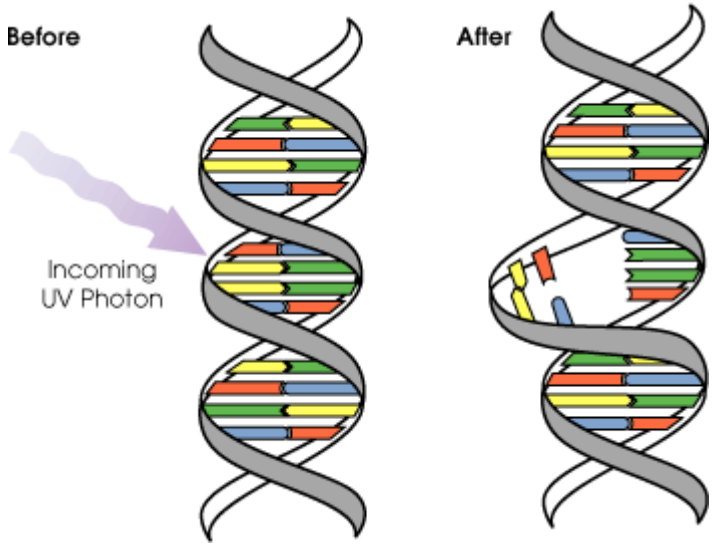
Voltage

- Starter voltage for a mercury-xenon lamp can be as high as 30 KV.
- Protection against accidental shock is required.
- Voltage of electric chair at Sing Sing was 2 KV.

- Most LEDs require about 4 volts.
- If 6 LEDs are connected in series, only 24 volts is required.

UV-C vs. DNA

- UV-C destroys DNA and is used to sterilize water or hard surfaces.
- Radiation at 250 nm can cause skin cancer: *basal cell carcinoma*, *squamous cell carcinoma* and *malignant melanoma*.
- Radiation at 250 nm can damage eyes: *photokeratitis* and *conjunctivitis*.
- Work place safety requires protection of personal from UV-B and UV-C.



Ref. www.earthobservatory.nasa.gov/Library/UVB/

Ozone Creation

- Ozone is created by all UV bulb systems because they generate radiation with wavelength < 240 nm.

- Ozone is toxic to humans so its concentration level in the workplace must be monitored.
- Excessive ozone must be properly vented to the outside.

- High concentration of ozone can damage the environment.
- OSHA, FDA and EPA have jurisdiction over ozone.

- LED systems do not create ozone.

LEDs Environmentally Friendly

- Mercury is the active ingredient of most UV bulbs.
- The Mercury is under pressure, and will be released with a bulb break.
- Mercury can be ingested, inhaled or absorbed through the skin.
- Mercury accumulates in the lungs, brain and other vital organs.
- Mercury caused
  - "Mad Hatters" illness in English hat workers.
  - More than 10,000 crippling deformities and agonizing death in Minamato, Japan.
  - Emotional instability, tremors, kidney failures, and weakened immune systems to those who came in contact with mercury.
- Mercury is a known poison.
  - Mercury UV bulbs must be carefully used and safely disposed.
  - Mercury use will be restricted by state and the federal government.
  - Restriction of Hazardous Substances (RoHS) restricts the use of mercury in electronic equipment after July 6, 2006. Exemptions for specified lamps may be dropped as an alternate light source becomes available.

- **LEDs have no mercury**.

Haitz Law (Moore's law for LEDs)

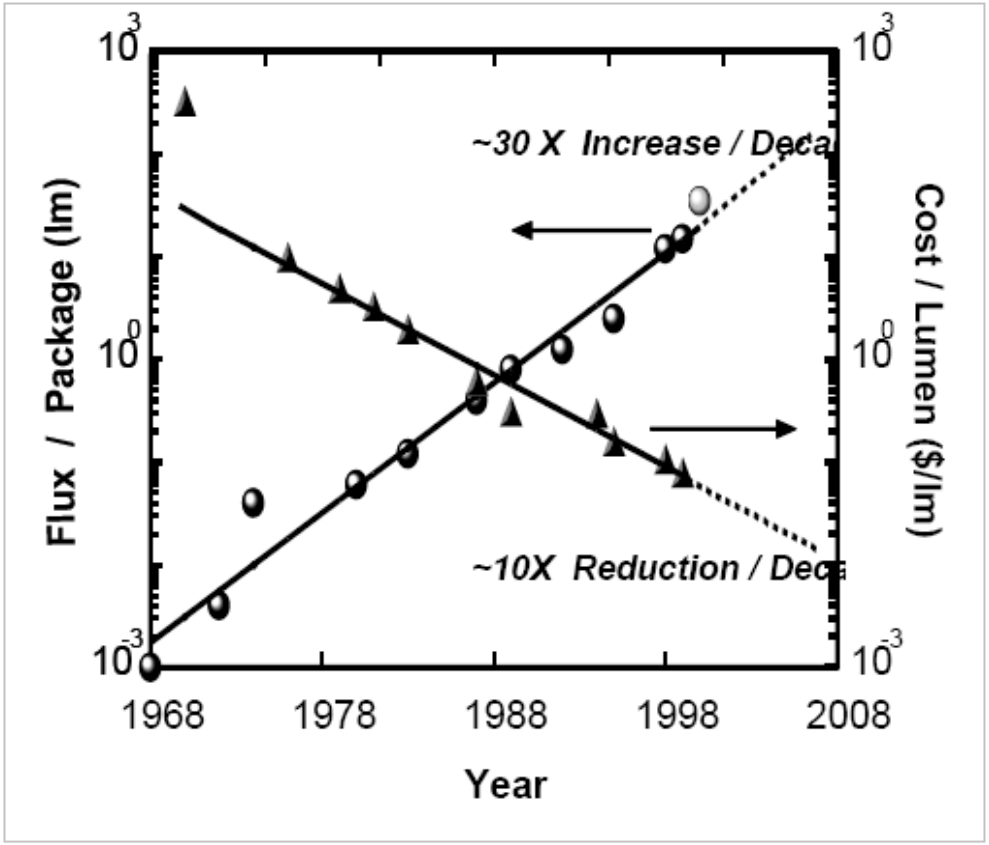


Figure 3. The evolution of lm/package and cost/lm for red LEDs. [Courtesy of Roland Haitz, Agilent Technologies.]

LED Lighting for General Illumination
Optical industry Development Association

- Design for rapid LED performance growth.
- Compatibility with high volume platforms

Summary

- LEDs have many practical advantages over bulb system
  - Life span of device, instant on
  - Environmentally friendly
  - No IR heating, no UV-C Damage

- Future Trends favor LEDs
  - LEDs-Higher power, more efficient, shorter wavelengths
  - Moore's law.
  - Materials-more sensitive, visible wavelengths
  - Alternate surface cure photo initiators