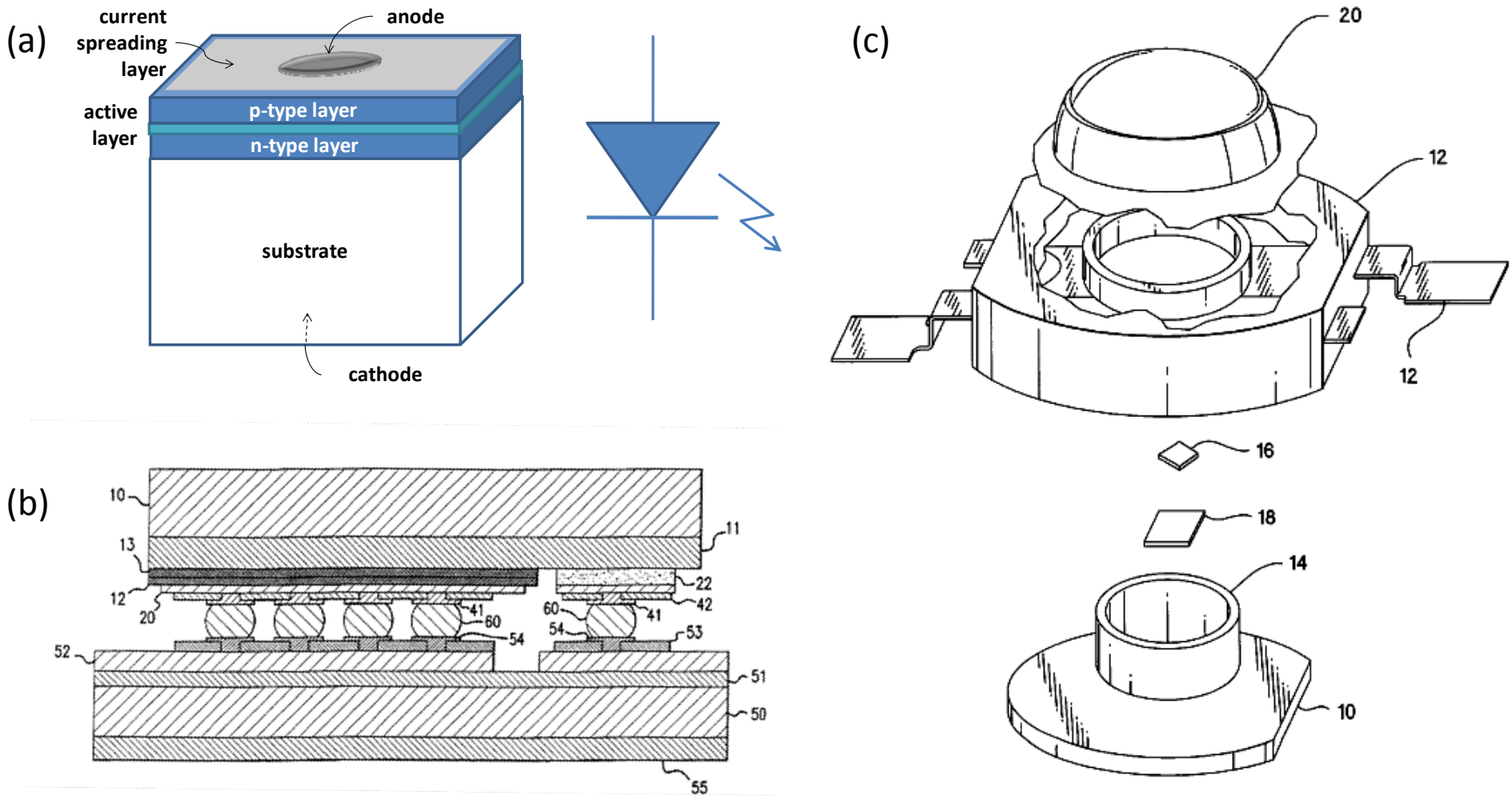

FIGURE 1 (a) Simple LED chip construction (conductive substrate). Typically, the n-type layers are epitaxially deposited, followed by the active layer(s), and then the p-type layers. Ohmic contact electrodes are formed for injecting current into the device. In many cases, current spreading means are employed to provide uniform electrical injection within the thin epitaxial layers. (b) Cross section of a high-power flip-chip LED, showing a considerably more complex structure that is the present requisite for state-of-the-art LEDs for illumination (Krames et al., 2003). (c) Exploded view of a high-power LED package (Carey et al., 2001). High-power chips

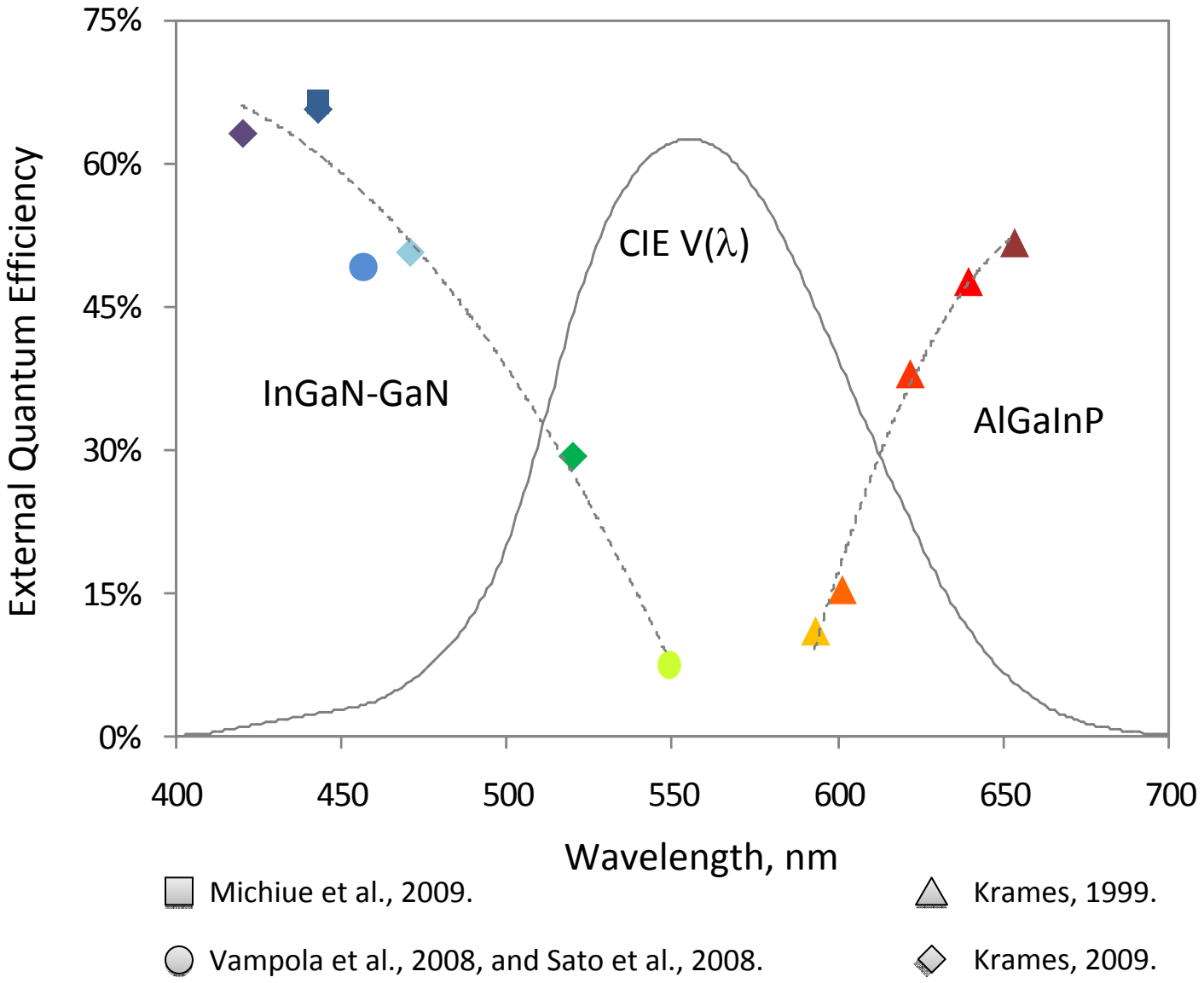

FIGURE 2 Best-reported external quantum efficiencies for high-power InGaN-GaN and AlGaInP LEDs vs. emission wavelength at reasonable operating current densities. Also shown is the human eye responsivity as determined by the photopic luminosity function, V(λ), wherein one Watt

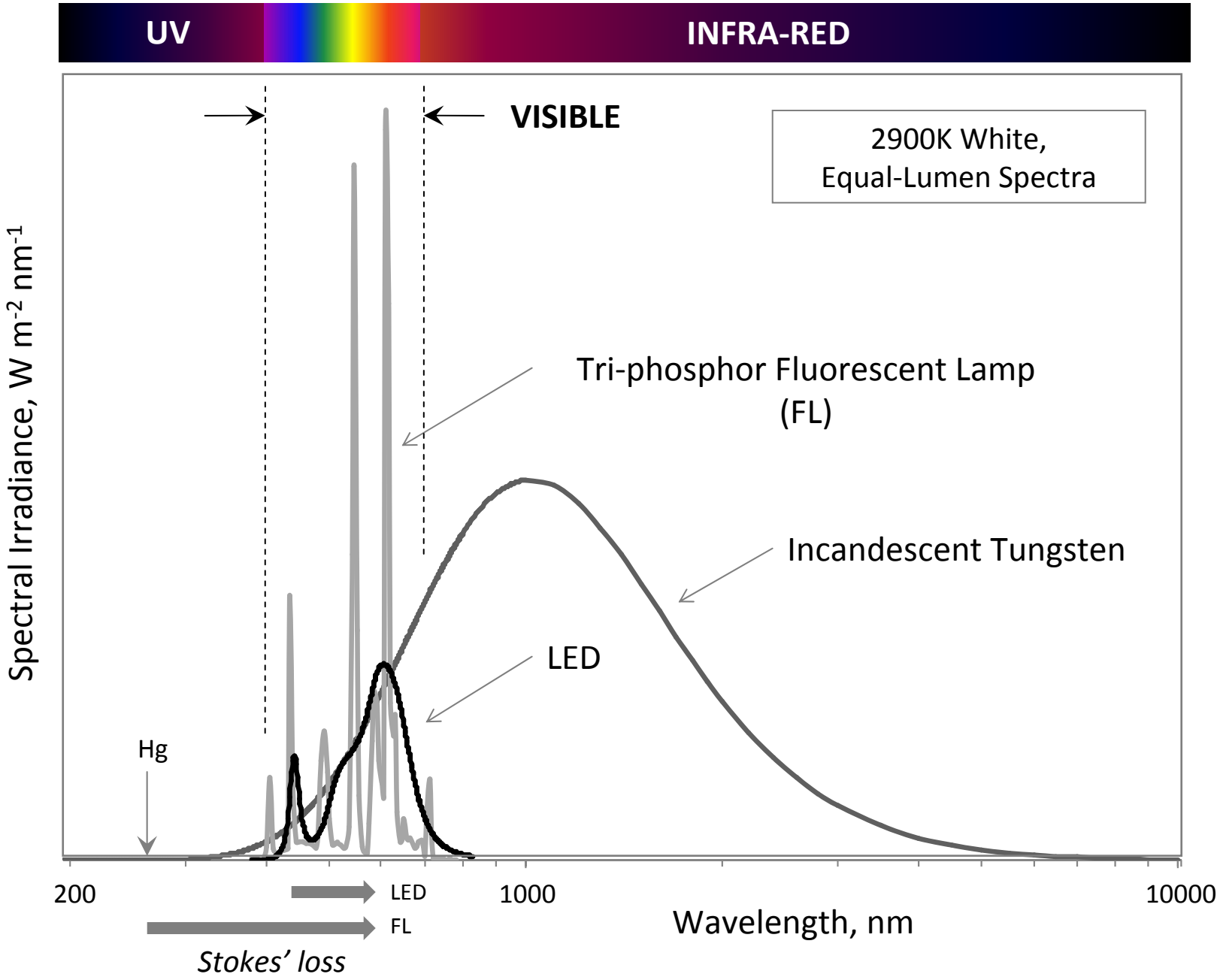

FIGURE 3 Equal-lumen spectra of white light emitters based on i) incandescent tungsten, ii) tri-phosphor fluorescence, and iii) phosphor-converted LEDs, all at a

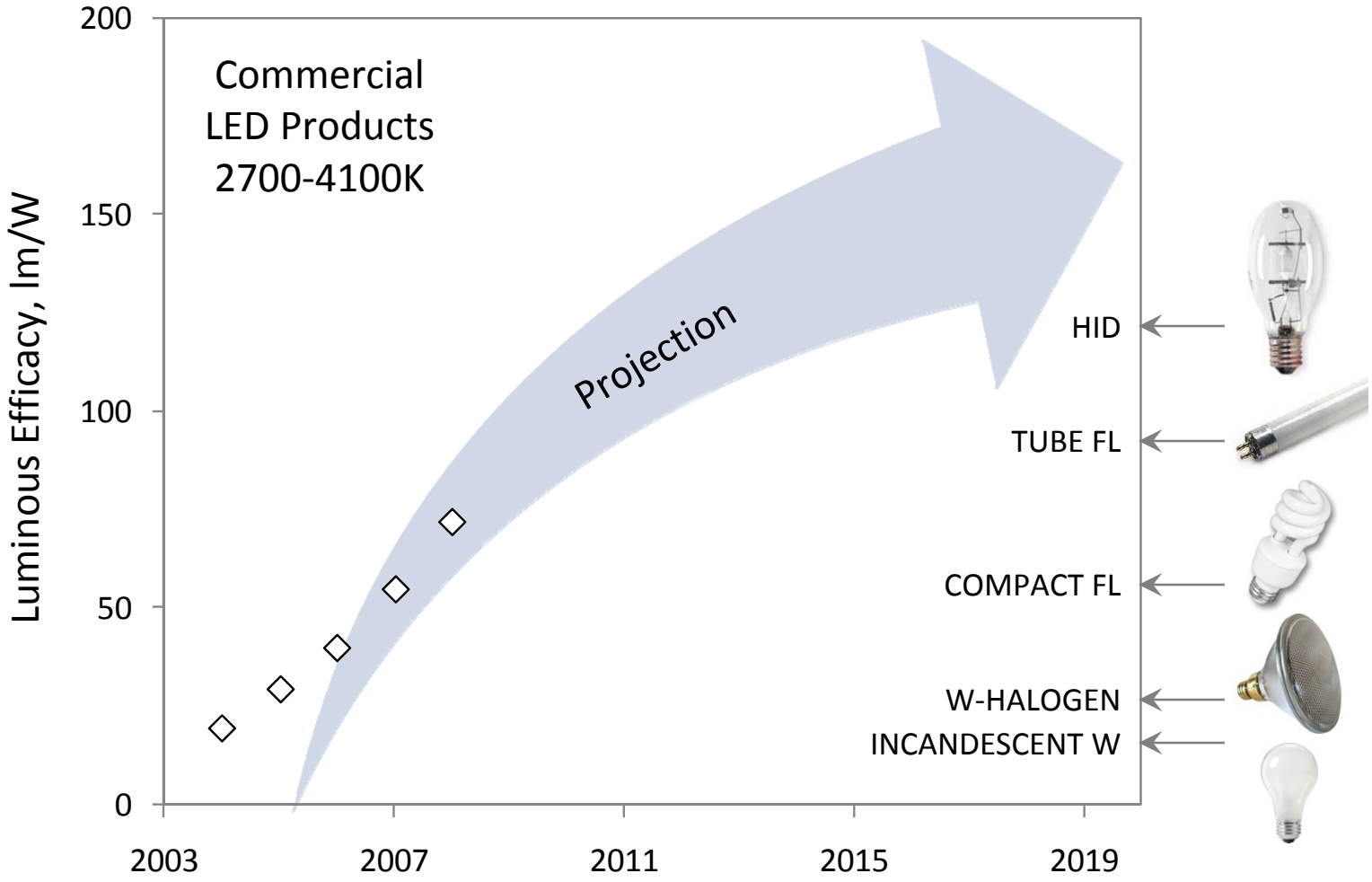

FIGURE 4 Evolution of luminous efficacy (lumens per electrical Watt) for commercial "warm white" (2700-4100K) LED products as well as a projected performance based on information compiled for the U.S. Department of Energy. At right, typical luminous efficacies are indicated for conventional lighting technologies including incandescent tungsten, tungsten-halogen, compact fluorescent, tube fluorescent, and high-intensity-discharge lamps.