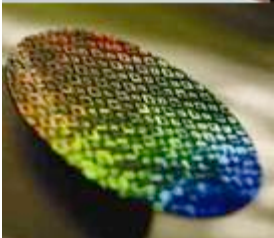
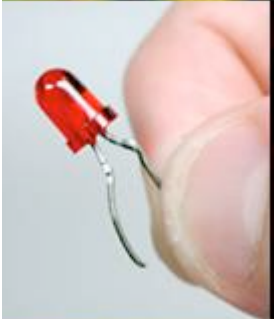
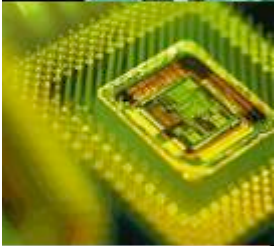
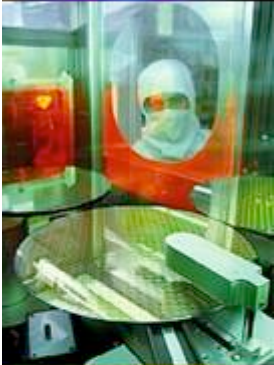


Innovation Challenges in the Lighting Industry

Susan Sanderson
Kenneth Simons
Judith Walls
Yin-Yi Lai

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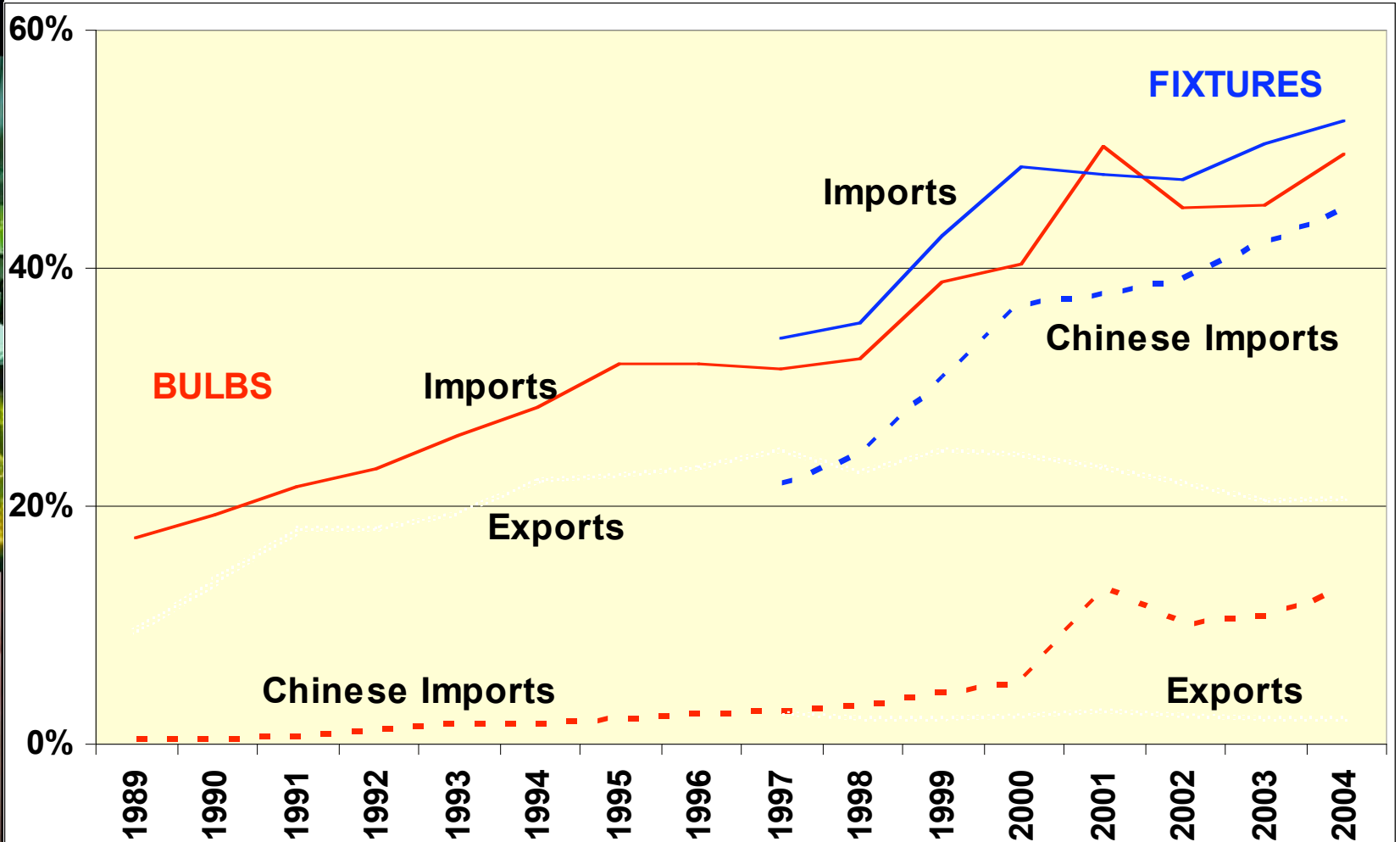
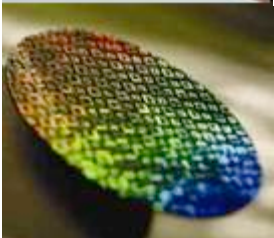
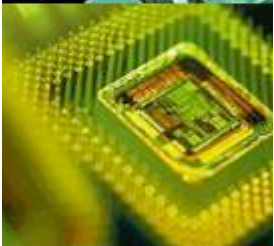
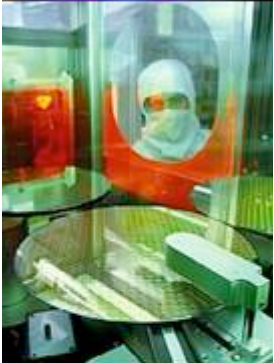
Sloan Industry Studies Annual Conference
April 26-27, 2007



Traditional Lighting Industry

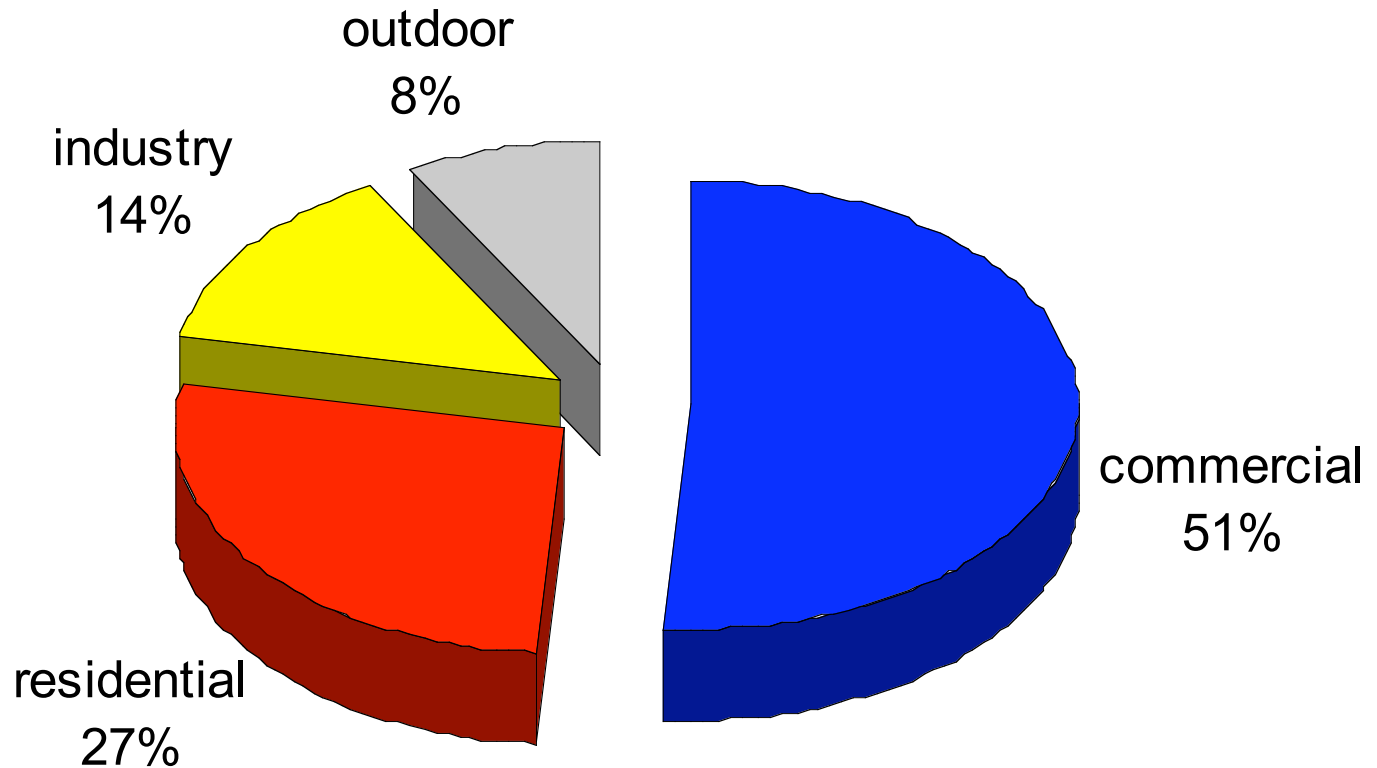
- Market size: \$40-100 bn
- U.S. consumption: \$4.8 bn
 - Lamps
 - Big Three: Philips, GE, Osram
 - 44.6% patents (1990-1993)
 - Fixtures
 - Other
- Increasingly imported, especially from Asia

Traditional Lighting Industry



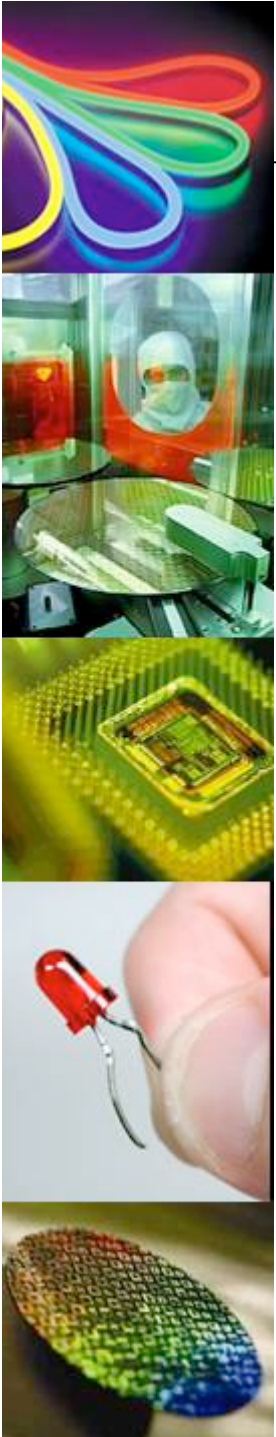
U.S.: 26% bulbs & 86% fixtures imported from China

U.S. Lighting Energy Consumption



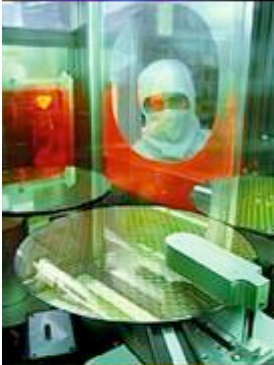
Enormous energy savings potential

- Residential – 90% incandescent
- Commercial – mostly fluorescent

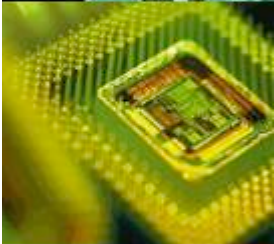




Innovation in Lighting



Shift to LED (light emitting diodes): semiconductor



Incandescent



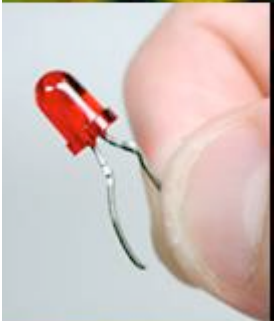
Halogen



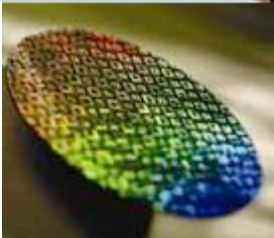
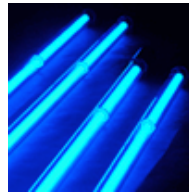
Fluorescent



Light emitting diodes (LEDs)

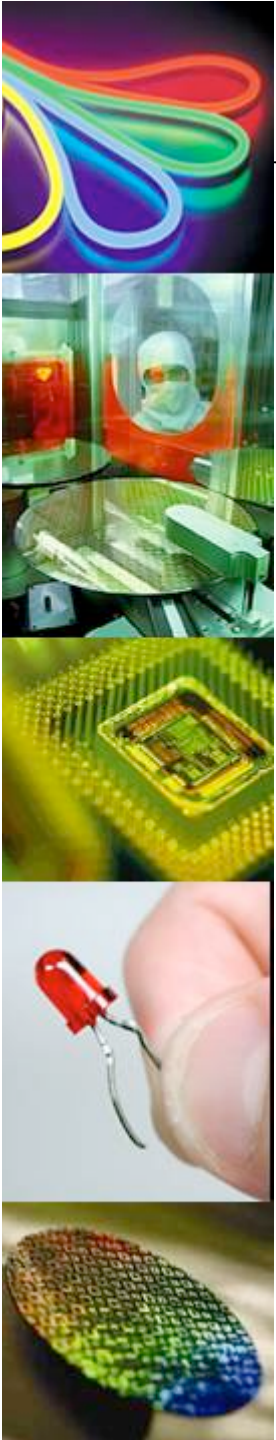


Gas-discharge (example: neon)

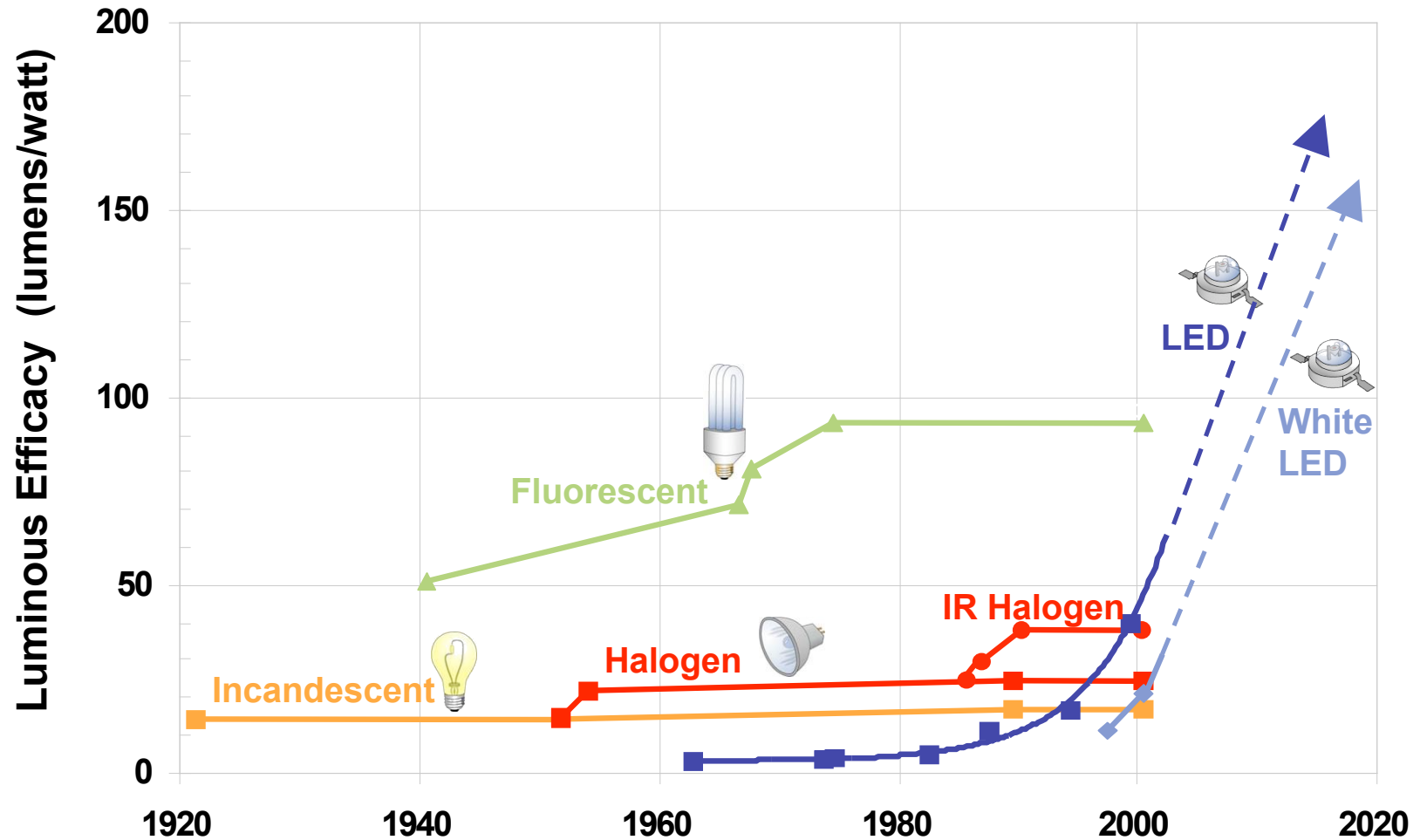


Source: Color Kinetics

Market Trends

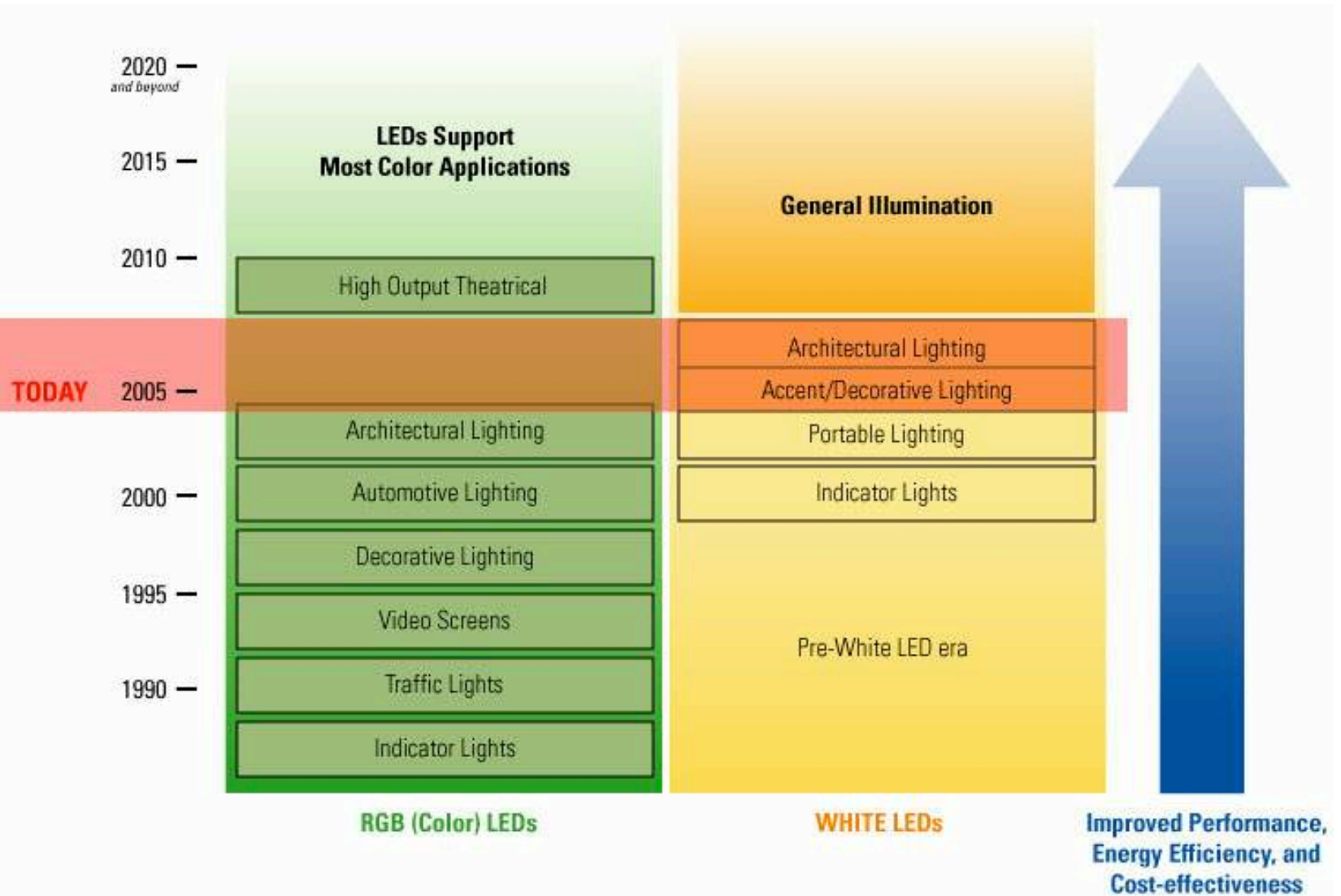
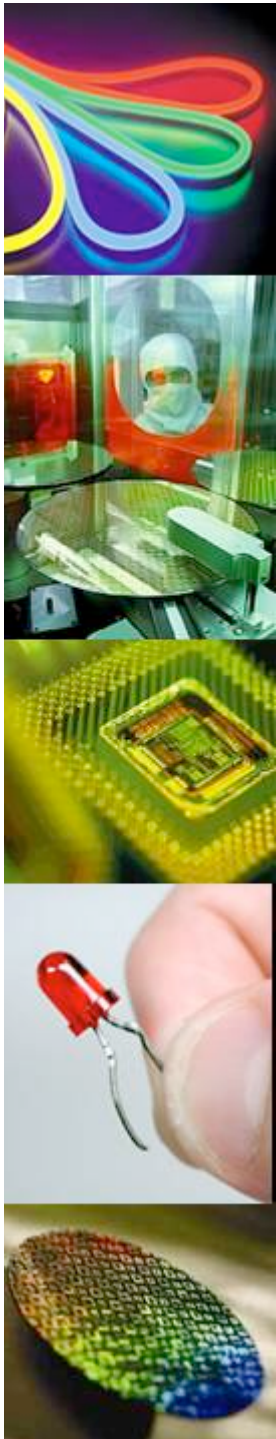


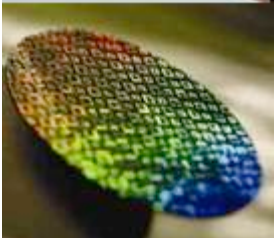
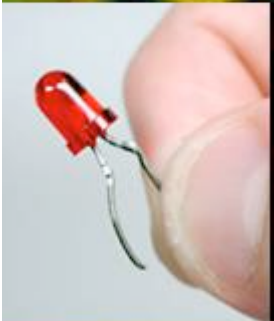
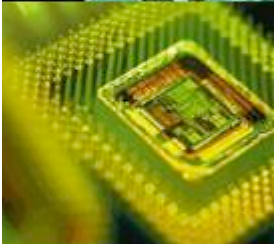
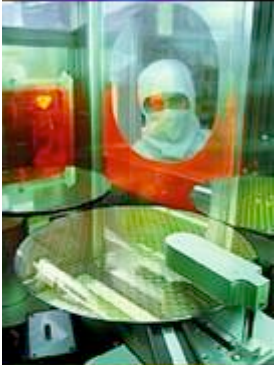
LEDs eclipsing traditional technologies



Source: Lumileds & Color Kinetics

Expansion through Market Niches

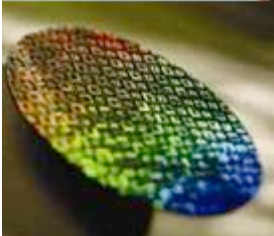
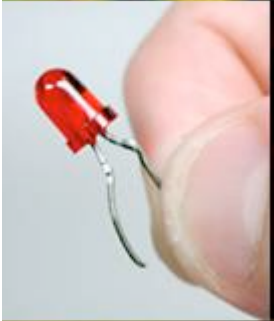
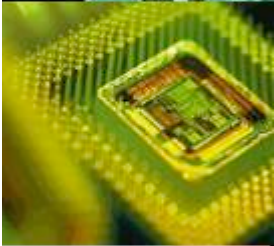
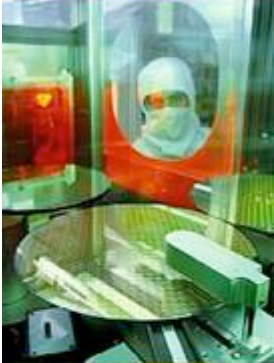




Disruptive Technology

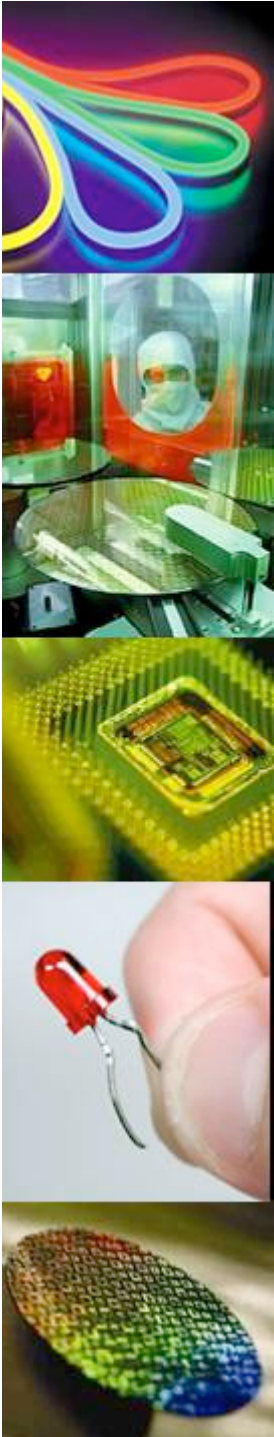
- Different technological skills
 - Semiconductors
- Entry of new firms

Traditional	Philips (Netherlands) GE (US) Osram (Germany)
Non-traditional	Nichia (Japan) Sharp (Japan) Eastman Kodak (U.S.) Samsung (Korea)
New firms	ColorKinetics (U.S.) Epistar (Taiwan) United Epitaxy (Taiwan)

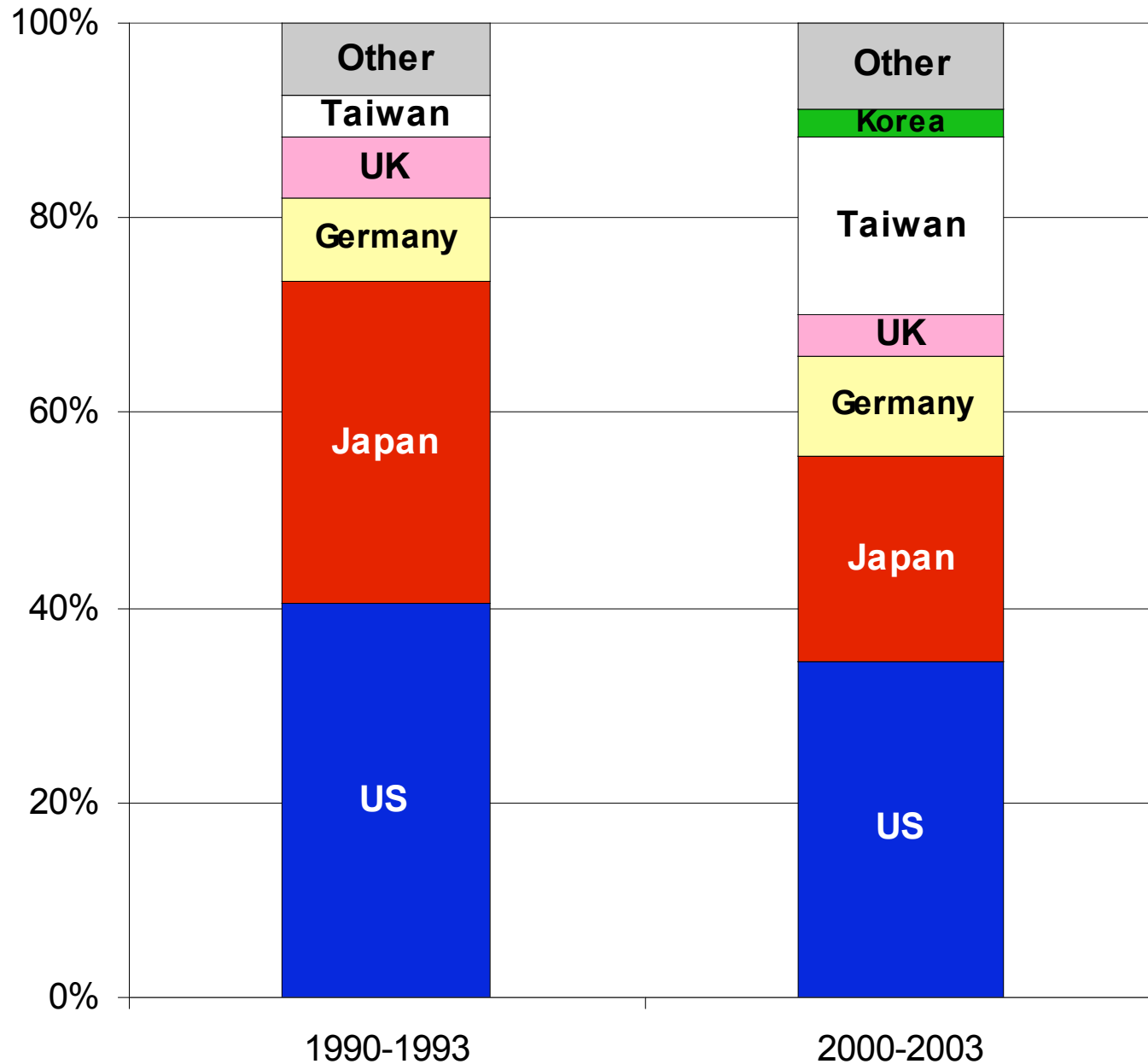


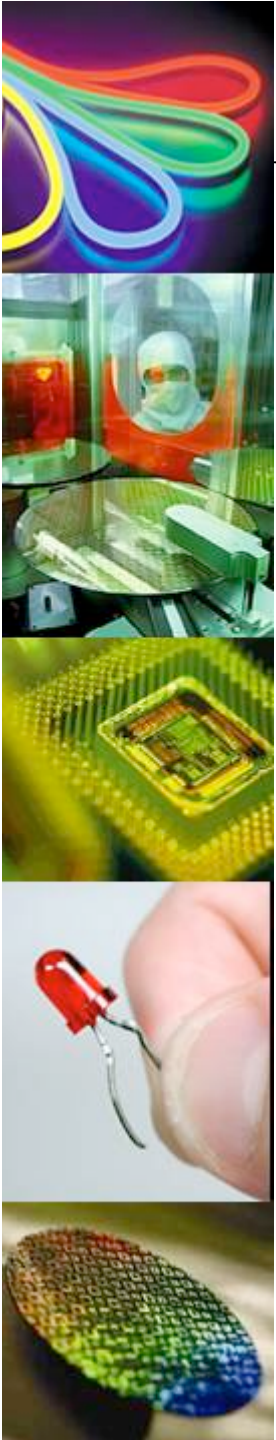
Patent Analysis Methodology

- U.S. & European patents
 - Espacenet
- Text search:
 - “LED”
 - “light emitting diode”
 - “lighting”
- Equivalents – patent counted once if filed multiple times
- High value patents – applied for and granted in multiple continents

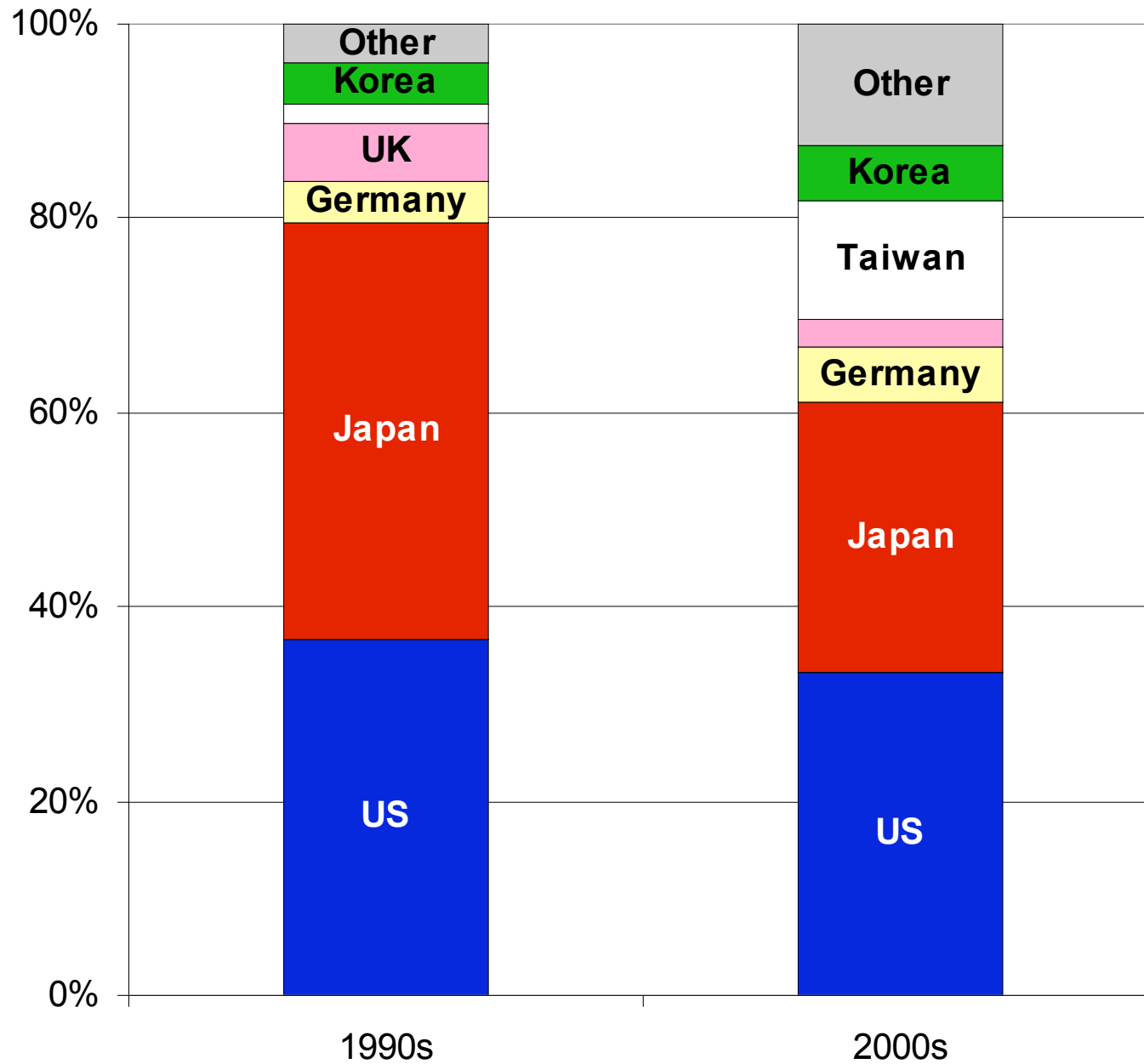


LED Patents by Inventor Location



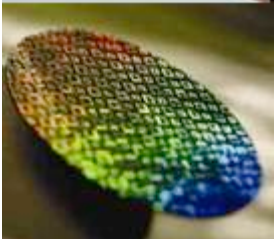
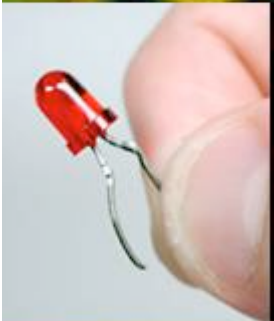
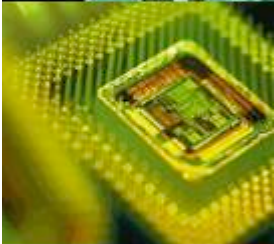
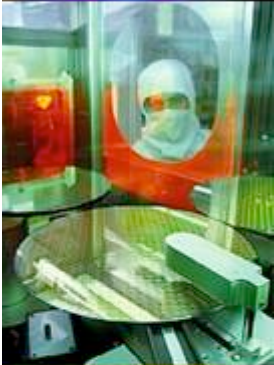


High Value LED Patents by Inventor Location



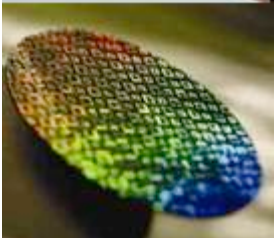
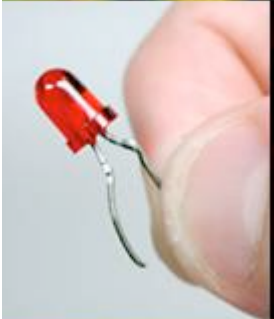
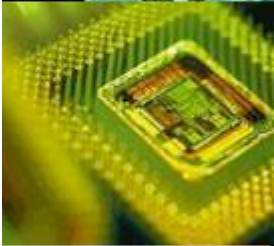
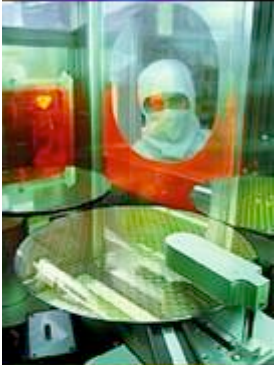


Top Ranking Firms by LED Patents



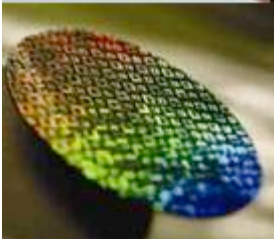
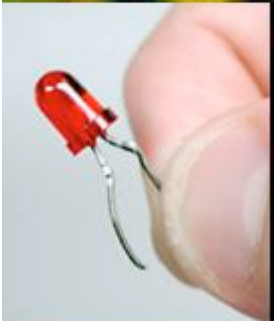
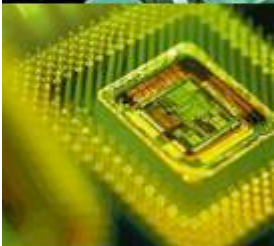
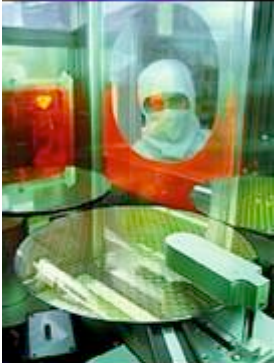
2000s	1990s	Company	HQ location	Patents 2000s
1	-	Philips/Lumileds	Netherlands/U.S.	13
2	7-16	OSRAM/Siemens	Germany	11
3	-	Nichia	Japan	8
4-5	7-16	Sharp	Japan	7
4-5	-	United Epitaxy	Taiwan	7
6-9	-	AXT	U.S.	5
6-9	3-4	Eastman Kodak	U.S.	5
6-9	-	GE/Gelcore	U.S.	5
6-9	7-16	Samsung	Korea	5

Big Three strong in LED via joint-ventures



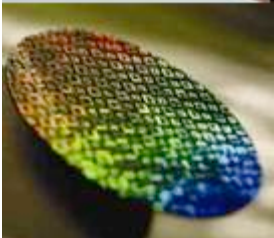
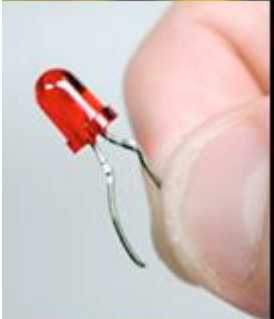
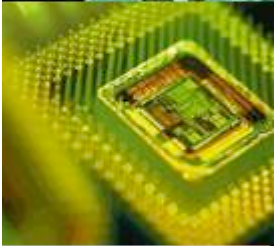
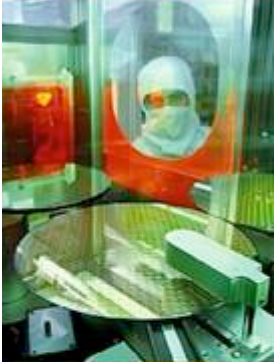
National Policies as R&D Drivers

- Japan: *Light for 21st Century*
 - 1979/1999 energy law is key driver
 - Early R&D funding by government & industry
- US: *Next Generation Lighting Initiative*
 - Industry led program initiated by DOE
 - Grants largely to private sector
- E.U.
 - Sixth Framework Program
 - Overall nanotechnology investment



National Policies as R&D Drivers

- Taiwan: *Next Generation Lighting*
 - Government & private sector consortium
 - 6-year nanotechnology initiative
- Korea: *Semiconductor Lighting Program*
 - Government backed KOPTI
 - LED Valley
- China: *Semiconductor Lighting Project*
 - Part of 11th 5-Year Plan
 - Developing five industrial parks for LED



Conclusion

- LEDs creating new lighting market opportunities
 - Big Three lighting firms remain strong participants
 - However, new competition from entrants especially from Asia
- Apparent fruitful policies
 - Government funding for R&D
 - Synergies with semiconductors
 - Education of engineers & researchers
 - Incentives to diffusion