Electronics

Cynthia F. Murphy
University of Texas at Austin
Center for Energy and Environmental Resources
(512) 475-6259
(512) 471-1720
cfmurphy@mail.utexas.edu

Electronics - Overview

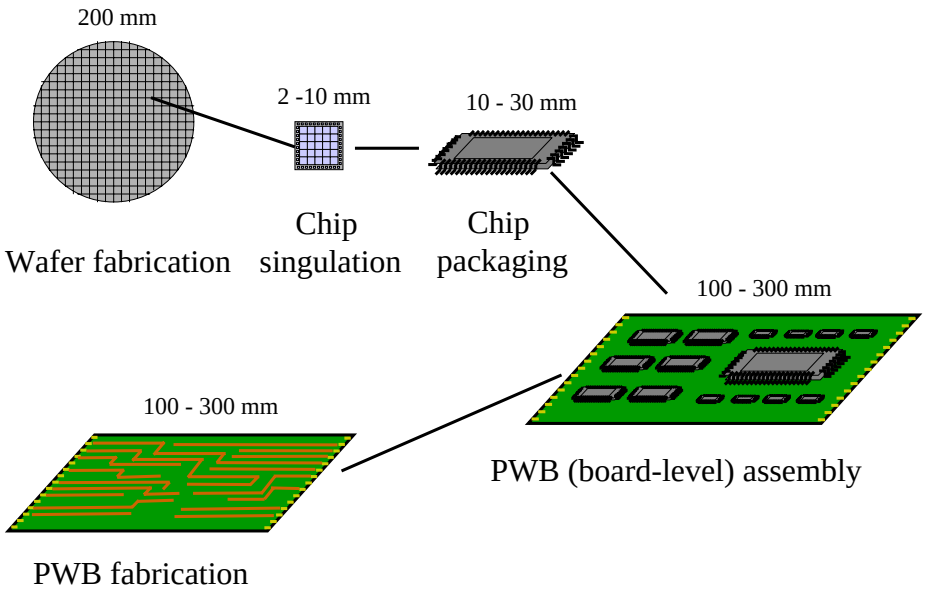
- Electronics industry tends to be proactive (worldwide)
  - Life-cycle Assessment (LCA)
  - Design for Environment (DFE)
  - End-of-Life Management (ELM)
- Industry culture of minimization, cost-reduction, and increased efficiency are all compatible with EBM
- Used to inserting and integrating new designs, technologies, and equipment
  - Average product life span of 18 to 48 months
  - Complete capital equipment turn-over every 5-10 years
- Expert at managing and analyzing large amounts of data (legacy of quality movement)

Design for Environment - Focus Areas

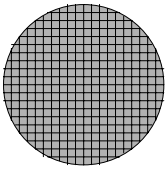
- Materials of concern
  - Reduction
  - Elimination/substitution
- Design for disassembly and reuse
  - Assembly technology and materials
  - Reduction in number of materials used
  - Reduction in use of coatings and other inseparable materials configurations
- Volume reduction
  - Manufacturing
  - Products (EOL disposition)

The Making of a Computer

- Wafer fabrication
- Chip packaging
- PWB fabrication
- Board-level assembly
- External housing
- Display (CRT or FPD)

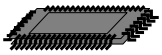


Materials and Environmental Concerns - Integrated Circuits



Wafer fabrication

Product materials: Si, SiO_2, Al, ± Cu
EBM Issues: Water, energy, gas emissions (especially PFCs - perfluoro compounds)



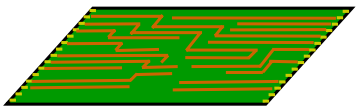
Chip packaging

Product materials: Polymers, Ceramics, Ni/Au alloys, Cu, Au
EBM Issues: Energy, metal-bearing liquid waste, flame retardants, material waste

Wafer Fabrication

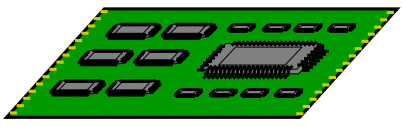
- Large, highly capital intensive manufacturers
- Equipment driven
- Small feature size (sub-micron) requires extremely clean processes
- Deposition of very thin layers is done using gaseous processes
- Key concerns are qualification of new materials, reduction in PFC emissions, reduction in energy and water usage (SIA Roadmap)
- NSF Engineering Center, SEMATECH

Materials and Environmental Concerns - Printed Wiring Boards



PWB fabrication

Product materials: Ceramic, epoxy-glass, or other polymers; Cu, Pd, Pb, Au
EBM Issues: Water, energy, flame retardants, Pb finishes, plating solutions



PWB (board-level) assembly

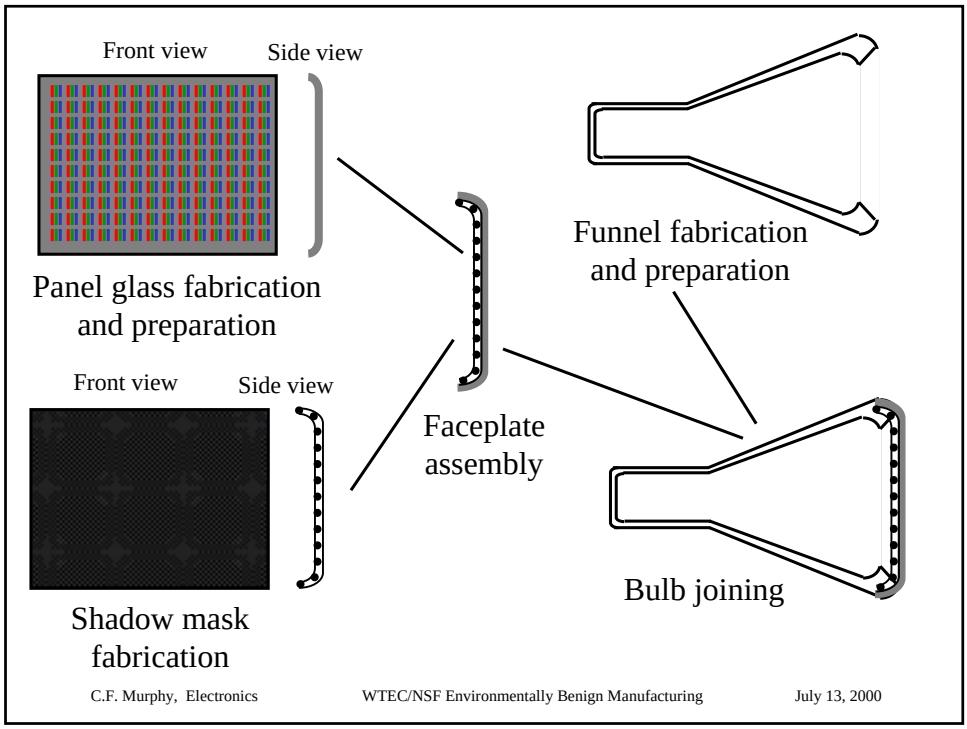
Product materials: Pb/Sn
EBM Issues: Energy, Pb

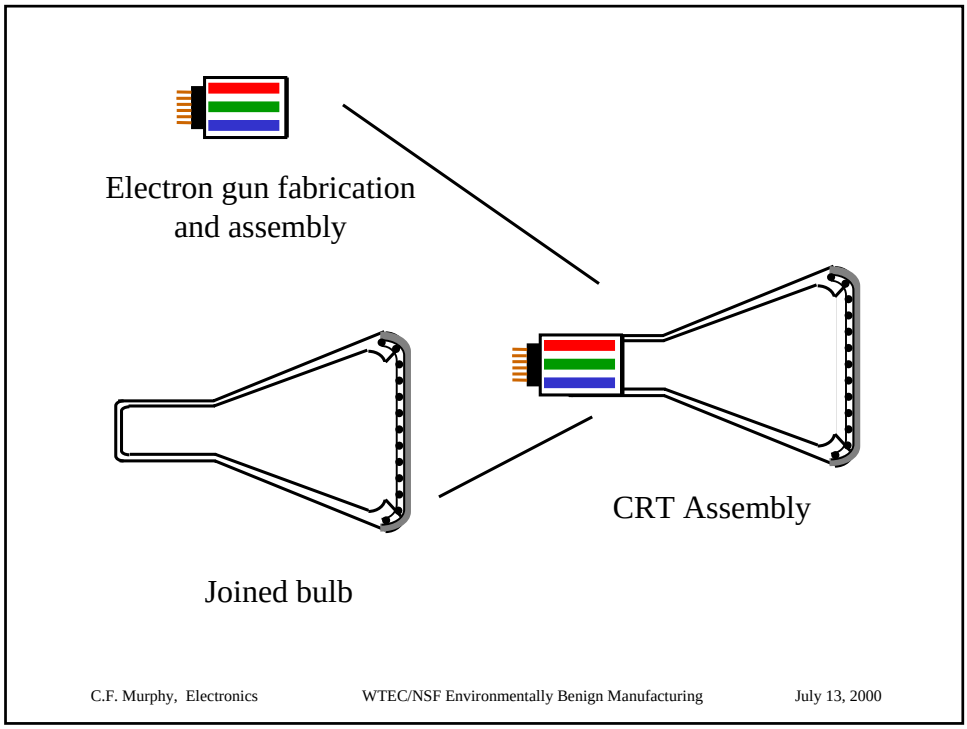
PWB Fabrication

- Many manufacturers of varying size, both independent and captive; moderately capital intensive
- Material and process driven
- Relatively small features (3 to 4 mils) require clean environment
- Plating baths use large amounts of water and complex chemistries (organic and inorganic compounds)
- Lamination of multiple layers is very energy intensive
- Several PWB projects under EPA's DfE Program and DARPA's Environmentally Conscious Manufacturing Program

PWB (Board-level) Assembly

- Capital intensive
- Use of Pb solder dominates environmental concerns
- Soldering processes can be very energy intensive and are higher for Pb-free solders
- Trim waste (epoxy-glass ± copper) can be 50% of the total material budget


Front view
Side view
Panel glass fabrication and preparation
Front view
Side view
Shadow mask fabrication
Faceplate assembly
Funnel fabrication and preparation
Bulb joining
C.F. Murphy, Electronics
WTEC/NSF Environmentally Benign Manufacturing
July 13, 2000


Electron gun fabrication and assembly
Joined bulb
CRT Assembly
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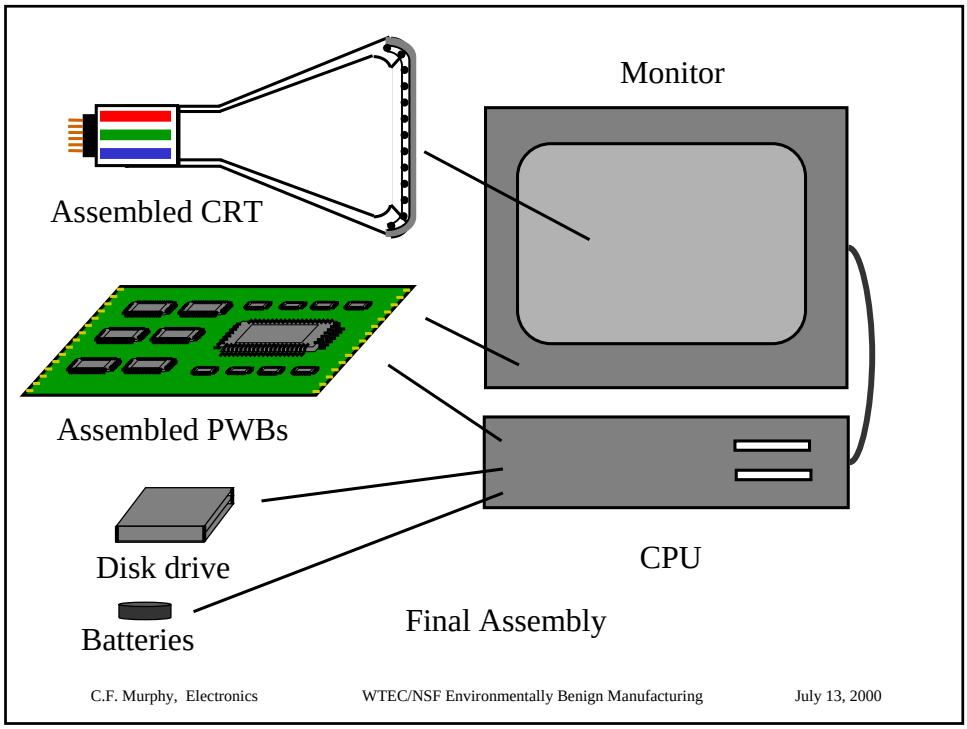
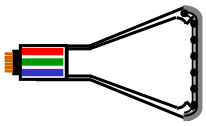


Materials and Environmental Concerns - Computer System

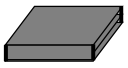


CRT

Product materials: Glass, Pb, phosphors, steel, Al, Cu
EBM Issues: Energy, Pb

Batteries

Product materials: NiCd
EBM Issues: Cd, life/efficiency



Storage Media

Product materials: Al or glass, Ni, Mg
EBM Issues: recyclability

Final Assembly

Product materials: Thermoplastics
EBM Issues: recyclability and FRs

Displays

- Glass formation is energy intensive
- Biggest concern is end of life, due to Pb content in glass
- Flat panel displays (FPDs) are replacing cathode ray tubes (CRTs) and may introduce new issues
- Study is currently underway under EPA's DfE program

Final Assembly

- Materials and design are biggest issues
- Take-back legislation in Europe is helping define needed infrastructure for recycling
- Desire to increase recycled content in housings - typically formed using thermal plastics such as ABS, PC, or PC/ABS
- Non-brominated flame retardants for ABS a challenge

End of Life Management

- Interest being driven by
  - Take back legislation in Europe
  - Material bans in Europe (Pb, halogenated FRs)
  - Landfill bans and labeling laws in US (e.g., CRTs, Hg)
  - Leasing agreements (increased producer responsibility)
- Reuse
  - Limited to systems less than 36 - 60 months old
  - Component harvesting economic only in tight markets
- Three primary materials commodities / issues
  - Plastics / separation, contamination, high cost-to-value ratio
  - Glass / Pb and FPDs
  - Metals / decreasing volume, especially precious metals

Japan

- Highly responsive to activities in Europe
  - Elimination of halogenated flame retardants
  - Pb-free solders
- ISO 14000 certification is a focus
- New recycling law to require 50% recycling of large appliances starting April, 2000 - expected to eventually apply to computers
- Using alternative PWB technologies (microvias) that are inherently less water, energy, and material intensive processes while providing better performance
- Sites visited: Hitachi, Sony, NEC, Fuji-Xerox

Europe

- Take-back legislation and WEEE (Waste Electrical and Electronic Equipment) Directive
  - Recycling
  - Material alternatives (Pb and non-brominated FRs)
- Dutch have a well-developed infrastructure for collecting and recycling computers
  - Glass and metals are re-introduced into the material stream
  - Plastic is incinerated
- "Green" products offered in parallel with conventional, but with a price differential
- Sites visited: MIREC, Siemens, Philips, Fraunhofer. Lucent

United States

- Responding to activities in Europe
  - Take-back
  - Pb-free solder
  - Non-brominated flame retardants
- Emphasis on metrics and supply chain management
- Recycling activities in partnership with OEMs (HP, IBM, Dell) or sponsored by government agencies (DoC, DoE, and DoD, EPA)
- Focus on recycling rather than incineration of plastic
- Sites visited: IBM, Applied Materials, DuPont (electronic materials), MBA polymers, Micro Metallics

Pb-free Solder - challenges

- Pb-free solders require higher temperatures
  - Need capacitors and resistors that can withstand increased temperatures
  - Need substrates that withstand increased temperatures
  - More energy intensive and lower yield (higher waste)
- Much more complex alloys
  - More difficult to maintain uniform composition
  - May be more difficult to recycle or disassemble to allow recycling of boards
- Unclear that Pb-free solders are actually more environmentally friendly
  - material extraction, increased processing difficulties, ease of recycling
- Best solution may be completely new attachment technologies (e.g., adhesive flip-chip)

Flame Retardants - challenges

- Elimination of brominated flame retardants is due to concern with dioxin formation upon incineration
  - Unclear whether this actually occurs
  - May occur only in older, lower temperature units
- Alternatives for thermoplastics exist (including choice of plastic)
  - Non-organic fillers may affect mechanical properties
  - Unclear that alternatives are more environmentally benign
- Currently no known alternatives for thermosets; may be solved by alternative PWB technologies