A Perspective

- OLEDs Yesterday
- OLEDs Today
- OLEDs Tomorrow
Milestones in OLEDs (1960-2000)

- **1963**
  - Pope et al. (NYU)
  - Organic EL in anthracene crystals

- **1977**
  - Heeger, MacDiarmid, Shirakawa (UCSB)
  - Conductive polymer

- **1983**
  - Partridge
  - National Physical Laboratory, UK
  - EL from polyvinylcarbazole

- **1987**
  - Tang & van Slyke Eastman Kodak
  - Fluorescent SMOLED

- **1990**
  - Burroughes, Friend et al. Cambridge University, (CDT)
  - Fluorescent Polymer OLED

- **1996**
  - UDC IPO (PANL)

- **1997**
  - Pioneer
  - 1st commercial OLED display: car audio display

- **1998**
  - Forrest & Thompson
  - Princeton/USC/UDC
  - Phosphorescent OLED

- **1999**
  - SK Displays
  - 2.4" full-color AMOLED

- **2000**
  - CDT\Epson
  - 2.8" IJP PLED

- **2000**
  - Pioneer
  - 5.2" full color
Samsung Electronics’ 40” AMOLED at SID05
TV Screens Get Smaller

- The New York Times: (February 15, 2005)
  - “Thanks to Cellphones TV Screens Get Smaller … You’ve got half the population going out and buying 60-inch television screens, and the other half is pulling down content onto smaller and smaller devices like phone and P.D.A.’s and iPods …”

- EETimes: (February 21, 2005)
  - “So many specs, such tiny screens … Mobile industry debates how to beam TV to handsets … The mobile-phone industry has given itself a deadline for bringing TV to handsets: June 9, 2006, in time for the World Cup in Germany.”
Portable Video– A Killer App Today?
Flexible Video—A Killer App Tomorrow?
Universal Display Corporation

- **Industry Pioneer** - Recognized as a leading OLED technology licensor and PHOLED material supplier
- **Strong Patent Portfolio** - Solid foundation in intellectual property and creative thinking with ~725 issued and pending patents worldwide
- **OLED Innovation** - World-class R&D team with more than 100 people including UDC researchers as well as those at Princeton University, USC and PPG Industries
- **Expanded state-of-the-art OLED facilities** - 40,000 s.f. headquarters with clean rooms for OLED development and prototyping, chemistry labs and analytical capabilities
- **Growing Market Opportunities** - Partnerships with world-class manufacturers for flat panel displays, lighting and future organic electronics
- **Solid Financial Position** - Strong cash position with growing revenue outlook
Key Technology Platforms

OLED Technologies
- PHOLED™ Phosphorescent OLEDs
- WOLED™ White OLEDs
- TOLED® Transparent and Top-emission OLEDs
- FOLED® Flexible OLEDs
- P²OLED™ Printable Phosphorescent OLEDs
- SOLED® Stacked OLEDs
- Encapsulation

Novel OLED Manufacturing Technologies
- OVPD™ Organic Vapor Phase Deposition
- Ink-Jet Printing
- Organic Vapor Jet Printing
- Stamping
Phosphorescent OLEDs (PHOLEDs) have up to 4 times the efficiency of traditional fluorescent OLEDs.

PHOLEDs provide reduced power consumption for portable, battery-powered devices.

PHOLEDs reduce display temperatures extending operational lifetimes.

PHOLEDs provide reduced power losses and heat dissipation issues for large-area displays.

PHOLEDs offer the potential to use existing low cost amorphous-Silicon (a-Si) backplane infrastructure in addition to emerging poly-Silicon (poly-Si) backplane technology.
OLEDS Today

- CRT TV quality that is thin and light weight
- High power efficiency with PHOLED
- Potential for low manufacturing cost
  - Simpler structure
  - Fewer process steps
  - Lower materials cost
Display Technology Comparison

- **Color gamut**
- **Lifetime**
- **Viewing angle**
- **Response time**
- **Form factor**
- **Power consumption**

**Display Technology Comparison**

- CRT
- PDP
- LCD
- OLED
TAIPEI (Dow Jones)--While many makers of flat-panel displays are focusing on the TV segment to drive future growth, some companies are betting on what industry players dub as the next-generation display for cellular phones and music players: active matrix light emitting diodes.
The Flexible Display Vision

• Information Display: (May 2005)
  – “The vision of the flexible flat panel display (FPD) entered popular consciousness in late 2002 when a prototype roll-up display from Universal Display Corp. was seen by millions on the CBS Evening News, in Time and Newsweek magazines, and elsewhere. The age of the flexible FPD is not yet upon us, but it is the subject of an extraordinarily energetic quest by many companies and institutions worldwide.”
Conformable and Flexible Displays

- Lightweight
- Thin
- Unbreakable
- Low cost processing potential, e.g. roll-to-roll
- New product possibilities
Universal Communication Device (UCD)

- Light weight, compact
- Advanced communication capability
Advances in FOLED™ Technology

- Plastic Substrates
AM-TOLED Display on Steel Foil

I. Steel foil substrate
II. Substrate planarization layer
IIIA. PS TFTs
IIIB. TFT passivation with vias for anode contact
IIIC. Anode
IIID. Grid
IV. OLED stack
V. Transparent cathode
VI. Encapsulation
VII. Drive electronics
Process Flow Overview

Poly-Si TFT backplanes are fabricated on 6”x6” steel foil substrates

Arrays undergo full color OLED deposition and first light up

Completed displays are encapsulated with a conformal, multilayer thin film encapsulation

Encapsulated displays are integrated with the drive electronics

Completed displays are test driven.
Why Metallic Substrates Today for AM-OLEDs

- High working temperature – compatible with LTPS TFT backplane process
- High dimensional stability
- No need for oxygen/water permeation barrier
- High thermal conductivity for heat dissipation during operation
- Rugged
Metallic Substrate FOLED™ Technology
Substrate Planarization

- Polyimide as planarization layer
  - Reduces roughness from 180nm RMS to 25nm RMS
  - Increases roughness length scale
  - Insulating barrier

Bare stainless steel

after planarization
Multi-Layer Thin Film Encapsulation

Barix™ Coating Technology

– Polymer film planarizes surface to reduce substrate defects
– Inorganic film provides barrier properties
– Organic film protects barrier layer from mechanical damage
– Multiple Barix layers yield an enhanced barrier by decoupling defects
Encapsulated TOLED Driven Lifetime

>5,000-h lifetime of TOLED pixel on steel foil is encouraging, demonstrates viability of approach.
High Precision Alignment FOLED Display System

- Manufactured by Tokki Corporation
Full Color Deposition Through Shadow Mask
Full Color QVGA AMOLED Demonstration

- 320x3x240
- 60 Hz refresh rate
- 64 grayscale levels
- Full color
- 100 dpi (85 um sub-pixel pitch)
- Top emission
- Multilayer thin film encapsulation
FOLED Continuous Process Flow

Barrier-coated, ITO-coated, plastic* roll stock

Unroll → Pretreatment & ITO patterning → Roll → Unroll → Substrate Pre-Patterning → Roll

Unroll → Unroll → Roll

Organic deposition → Metal deposition → Patterning → Encapsulation → Roll

Unroll → Singulation → FOLED → To Module Assembly
OLED Roadmap: Now and Into the Future

1997

Small Area
Multi-color/Monochrome
OLED Products

Full-color
Product
Prototypes

Small Area
Full-color
OLED Products

Large area
OLED TVs

Flexible OLEDs

Increasingly demanding product targets
Requires PHOLED Technology to Enable

Lighting
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