UniversalPHOLED® Technology and Materials

UniversalPHOLED Phosphorescent OLED technology and materials offer record-breaking performance to bring competitive advantages to your OLED display and lighting products. In commercial use since 2003, our patented technology and award-winning materials are especially critical for reducing power consumption, making them an essential choice for your 'eco-friendly' OLED display and lighting products.

Our Transparent Lighting Origami (TLO) combines a variety of UniversalPHOLED colors with our transparent TOLED technology.

ENERGY EFFICIENT TECHNOLOGY

:: Reduce needs for heat dissipation components

:: Extend battery life in mobile products

:: Save power and reduce heat generation in TVs

:: Key to your 'green' solution

UNIVERSALPHOLED MATERIAL SYSTEMS

:: Array of vibrant colors

:: Low-power, long lifetime

:: Up to 4x efficiency advantage over fluorescent OLEDs

:: Widely used in vacuum thermal evaporation systems

Color Is Universal™

Universal Display has developed a range of UniversalPHOLED material systems based on our proprietary materials and device structures. The following table highlights key attributes for a number of these systems.

PHOLED Performance (at 1000 cd/m²)	*1931 CIE Color Coordinates*	*Luminous Efficiency (cd/A)*	*Operating Lifetime (hrs)* *LT 95%*	*LT 50%*
DEEP RED	(0.69, 0.31)	17	14,000	250,000
RED	(0.66, 0.34)	24	25,000	600,000
RED	(0.64, 0.36)	30	50,000	900,000
GREEN-YELLOW	(0.46, 0.53)	72	70,000	1,400,000
GREEN	(0.34, 0.62)	78	18,000	400,000
LIGHT BLUE	(0.18, 0.42)	47	600	20,000

These results are for bottom-emitting structures (with no cavities). Lifetime data are based on accelerated current drive conditions at room temperature without any initial burn-in.

UniversalPHOLED technology and materials offer major power consumption savings. The following chart shows the savings possibilities.

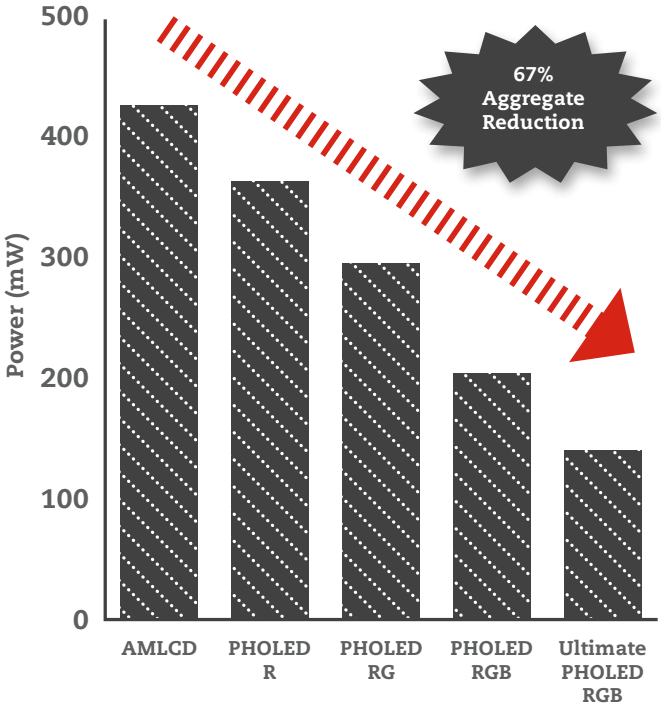
:: **RED:** Reduces power consumption by 15% (compared to AMLCD)

:: Add **GREEN:** 30% cumulative reduction

:: Add **BLUE:** 50% cumulative reduction

:: Further enhancement to an aggregate 67%

Based on 4.0" diagonal display, operating at 300 cd/m^2 with video rate (40% pixels on)



Designed To Meet Your Specific Application Needs

UniversalPHOLED technology and materials can be optimized to meet your custom display and lighting requirements. The following table illustrates examples using our material systems in top-emission structures that have been optimized for mobile applications. In addition, UniversalPHOLED material systems have been developed for TV and white lighting applications.

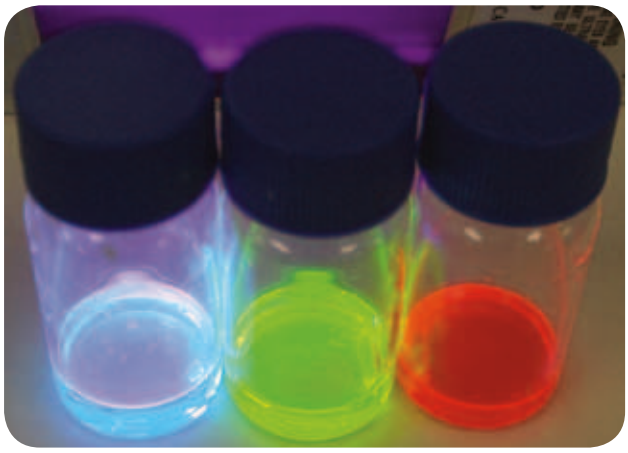
Top-Emission Structures Optimized for Mobile (at 1000 cd/m^2)	*1931 CIE Color Coordinates*	*Luminous Efficiency (cd/A)*	*Operating Lifetime (hrs) LT95%*
RED	(0.67, 0.33)	46	70,000
RED	(0.64, 0.36)	51	70,000
GREEN	(0.25, 0.71)	116	30,000

Our proprietary, patented materials are produced to exacting quality standards, and fully device-qualified using ISO 9001:2008 compliant quality management systems.

To learn more about our exciting new products, visit **www.universaldisplay.com**
or contact us at 609.671.0980 [p] 609.671.0995 [f]; 375 Phillips Boulevard, Ewing, NJ 08618

UniversalP²OLED™ Technology and Materials

UniversalP²OLED printable, phosphorescent OLED materials and technology are designed to combine the high efficiency of our UniversalPHOLED® technology and materials with the advantages of direct printing and coating processes. Solution-processing techniques have the potential to offer a low-cost route to large-area, full-color OLED displays and lighting panels.



Our UniversalP²OLED inks provide an excellent route to high efficiency performance by solution-processing means.

INNOVATIVE TECHNOLOGY SOLUTIONS

- Excellent power savings based on our UniversalPHOLED technology
- Potential low-cost manufacturing
- Key to your 'green' solution

UNIVERSALP²OLED MATERIAL SYSTEMS

- Efficiencies approaching performance of material systems for use in vacuum thermal evaporation
- Lifetimes rapidly improving
- Compatible with a variety of solution processing techniques

Rapid Progress in P²OLEDs

UniversalP²OLED technology and materials can play an important role in the development of high-performance, cost-effective, large-area displays and lighting panels made by solution processing techniques. Our UniversalP²OLED technology and materials continue to advance toward commercial targets.

The following table highlights key attributes for a number of these systems.

P²OLED Performance (at 1000 cd/m²)	*1931 CIE Color Coordinates*	*Luminous Efficiency (cd/A)*	*Voltage (V)*	*Operating Lifetime (hrs) LT50%*
RED	(0.66, 0.34)	18	4.8	126,000
GREEN	(0.32, 0.63)	68	4.2	176,000
LIGHT BLUE	(0.18, 0.42)	29	6.4	8,000

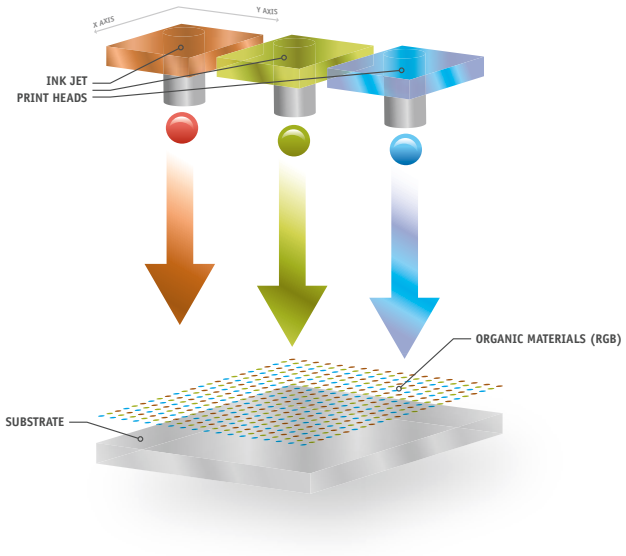
These results are for bottom-emitting structures (with no cavities). Lifetime data are based on accelerated current drive conditions at room temperature, without any initial burn-in.

Our UniversalP²OLED solution-processible material systems – red, green and light blue – have progressed significantly over the past seven years, as shown in the following charts. These advances have included luminous efficiency increases and operating voltage reductions – to effect the increases in power efficiency shown below. In addition, operating lifetimes have steadily improved to put commercial viability in sight.

Designed To Meet Your Specific Applications Needs

Ink-jet printing, screen printing and nozzle printing may lower the manufactured costs of high-resolution, full-color, large-area OLED displays and large-area lighting panels, especially if manufacturing formats evolve from batch to in-line or roll-to-roll. The challenge has been to adapt OLED materials to these printing techniques without compromising performance. With continued advances in our material systems, these differences continue to narrow.

Our UniversalP²OLED material systems can be adapted, through custom formulation, to work with a variety of solution-processible techniques and equipment designs. Our proprietary, patented materials are produced to exacting quality standards, and fully device-qualified using ISO 9001:2008 compliant quality management systems.



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UniversalWOLED™ Technology and Materials

UniversalWOLED technology, thanks to our breakthrough UniversalPHOLED® technology and materials, is paving the way for the next generation in solid-state white lighting. Combining the novel form factor – thin and even flexible – of a white OLED lighting panel with the energy efficiency of our phosphorescent and other proprietary OLED technologies, this new form of light is an ideal choice for specialty lighting applications today and general lighting uses in the future.

- Enabled by our high-efficiency UniversalPHOLED technology and materials
- Excellent diffuse lighting with uniform, high-quality light emission
- Significant energy savings and environmental advantages over incandescent bulbs and fluorescent tubes
- Novel form factor – ultra thin, rugged, and, even transparent and flexible
- Key to your 'green' solution

UNIVERSALWOLED MATERIAL SYSTEMS

- Over 100 lumens/Watt (lm/W) achieved at research scale
- Bright, uniform white colors ranging from warm white to cool white
- Color rendering indices (CRIs) of >80 typical, with CRIs of >90 demonstrated in the lab
- Long operating lifetimes

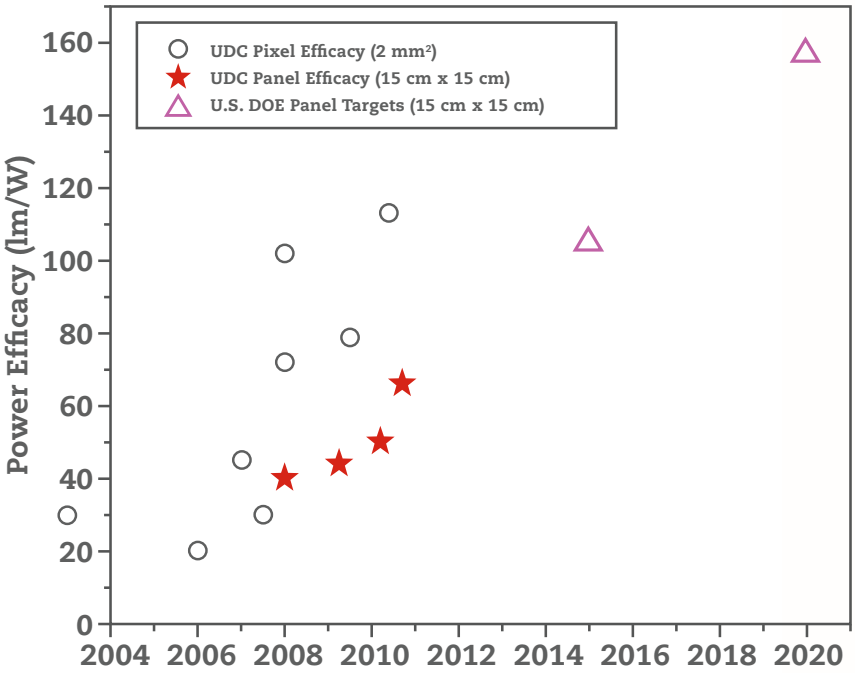
A New Form of Light

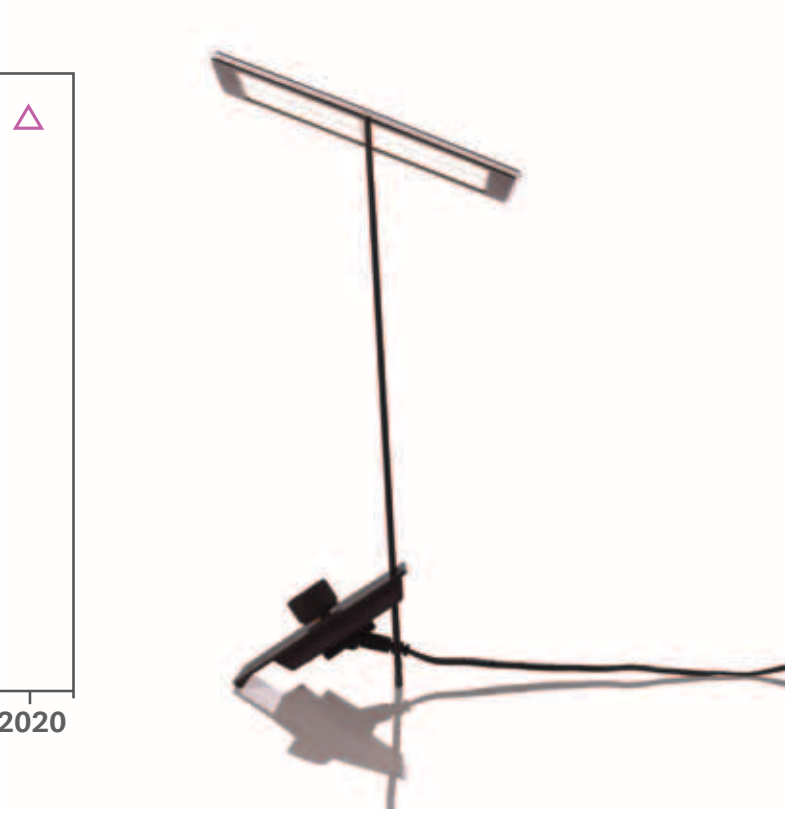
Technology developments at Universal Display continue to narrow the gap between small-area 'pixel' and 'panel' performance. Using the same warm white device structure that achieves 72 lm/W and 55k hours at the pixel scale, Panel 1 has been optimized to achieve 30k hours of operating lifetime and Panel 2 has been optimized to achieve a record 62 lm/W.

WOLED Performance (at 1000 cd/m²)	*Pixel*	*Panel 1*	*Panel 2*
AREA	2 mm²	15 cm x 15 cm	15 cm x 15 cm
POWER EFFICACY (lm/W)	72	58	62
CRI (Ra)	86	83	82
VOLTAGE (V)	3.8	3.8	3.8
1931 CIE COLOR COORDINATES	(0.475, 0.421)	(0.471, 0.413)	(0.446, 0.417)
CCT (K)	2580	2580	2950
EFFICACY ENHANCEMENT	2.12x	1.75x	1.70x
OPERATING LIFETIME (hrs), LT70%	55,000	30,000	18,000

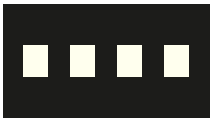
These results are for bottom-emitting structures and include optical outcoupling enhancement. Lifetime data are based on accelerated current drive conditions at room temperature.

Universal Display has steadily achieved new records in power efficacy, at the 'pixel' and the commercial-sized 'panel' scales. Funded in part by the U.S. Department of Energy, these advances now meet a variety of niche performance targets and move white OLEDs closer to general lighting targets set by U.S. DOE.

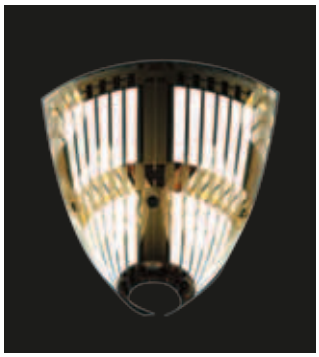




PIXEL (2 mm²)



PANEL (15 cm x 15 cm)



White PHOLED lighting panels. Their ultra-thin, and even flexible, form factor, create myriad design opportunities for use in a variety of novel ways.

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Universal **Encapsulation** Technology

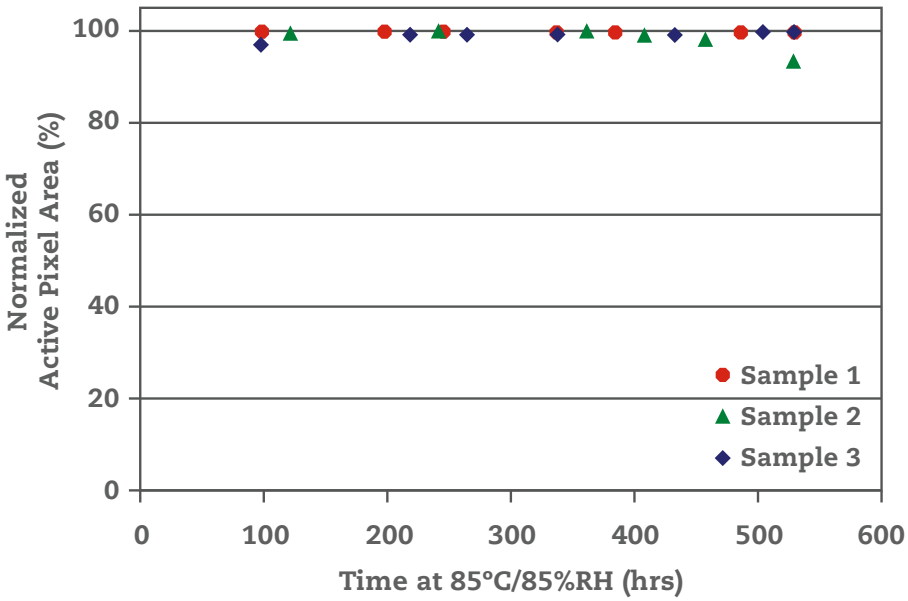
Universal Display has developed a novel, single-layer, encapsulation technology for the cost-effective packaging of thin-film devices and plastic substrate systems.

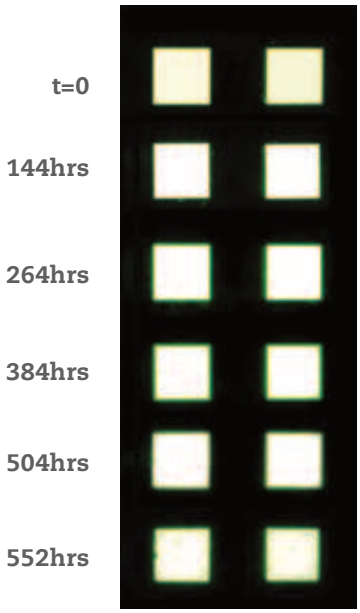
Flexible OLED, built-in collaboration with LG Display and L3 Display Systems, is on metallic foil using thin-film encapsulation.

- Effective permeation barrier with single, hybrid organic-inorganic layer
- Transparent and flexible film properties
- Cost-effective process and compatible with roll-to-roll processing
- Well suited for OLED, PV, battery and other thin-film devices

High-Performance, Single-layer, Barrier Film

Developed in collaboration with Princeton University, Universal Display's new proprietary, patented encapsulation technology has been shown to provide the barrier performance to meet the demanding requirements of OLED displays and lighting. As shown here, OLED exposed to conditions of 85°C and 85% relative humidity have demonstrated lifetimes exceeding 500 hours, a target typically set for commercial readiness.

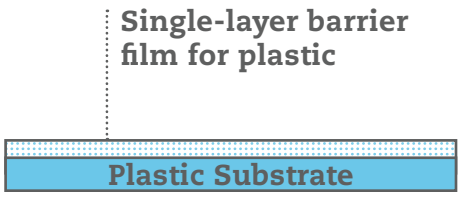




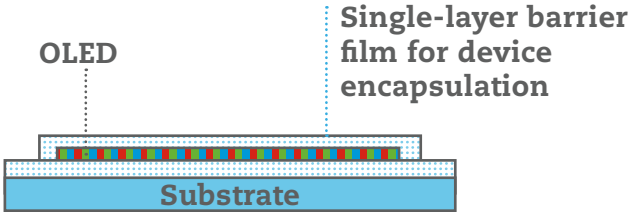
OLED pixels show no signs of degradation after 500 hours of exposure to 85°C and 85% relative humidity.

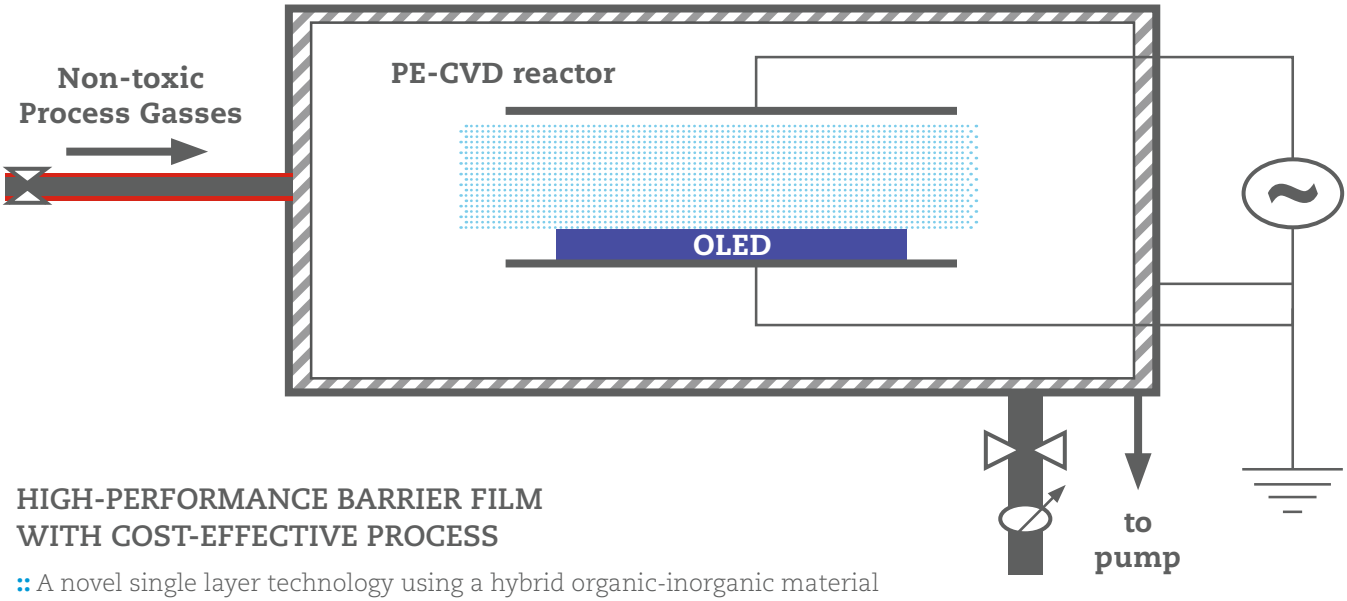
Thin-film environmental barriers are required for OLED displays and lighting as well as flexible solar cells and transistor backplanes. Our proprietary, patented encapsulation approach uses a single, hybrid layer that combines the impermeability of one component with the toughness of the second component to create a effective barrier structure. This barrier film offers excellent performance for application to both plastic substrates as well as directly onto OLED and other thin film devices.

[Plastic Substrate System]



[Thin Film Encapsulation]





HIGH-PERFORMANCE BARRIER FILM WITH COST-EFFECTIVE PROCESS

:: A novel single layer technology using a hybrid organic-inorganic material

:: Deposited by plasma-enhanced chemical vapor deposition (PECVD)

:: Inexpensive, non-toxic process gasses

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