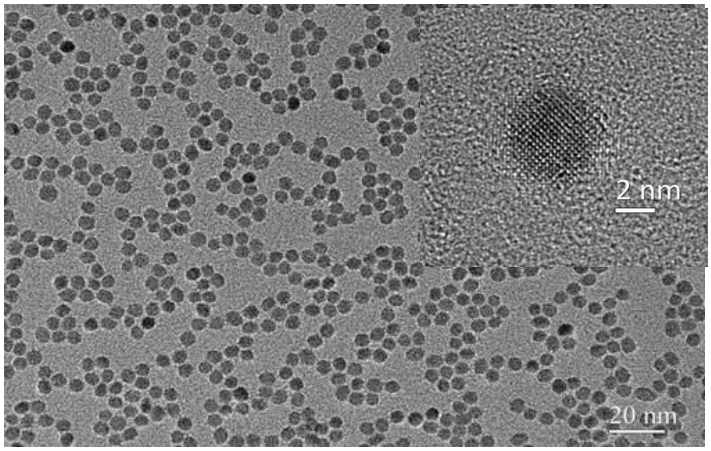
Application Notes: PixClear® for OLED Internal Light Extraction

Pixelligent offers an OLED starter kit for OLED customers. It includes two solvent dispersion samples PCOPA-50-PGA and PCOPM-50-PGA, and two UV curable polymer formulations PCOPM-2-47-BPA, and PCOPR-2-47-BPA. Zirconia nanocrystals significantly increase refractive indices up to 1.85 in many polymers used for OLED products and deliver many optical benefits, including high transparency (>95%) and low haze (<0.5%) in coatings. The materials are solution-processable, for simple manufacturing scale-up, and compatible with existing manufacturing processes.

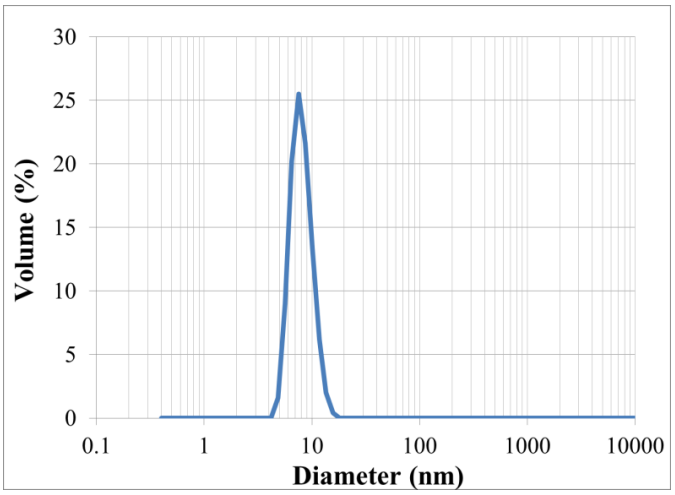
PCOPA-50-PGA and PCOPM-50-PGA are zirconia nanocrystal dispersions in solvent for OLED applications, available at 50 wt% in PGMEA. Each material has unique capping agents and slightly different chemical properties. Both materials are compatible with many polymers including acrylics, siloxanes, and epoxies. PCOPM-50-PGA is designed to crosslink with acrylics when cured.

Typical physical properties of solvent dispersions are listed as follows:

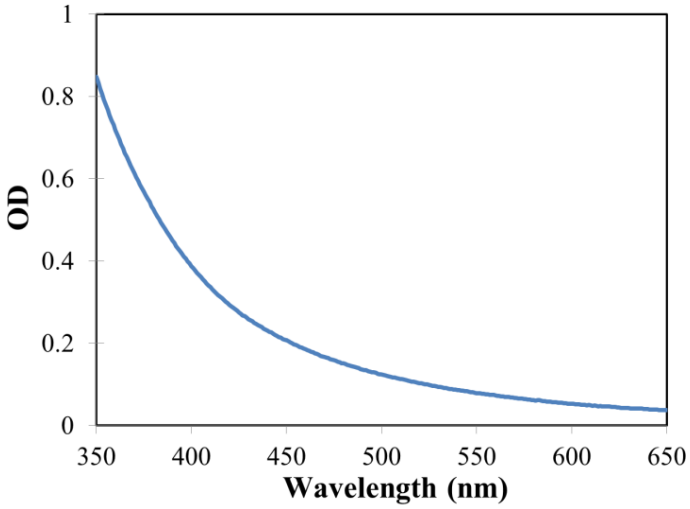
Particle Size: A typical TEM pattern shows spherical nanocrystals with 5 nm size and narrow size distribution.



Particle Size Distribution: The dispersions are aggregate free with 99.99% (by volume) of the zirconia contained in nanocrystals with a diameter < 30 nm as measured by Dynamic Light Scattering (DLS).



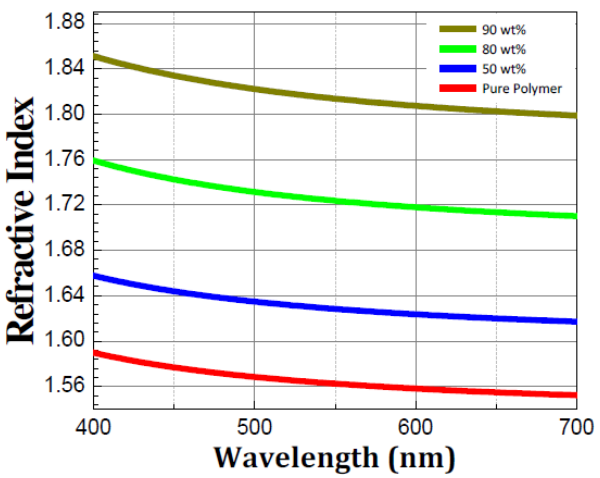
UV-Vis Spectrum: A typical UV-Vis spectrum of solvent dispersion shows low absorbance and scattering in the suspension through a 1 cm path length even at 50 wt% loading in a solvent.

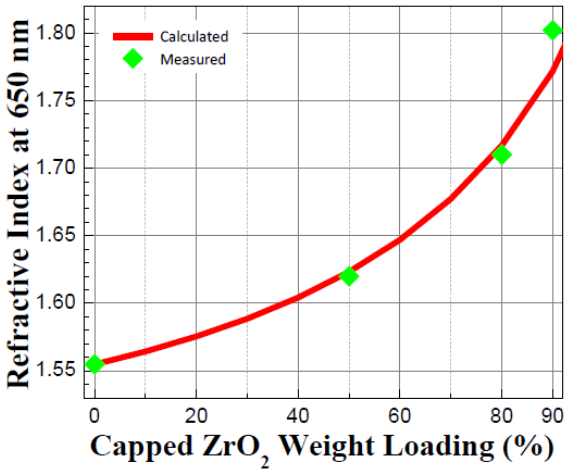


PCOPM-2-47-BPA and PCOPR-2-47-BPA are formulated products to be integrated as the Internal Light Extraction layer (ILE) in OLED lighting panels. With our ILE layers, the external quantum efficiency can be enhanced by as much as 200% compared to panels with no light extraction layer. The products can replace or complement the benefits of external light extraction layers, and are compatible with existing OLED manufacturing processes. Both PCOPM-2-47-BPA and PCOPR-2-47-BPA are zirconia nanocrystals dispersed into monomer Bisphenol A Diglycerolate Dimethacrylate which cross-links after the photo curing process. While PCOPM-2-47-BPA has higher refractive index, PCOPR-2-47-BPA has a better chemical resistance.

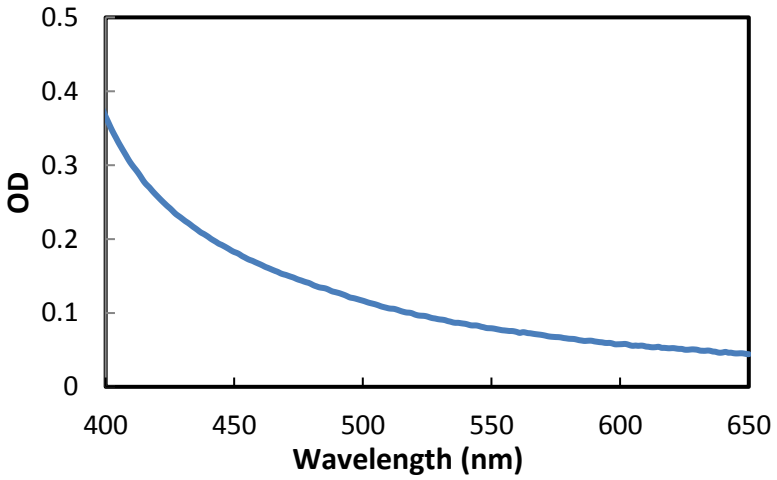
Typical physical properties of PCOPM-2-47-BPA are listed as follows:

Refractive Index: the refractive index reaches as high as 1.85 at 400 nm.

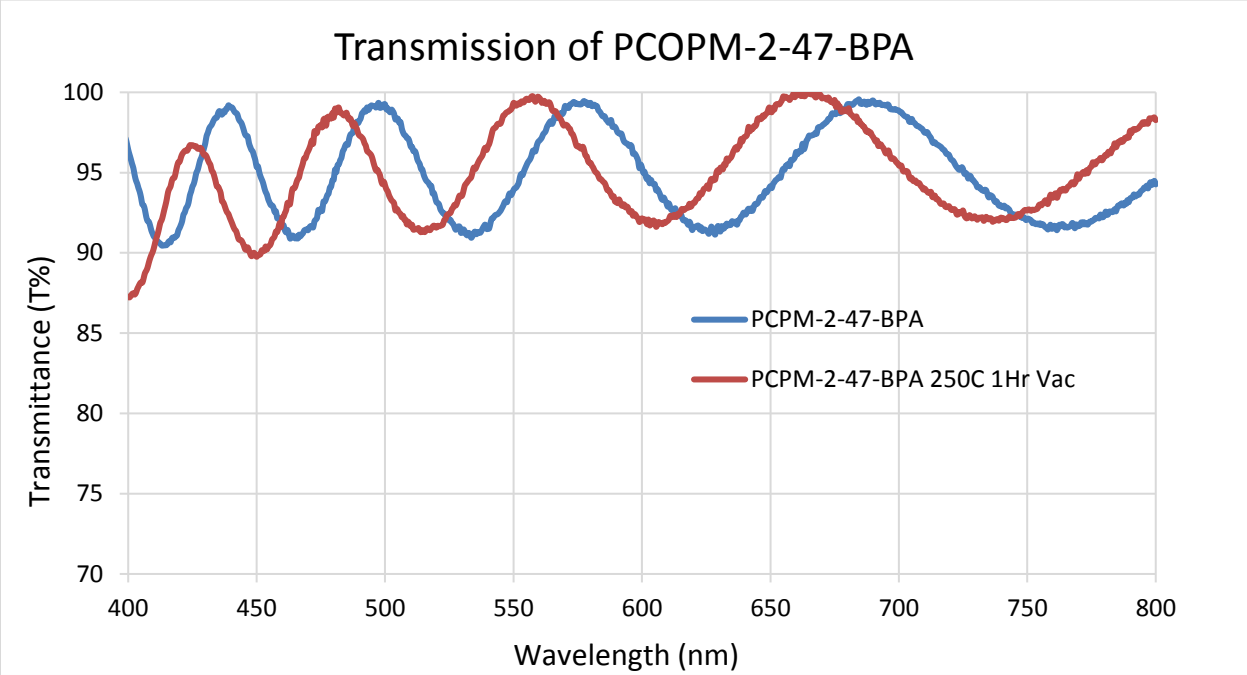




UV-Vis Spectrum: A typical UV-Vis spectrum of PCOPM-2-47-BPA shows low absorbance and scattering in the suspension through a 1 cm path length.



High Temperature Stability: the blue solid curve is the transmittance of the freshly made film while the red dot curve is the transmittance of the film after 1 hour 250 °C baking under vacuum. The consistency of percent transmittance demonstrates the high temperature stability of PCOPM-2-47-BPA formulation.



Film Properties: a 3 um spin-cast film shows high transparency, low haze, and high hardness.

Loading (%wt)	Transparency * (%T@650nm)	Haze* (%)	Pencil Hardness**	Water Contact Angle** (Deg.)
0%	97.9	0.6	6H	57.2
50%	98.3	0.4	8H	57.0
80%	98.3	0.5	8H	48.0
90%	96.3	0.4	6H	39.8

* Substrate is Fused Silica
** Substrate is Silicon

Chemical Resistance: the following table shows that PCOPM-2-47-BPA resists all the common wet-processes during OLED panel fabrication. Adhesion to glass substrate is tested by scotch tape with no cross-hatching and a green check mark indicates passing performance.

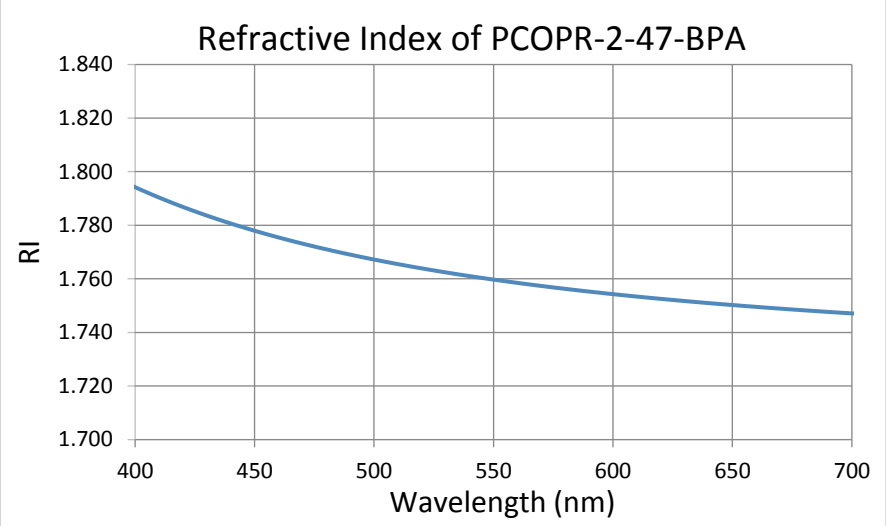
	HCl/H_2O (1:3) 5 min	HCl/H_2O (1:1) 5 min	KOH (0.5wt%) 5 min	KOH (1wt%) 5 min	KOH (5wt%) 5 min	Acetone/ Sonicate 5 min	IPA/ Sonicate 5 min	DI Water 5 min
PCOPM-2-47-BPA	√	×	×	×	×	√	√	√

Process Recipe for PCOPM-2-47-BPA Film Formation

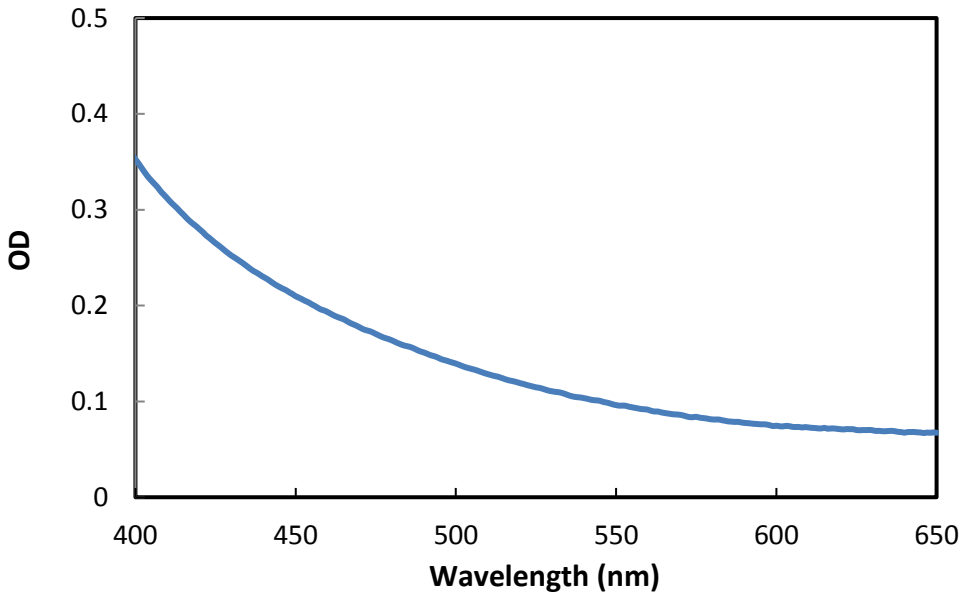
Nanocrystal	ZrO_2 – PM (90 wt% loading with respect to monomer)
Monomer	Bisphenol A Glycerolate Dimethacrylate
Solvent	PGMEA
Spin speed	4000 rpm for 60 sec
Pre-bake	100 °C for 1 to 2 minutes in air
Curing	60 to 120 sec using a Dymax EC-5000 system with a mercury "H" bulb (50 mW/cm^2). Results may vary with different UV curing systems
Post-bake	100 - 130 °C for 10 mins in air
Film thickness	~1 micron at 4000 rpm

Typical physical properties of PCOPR-2-47-BPA are listed as follows:

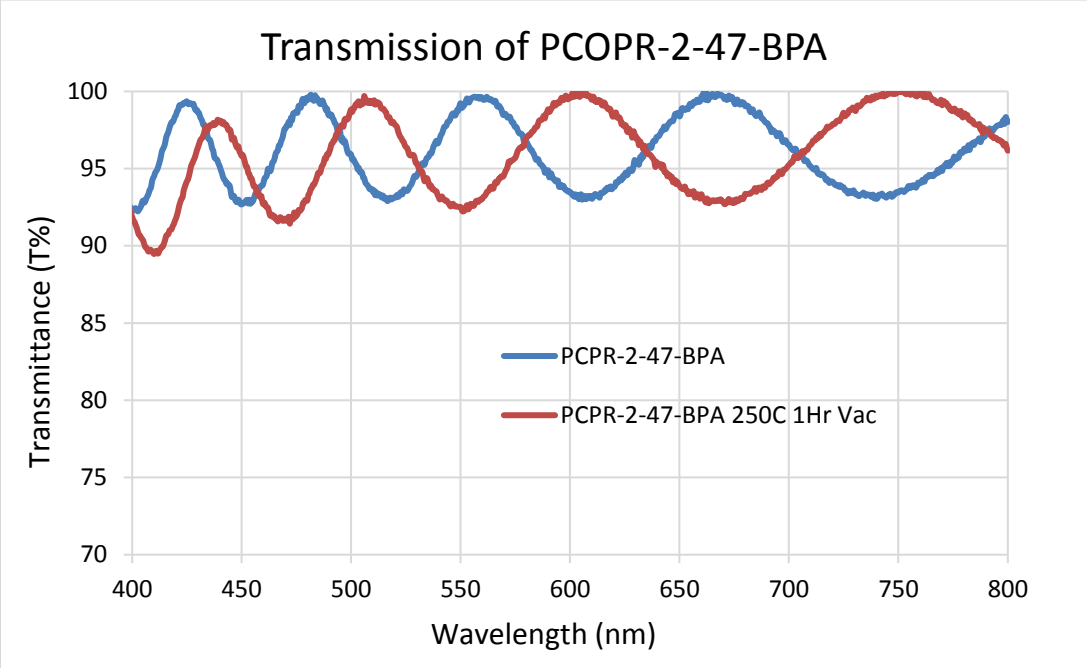
Refractive Index: the refractive index reaches as high as 1.77 at 450 nm.



UV-Vis Spectrum: A typical UV-Vis spectrum of PCOPR-2-47-BPA shows low absorbance and scattering in the suspension through a 1 cm path length.



High Temperature Stability: the blue solid curve is the transmittance of the freshly made film while the red dot curve is the transmittance of the film after 1 hour 250 °C baking under vacuum. The consistence transmittance demonstrates the high temperature stability of PCOPR-2-47-BPA.



Chemical Resistance: the following table shows that PCOPR-2-47-BPA resists all the common wet-processes during OLED panel fabrication. Adhesion to glass substrate is tested by scotch tape with no cross-hatching and a green check mark indicates passing performance.

	HCl/H_2O (1:3) 30 min	HCl/H_2O (1:1) 30 min	KOH (0.5wt%) 30 min	KOH (1wt%) 30 min	KOH (5wt%) 30 min	Acetone/ Sonicate 5 min	IPA/ Sonicate 5 min	DI Water 30 min	NMP 30 min
PCOPR-2-47-BPA	√	√	√	√	√	√	√	√	√

Process Recipe for PCOPR-2-47-BPA Film Formation

Nanocrystal	ZrO_2 – PR (90 wt% loading with respect to monomer)
Monomer	Bisphenol A Glycerolate Dimethacrylate
Solvent	PGMEA
Spin speed	4000 rpm for 60 sec
Pre-bake	100 °C for 1 to 2 min in air
Curing	60 to 120 sec using a Dymax EC-5000 system with a mercury "H" bulb (50 mW/cm^2). Results may vary with different UV curing systems.
Post-bake	100 to 130 °C for 10 mins in air
Film thickness	~1 micron at 4000 rpm

Spin Curve for PCOPR-2-47-BPA Film Formation