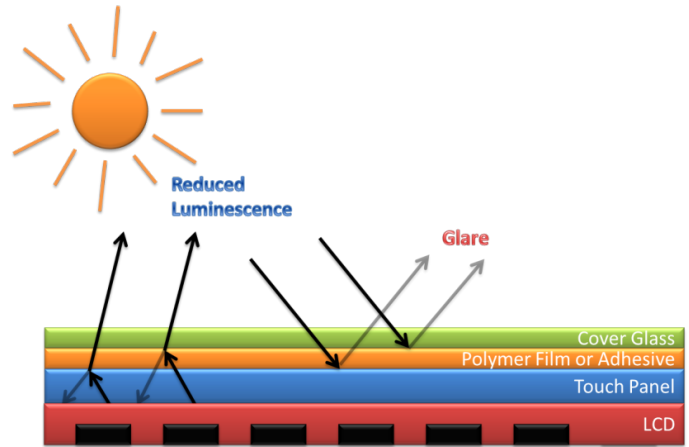


PixClear™

High Performance Nano-Zirconia Additives for Advanced Electronic Applications

PixClear™ nanocrystal dispersions are revolutionizing light management in display and lighting applications. Poorly matched materials in display devices can lead to glare, lower brightness, reduced luminescence and wasted energy and can even result in premature **device failure**. There has never been a greater need to match the refractive indices between polymer films and inorganic materials which can significantly **improve the light output** and readability of modern **touch screens and displays**. Additionally, when incorporated in solid state lighting applications, such as **LEDs and OLEDs**, index matching can significantly improve light output and device reliability. The addition of high refractive index PixClear™ nanocrystals to polymer systems achieves this goal cost effectively, without the need for special equipment or high temperature thermal cycles typically required with similar inorganic solutions.

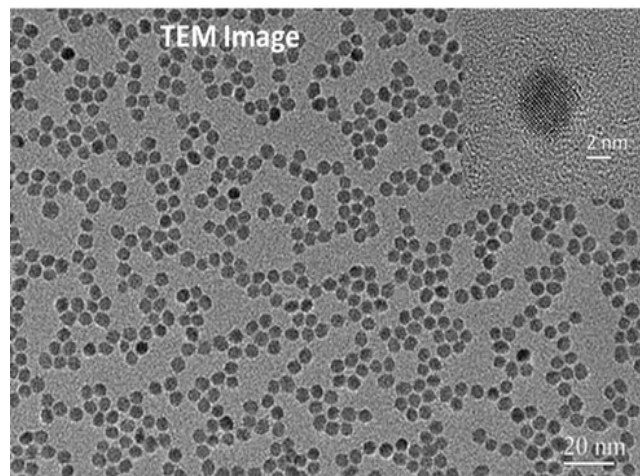
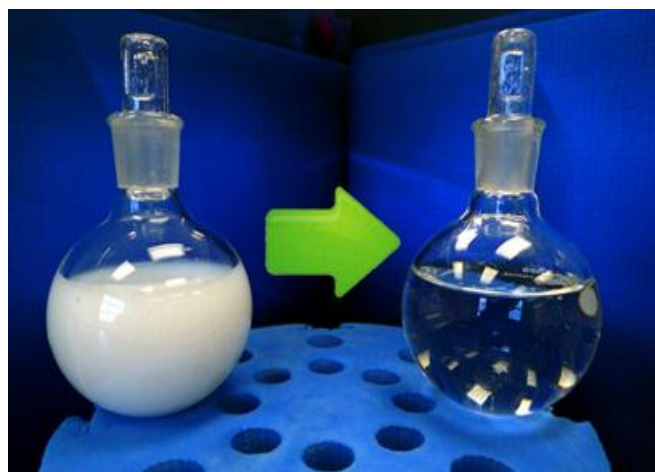


Typical Touch Screen

Applications	Properties	Advantages
<ul style="list-style-type: none"> ITO Hiding Layer for Touch Screen LED & OLED Light Extraction CMOS Image Sensor Lenses and Packaging Hard Coatings with Index Matching Wafer Level Opto Assemblies 	<ul style="list-style-type: none"> Tunable Nanocrystal Size from 3 nm to 7 nm with Narrow Size Distribution Highly Crystalline Well Passivated Surface Aggregate Free Suspensions Compatible with Various Solvents, and Polymers High Specific Surface Area High Bulk Hardness 	<ul style="list-style-type: none"> High Refractive Index Highly Transparent at the Visible Wavelengths Low Haze Coatings Even at High Nanocrystal Loading Improved Scratch Resistance and Hardness Improved Anti-Corrosion Improved Chemical Resistance

PixClear™

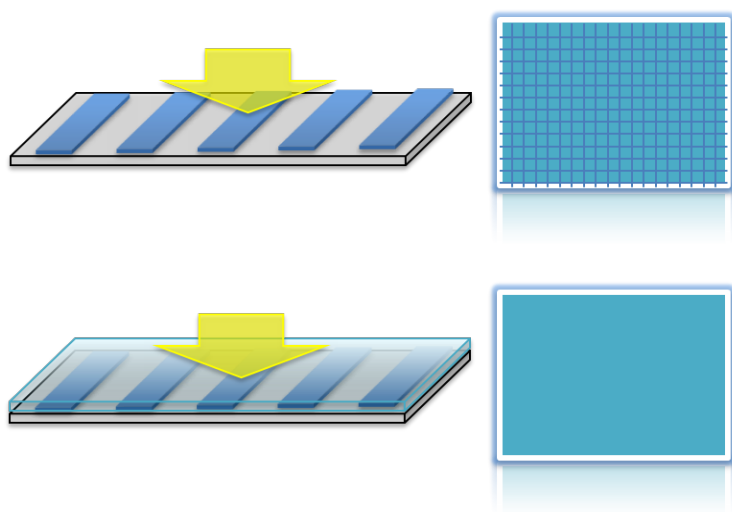
Challenge: Typical nanocrystals are poorly dispersed and highly agglomerated, which translates into poor performance when incorporated into a polymer matrix. Many have shelf lives measured in days versus months and have high viscosities that inhibit processibility and cannot be used in standard manufacturing process equipment.



Standard dispersed vs PixClear™ dispersed nanocrystals

TEM Image of PixClear™

Typical Nanocrystals	Pixelligent PixClear™ Nanocrystals
<ul style="list-style-type: none"> • Poor dispersion (cloudy) • Significant increase in viscosity • Poor transparency • Limited loading capability • Limited options on suspension media 	<ul style="list-style-type: none"> ✓ Well dispersed high transparency suspensions ✓ Little change in viscosity even at high loadings ✓ >3 month self-life with high transparency ✓ Capability to load nanocrystals > 80 wt% ✓ Compatibility with large selection of monomers and polymer



ITO hiding without (top) and with (bottom) index matching conformal coating

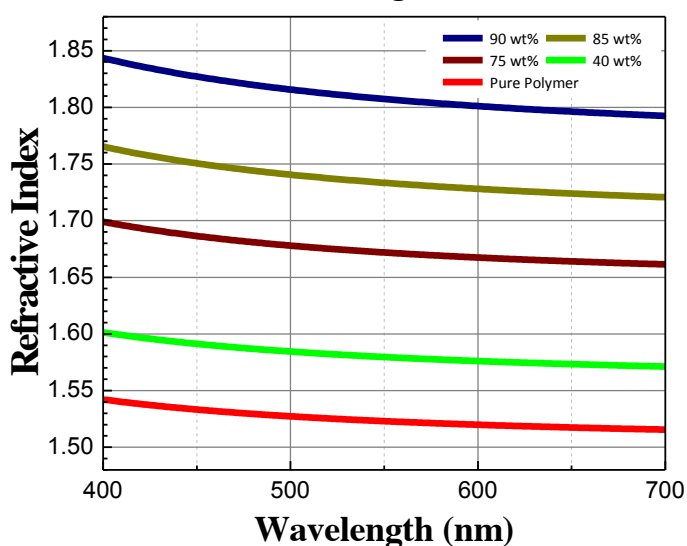
Solution: Pixelligent PixClear™ zirconia nanocrystals are **tailored to be dispersible** in a wide variety of monomers, and polymers. Pixelligent's **patent pending** synthesis and surface modification technologies produce **high quality** dispersions that are easily incorporated into many of the most widely used polymer systems. This results in **better** end-product **performance** and enables formulations with nanocrystal loading in excess of 80 wt% to reach a **refractive index** as high as **1.85**. This added benefit translates into greater flexibility to **index match** dissimilar materials, and compatibility with modern high-speed polymer **film forming techniques**.

High Refractive Index Coatings for Electronic Applications

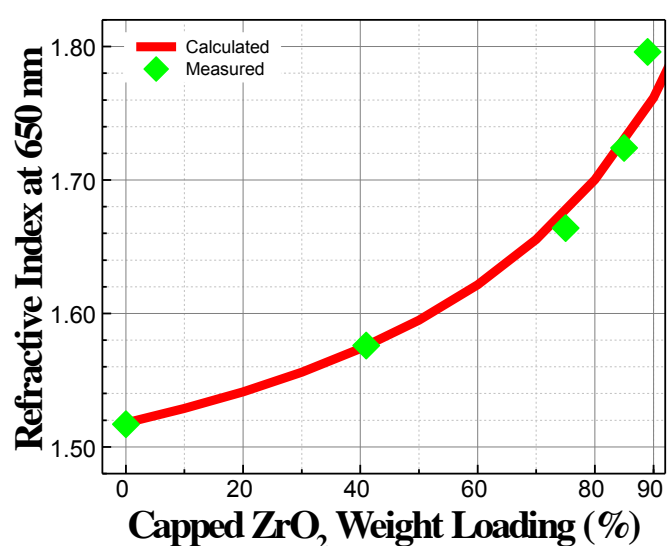
PixClear™-PM is a ZrO₂ nanocrystal dispersion that is available in 50wt% dispersion in Propylene Glycol Monomethyl Ether Acetate (PGMEA). This dispersion is highly stable (shelf life > 3 months) and can be mixed with various polymers including acrylates. It is functionalized to improve dispersion in acrylic monomers and polymers and to crosslink when cured.

Typical properties of a photo-developable acrylic polymer formulation with PixClear™-PM

Refractive Index as high as 1.84 at 400nm



Measured vs. Calculated Refractive Index



Please use our **Refractive Index Calculators** to calculate the Refractive Index of a nanocomposite at a given loading of nanocrystals **and Nanocrystal Loading Calculator** to calculate the loading of nanocrystals required in a polymer to achieve a desired Refractive Index.

Typical Properties for a 3 μm Spin-cast Film

Loading (%wt)	Transparency* (%T@650nm)	Haze* (%)	Pencil Hardness**	Water Contact Angle** (Deg.)
0%	99.2	0.4	6H	55.9
50%	97.9	0.5	6H	56.5
80%	96.8	0.5	6H	58.1
90%	97.3	0.5	6H	51.5

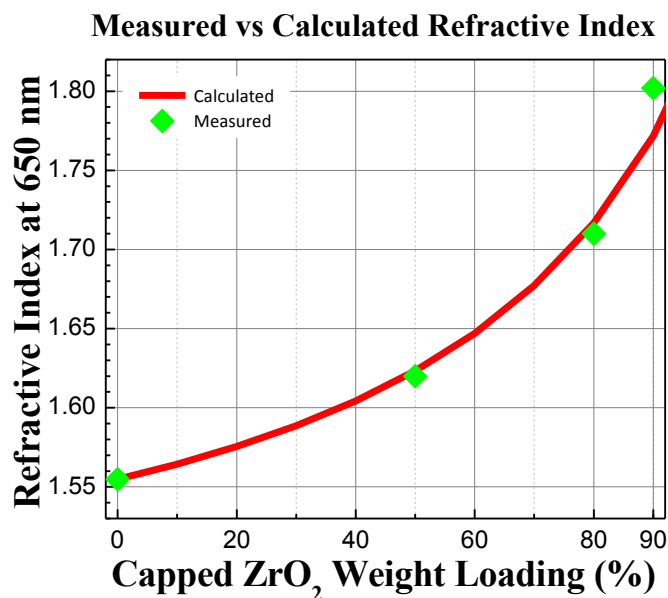
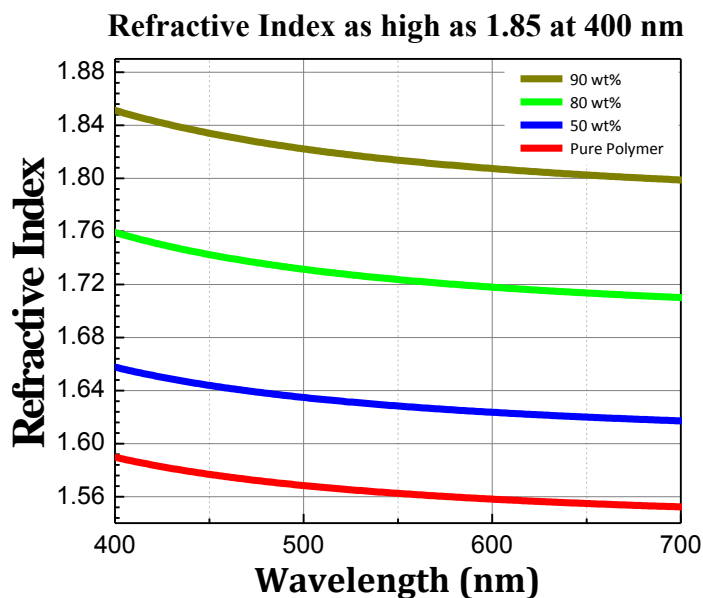
* Substrate is Fused Silica

** Substrate is Silicon

Process Recipe for Obtaining Acrylate Nanocomposite Film By Spin Coating:

Nanocrystals:	PixClear™-PM 50wt% in PGMEA
Base Resin:	Sartomer Sarbox SB500E50 acrylic resin
Photo initiator:	Cytec EBecryl P-39 (4 wt% of base resin)
Photo sensitizer:	EBecryl P-115 (8 wt% of base resin)
Resin Solvent:	PGMEA
Spin Speed:	3000 rpm for 60 sec
Pre-bake:	110 C for 90 sec
Curing:	60 sec using a Dymax EC-5000 system with a mercury “H” bulb
Post Bake:	120 C for 30 min
Thickness range:	~ 3 μm
Substrate:	Silicon or Fused Silica

Typical properties of a high temperature stable acrylic polymer formulation with PixClear™-PM



Typical Properties for a 3 μm Spin-cast Film

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

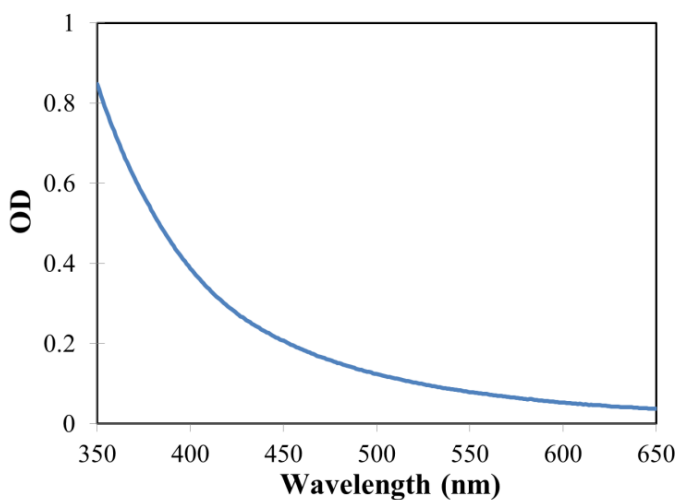
Process Recipe For Obtaining Bis-Phenol A Nanocomposite film by spin coating:

Nanocrystals:	PixClear™-PM 50wt% in PGMEA
Base Resin:	Bisphenol A diglycerolate dimethacrylate
Photo initiator:	Cytec EBecryl P-39 (3 wt% of base resin)
Photo sensitizer:	EBecryl P-115 (6 wt% of base resin)
Resin Solvent:	PGMEA
Spin Speed:	3000 rpm for 60 sec
Pre-bake:	100 C for 60 sec
Curing:	100 sec using a Dymax EC-5000 system with a mercury “H” bulb
Post Bake:	100 C for 3 min
Thickness range:	~ 3 μm
Substrate:	Silicon or Fused Silica

PixClear™ Typical Physical Properties

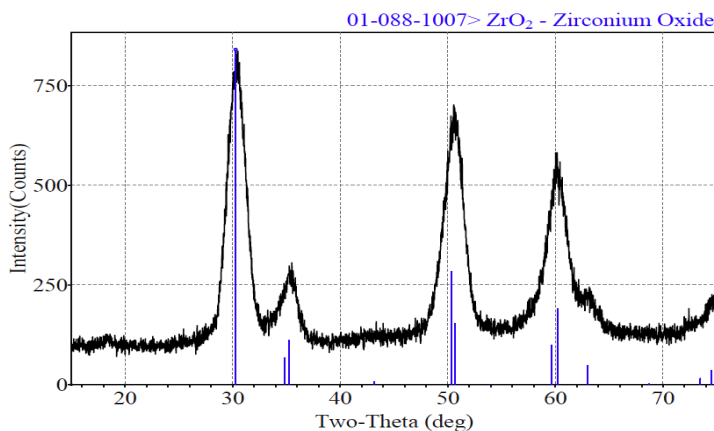
UV-Vis Spectrum

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



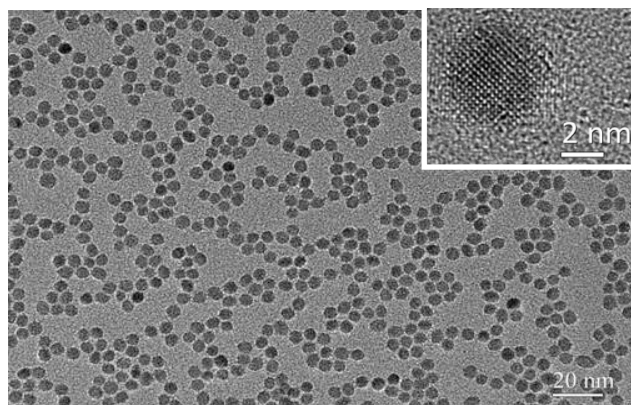
XRD Pattern

A typical XRD pattern shows highly crystalline particles.



Particle Size

A typical TEM image of PixClear™ 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).

