Introduction to Pixelligent Technologies

2024 Phabuloμs Micro-Optics Summit & Expo, Dec 2, 2024

Alex Everett– Account Manager

Pixelligent at a Glance

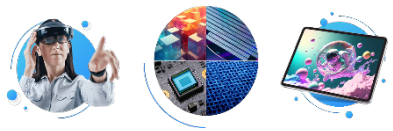
Pixelligent is a leading manufacturer of market-leading nanocomposites for multiple fast-growing applications

What We Do

- We synthesize and cap small metal-oxide nanocrystals
- We make custom formulations for various applications

Why We Do it

- To create unparalleled optical properties that enable superior light management in devices



How We Do it

- Award-winning development & manufacturing platform
- Leverage AI to accelerate product development

Who We Do it for

- Leading consumer electronics companies across the globe

What Are Our Core Markets

Extended Reality ("XR"): AR / MR

- **PixNIL®** enables the widest field of view in XR devices
- Refractive Index 1.7 - 2.0
- Solvent containing
- Nanoimprint Lithography (NIL)

Optics / Sensors

- **PixClear®** improves light capture & focusing power on sensors & optics
- Refractive Index 1.65 - 1.9
- Solvent-free formulations
- Microimprintable

Displays

- **PixJet®** significantly increases brightness in displays & extends battery life
- SFZ5 is designed for OLED outcoupling

Award Winning Manufacturing

Scalable, High Yield, Efficient and High-Quality Manufacturing

- **In-Place High Volume Capacity:** Current manufacturing facility provides foundation to support near-term demand and growth.
- **Raw Materials:** Readily available from multiple global sources.
- **Equipment:** Standard equipment and processes in custom configurations. Equipment parts are available from multiple suppliers.
- **Process:** Uses standard proven wet chemistry processes.
- **Technology:** Proprietary, scalable, repeatable and robust.
- **Environmental Compliance:** Fully TSCA and REACH compliant in all required countries.
- **Quality Management:** ISO9001 Certified.
- **Award Winning:** Named Manufacturer of the Year by Frost & Sullivan in 2017.

Facilities Overview

Location:	Headquarters, Manufacturing Facility in Baltimore, MD.
Square Feet:	18,000 square feet of chemical manufacturing and lab space.
Current Capacity:	• **PixClear® Zirconia:** 10 metric tons / year • **PixClear® Titania:** 15 metric tons / year • **PixClear® Formulations:** 20 metric tons / year
Standby Capacity:	80 metric tons of PixClear® Zirconia/Titania

10 Ton Synthesis Reactor

Capping Reactor

80 Ton Synthesis Reactor

Pixelligent Evolution

Pixelligent 1.0

Develop and scale synthesis & capping of NPs < 20nm at multi-ton scale

Pixelligent 2.0

Extend the PixClearProcess® to 3 metal oxide platforms, PixClear HfO_2, ZrO_2, and TiO_2

Pixelligent 3.0

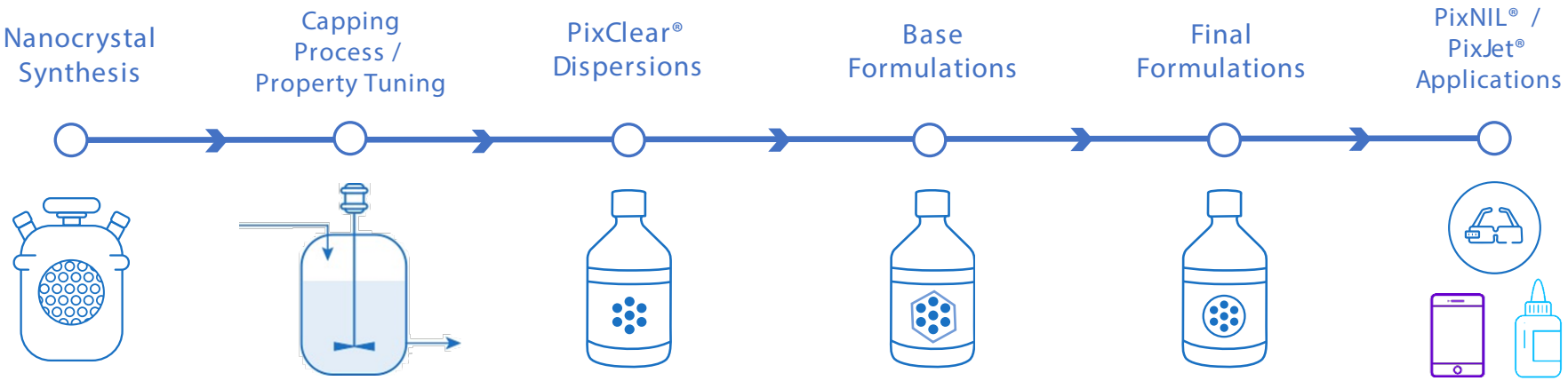
Introduce formulated products for the display, XR, and Optics markets – PixJet® , PixNIL® , PixCor™

Pixelligent 4.0

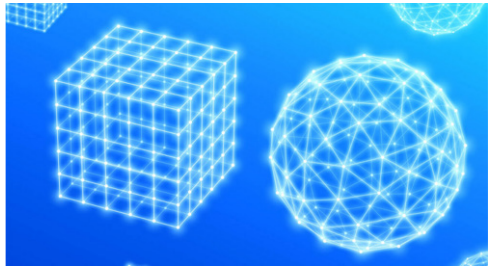
Implementing AI platform to accelerate introduction of 15-20 new PixClear® metal oxides across Display, XR, Optics, Semiconductor, and Energy storage markets.

The PixClearProcess®

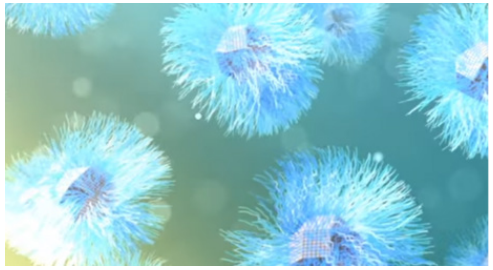
The Proprietary PixClearProcess® Development and Manufacturing Platform



NANOCRYSTALS



DISPERSIONS



PIXNIL APPLICATION

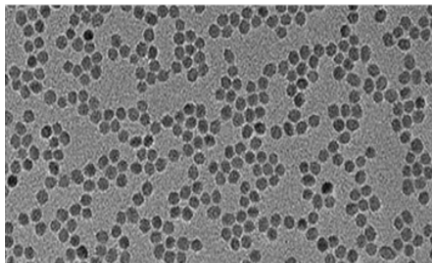
25 Additional Metal Oxide materials in the Pipeline that will leverage the PixClearProcess® Platform → Barium Titanate next.

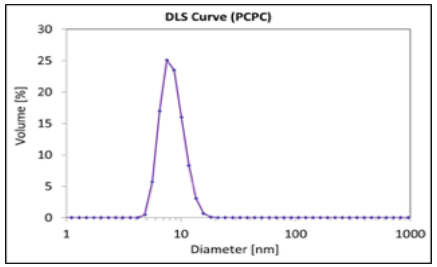
Highest Quality Nanocrystals

Nanocrystal Synthesis → Capping Process / Property Tuning → PixClear® Titania & Zirconia Dispersions → Base Formulations → Final Formulations → PixNIL®/PixJet® Applications

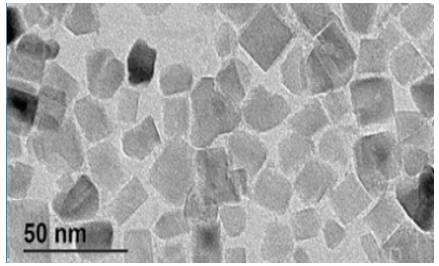
The PixClearProcess® is a proprietary synthesis and capping process for uniform and controlled particle sizes:

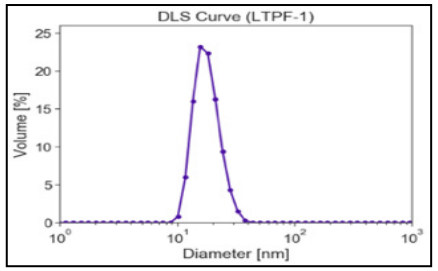
- ✓ Core Particle size to 3nm – 15nm; 5nm -20nm capped (TEM)
- ✓ Film RI: 1.7 – 2.0+ at 589 nm
- ✓ > 95%+ transparencies in the visible light range
- ✓ Organic/ Inorganic capping agents; polar/ non-polar solvents (move to capping agent slide)
- ✓ Monodisperse with 99.99% of particle diameter < 30nm for ZrO2 and < 70 nm for TiO2 dispersions



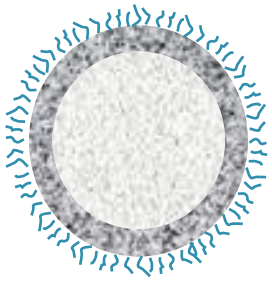


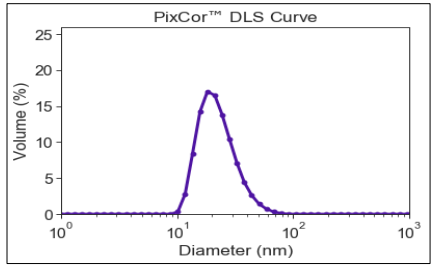
Zirconia (10 nm)





Large Titania (20 nm)





PixCor™ (20 nm)

Nanocrystal Surface Modification

Nanocrystal Synthesis → Capping Process / Property Tuning → PixClear® Titania & Zirconia Dispersions → Base Formulations → Final Formulations → PixNIL®/PixJet® Applications

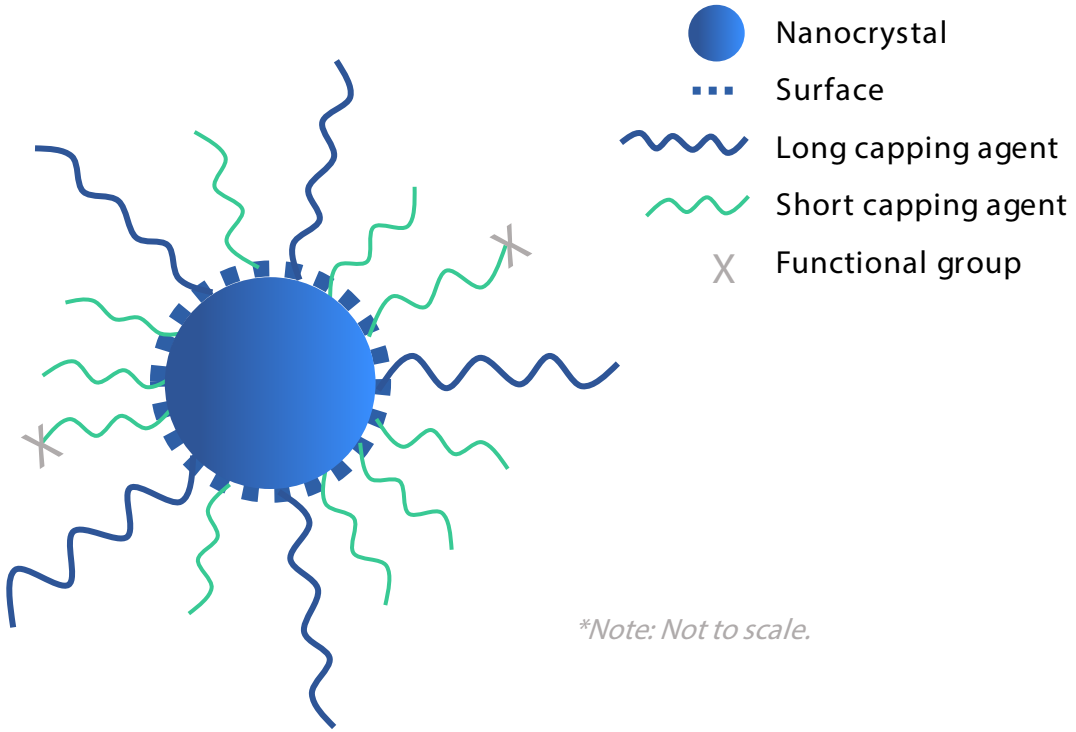
Capping agents
- Improve dispersibility
- Enables compatibility
- Reduces surface effects

Long capping agent
- Low/ loose packed surface coverage

Short capping agent
- High/ dense packed surface coverage

Functional capping agents
- Crosslink into polymer
- Acrylates and others

Multiple capping agents
- Can control ratio of capping agent to crosslinker density - depending on final property requirements



*Note: Not to scale.

PixJet & PixNIL High RI Formulations

Nanocrystal Synthesis → Capping Process / Property Tuning → PixClear® Titania & Zirconia Dispersions → Base Formulations → **Final Formulations** → PixNIL® / PixJet® Applications

- Curable liquid with capped nanocrystals + polymer/ monomer + additives
- Achieves a high level of performance:

✓ *High RI*
✓ *High level of reliability*
✓ *Low shrinkage*
✓ *Low dose UV curing – Air Curing*
✓ *Smooth surface*
✓ *Low particle defects*
✓ *No pin hole*
✓ *Clear light-path*

- Solvent-free or solvent-containing
- Compatible with commonly used deposition and manufacturing methods:

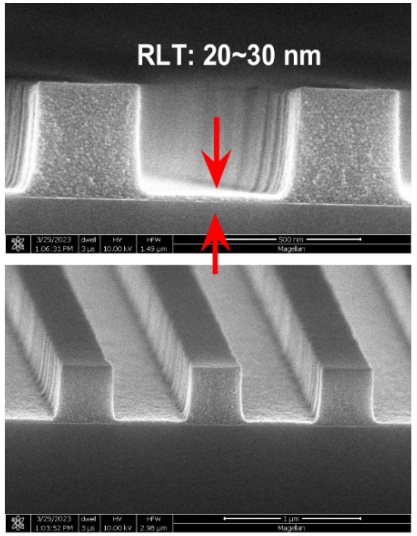
✓ *Inkjet printing*
✓ *Nano Imprint lithography*
✓ *Inkjet/nanoimprint**
✓ *Spin-coat*
✓ *Dispense*
✓ *Spray coating*
✓ *Slot die coating*
✓ *Screen printing*

PixNIL® Solvent Containing Product Offerings

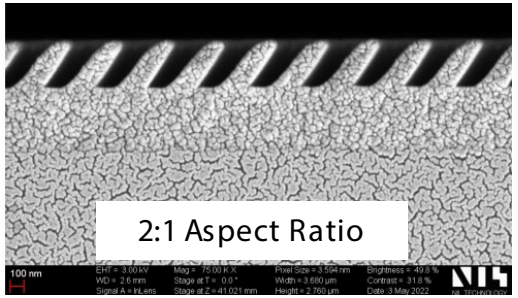
Nanocrystal Synthesis → Capping Process / Property Tuning → PixClear® Titania & Zirconia Dispersions → Base Formulations → **Final Formulations** → PixNIL® / PixJet® Applications

Product	Core	Solvent	Viscosity (cP)	RI (589 nm)
PixNIL® SZ1	Zirconia	Yes	4	1.7
PixNIL® SCS1	PixCor	Yes	4	1.86
PixNIL® ST13	Titania	Yes	4	1.86
PixNIL® ST2	Titania	Yes	4	1.9
PixNIL® ST5	Titania	Yes	4	1.98

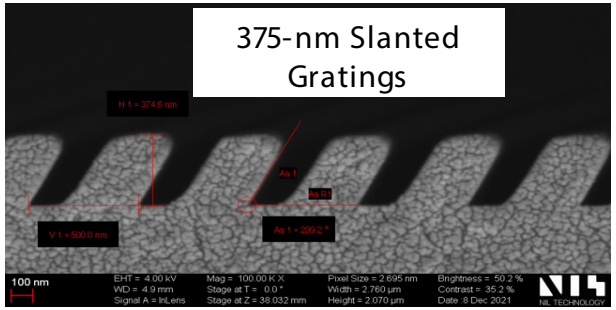
✓ **PixNIL® ST2A** can achieve **<50 nm Residual Layer Thicknesses**



1.9 RI ST6

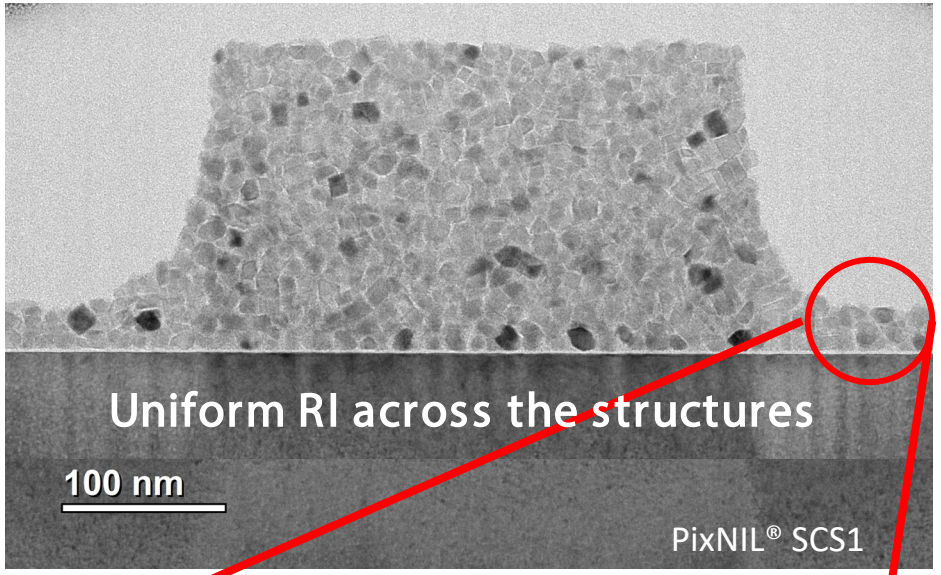


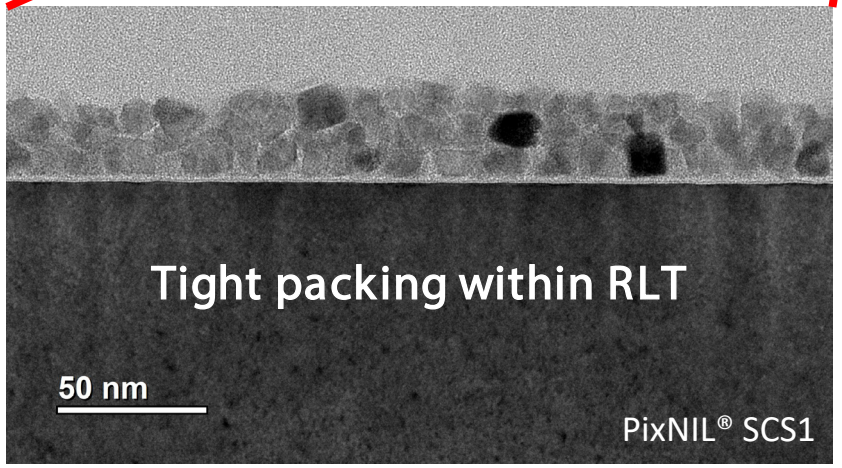
2.0 RI ST5



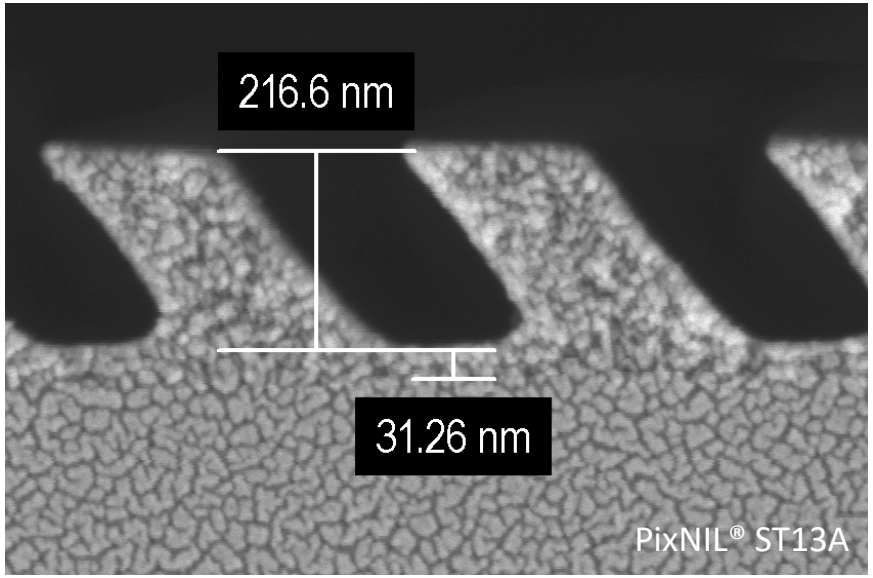
Courtesy of NIL Tech

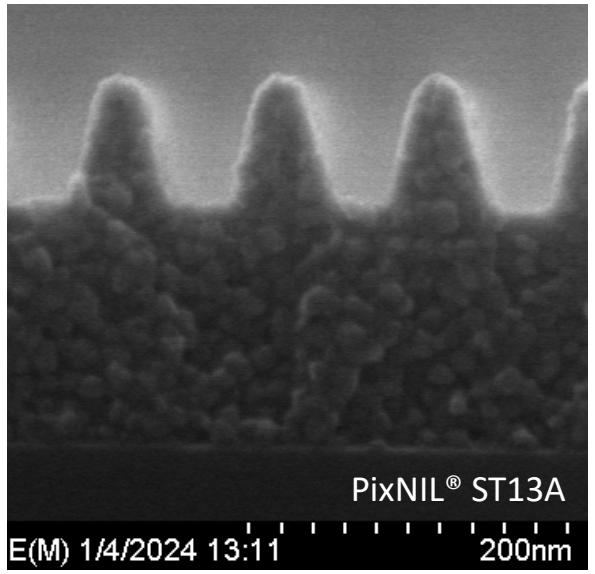
Well-Distributed Nanoparticles in PixNIL® Nanoimprints





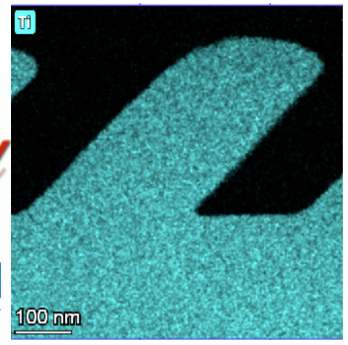
TEM images

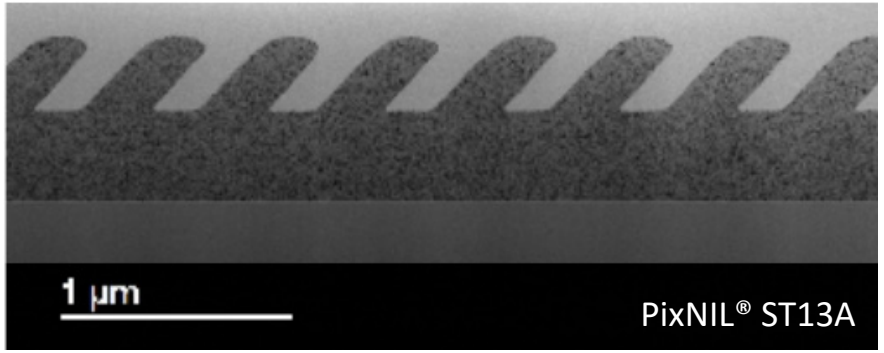




EVG 6200 NT SmartNIL UV NIL System

SMILE - Mask Aligner 8
Gen 5 - Imprint Tool



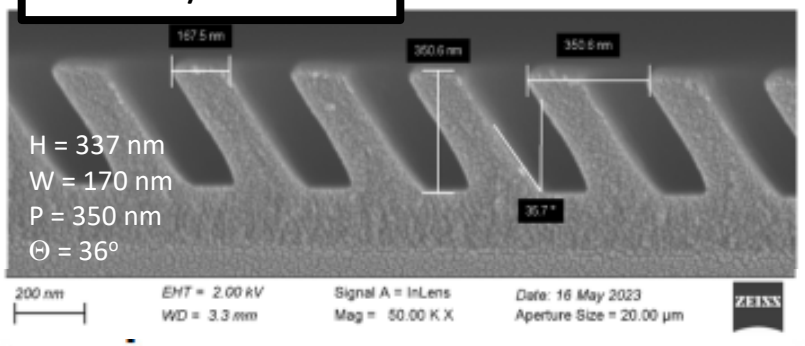


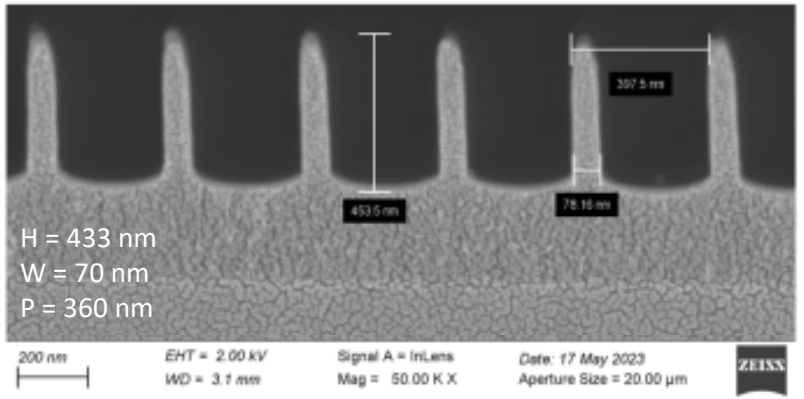
Nanoimprinting

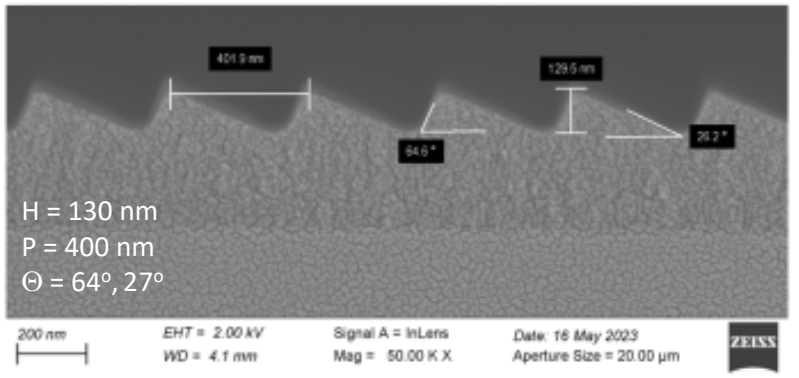
- Side-by-side comparison of EVG UV/ A2 1.5RI imprint resin and PixNIL® SCS1

- <u>Highlights:</u>
  - Versatility of structures
  - Ability to fill small structures
  - Sharp edges (positive for NPs)
  - Use of AS5 (PFOS-free) stamp

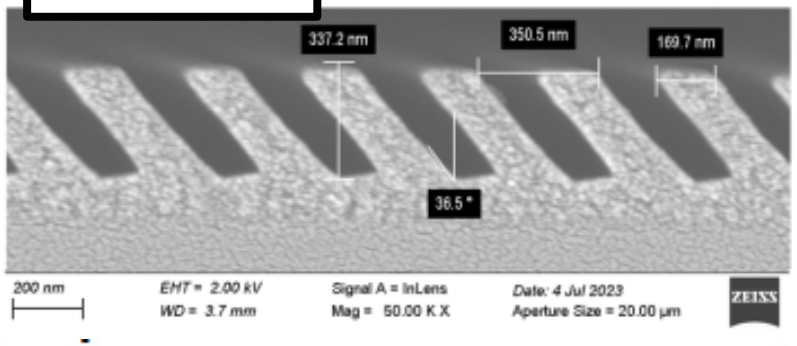
EVG UV/A2 1.5 RI

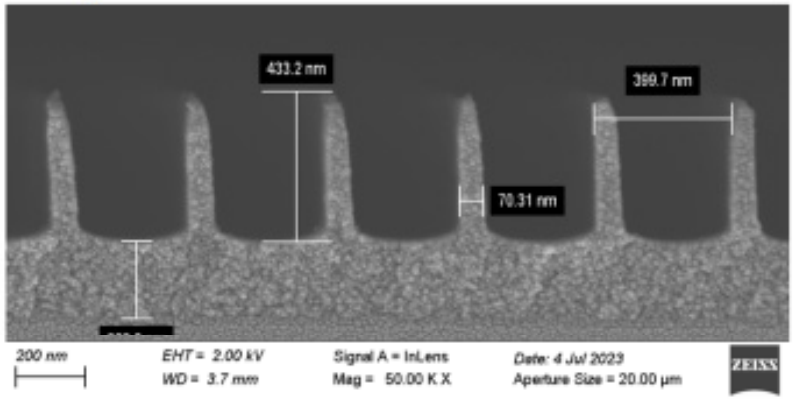


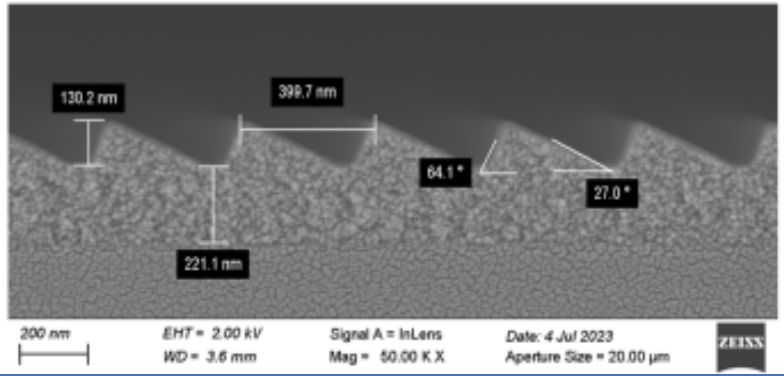




PixNIL® SCS1







Courtesy of EV Group

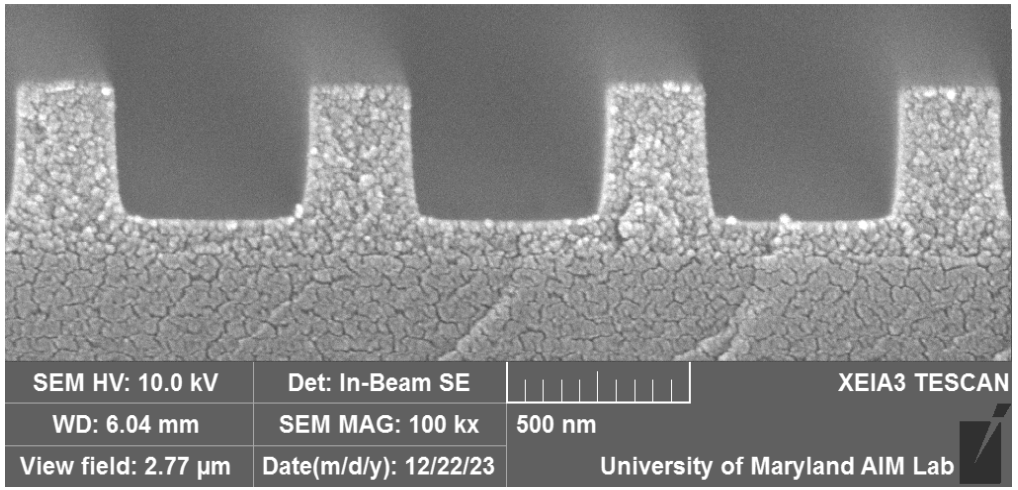
Improved Process Window

Spin Coat → **Soft bake** → Imprint & UV cure

ST2A – Imprinting Process Window at 250 nm FT			
Temperature (°C)	Time (min)		
	1	2	3
50			
70			
80			
90			
100			

ST13A – Imprinting Process Window at 250 nm FT			
Temperature (°C)	Time (min)		
	1	2	3
50			
70			
80			
90			
100			

Imprinted with EVG AS5 stamp: binary line grating structures with ~390 nm height (green-pattern transfer success, red-pattern transfer failure)

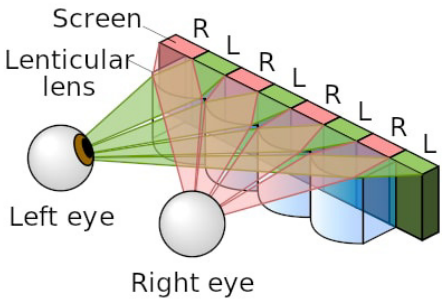


ST13A imprinted at 250 nm film thickness after an 80° C/ 1min soft-bake; binary line grating structures with ~390 nm height.

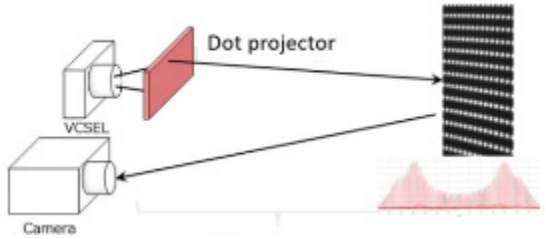
Stamp Material: EVGNIL® UV/ AS5 supplied by EV Group

Micro-Optics for 3D sensing and 3D Display Applications

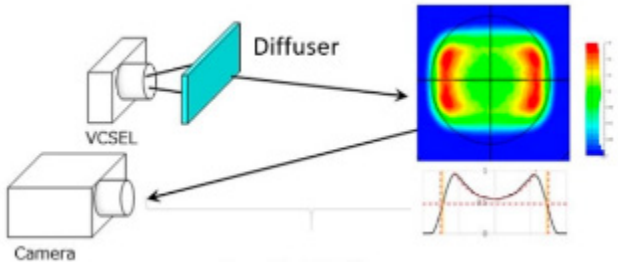
- ✓ HRI-based DOEs combine collimation and dot projection into a single component delivering advanced sensing performance in a compact form factor
  - ✓ PixNIL® ST6: RI = 1.9, solvent-containing, >6:1 aspect ratio
- ✓ HRI micron-scale lens structured diffusers enable improved **wide-angle sensing** for mobile phones and automotive interiors
  - ✓ PixNIL® Solvent-free formulations, RI = 1.65-1.80, 30-50 µm films, MLA structure
  - ✓ Also used for 3D displays



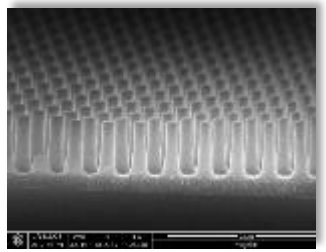
Dot Projector:



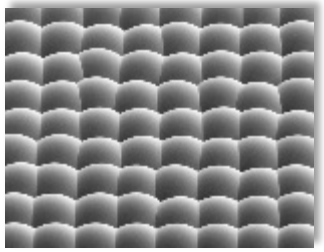
Diffuser:



PixNIL® high-index nano- and micro-imprinted components



Solvent-containing HRI resin (<1um)

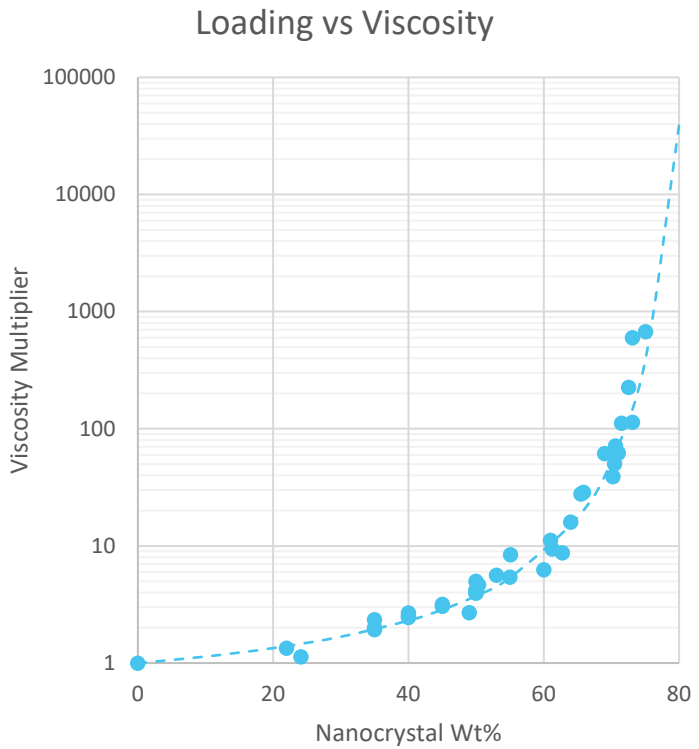


Solvent-free HRI resin (30-50um)

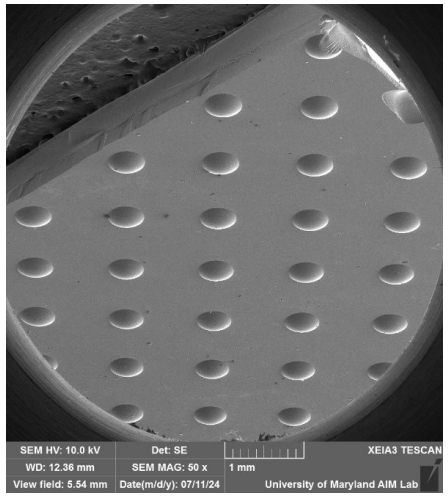
PixNIL® Solvent Free Product Offerings

Nanocrystal Synthesis → Capping Process / Property Tuning → PixClear® Titania & Zirconia Dispersions → Base Formulations → **Final Formulations** → PixNIL® / PixJet® Applications

Product	Core	Solvent	Viscosity (cP)	RI (589 nm)
PixNIL® SFZ4	Zirconia	No	550	1.65
PixNIL® SFZ1	Zirconia	No	850	1.70
PixNIL® SFCS1	PixCor	No	1500	1.80
PixNIL® SFT1	Titania	No	700	1.85
PixNIL® SFT2	Titania	No	1000	1.85



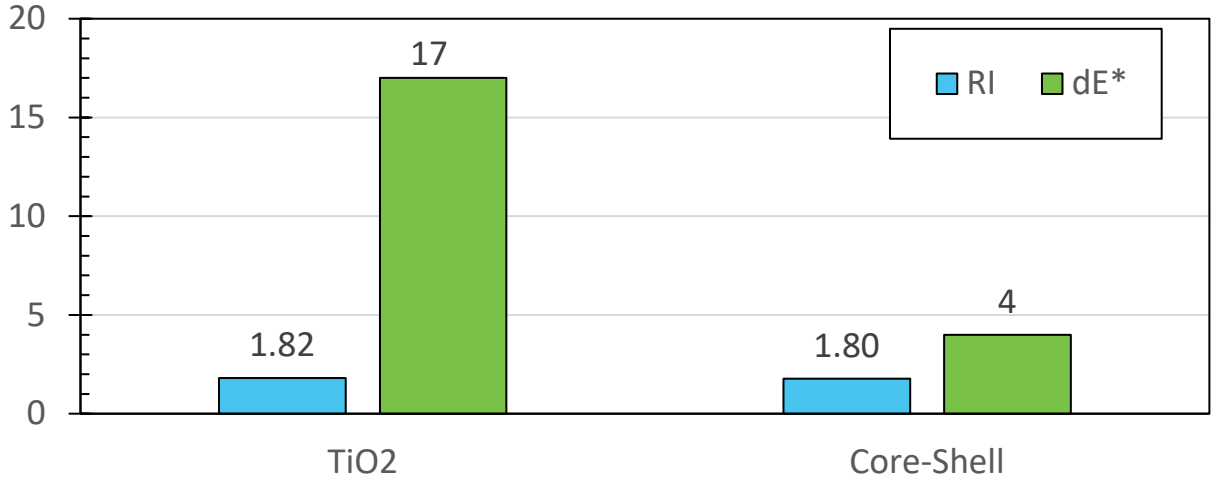
- Wafer Level Optics imprints shown
- Hemispherical lenses imprinted using Silicone stamp, Elastosil RT 601
- Compatible with PDMS stamps
- Looking for new applications and partners



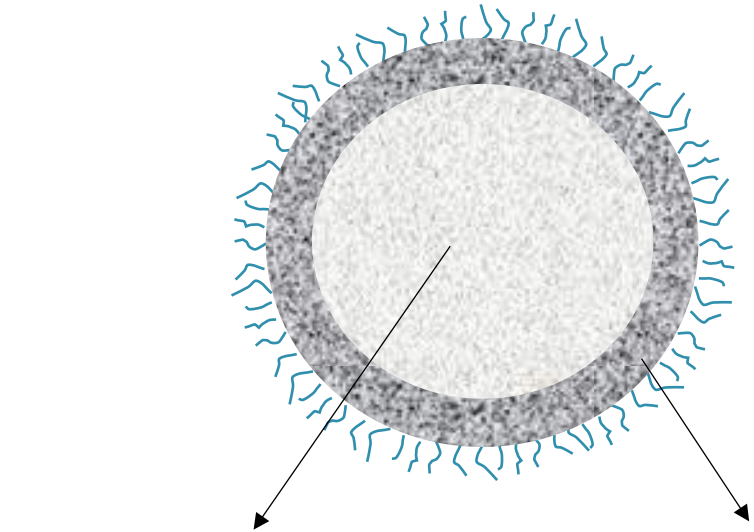
Award-Winning PixCor™ Formulations Improve TiO_2 Stability

PixCor™ TiO_2/ ZrO_2 Nanocrystals

- 20-nm Core-Shell size by DLS with narrow particle size distribution maintained.
- Dispersions with no aggregation or settling.
- Compatible with various solvents/ monomers.
- > 85% improvement in light stability with 405 – 450 nm exposure.
- Same compatibility as PixNIL® formulations in similar resin systems.
- Films with > 95% transmission, < 0.1% haze.

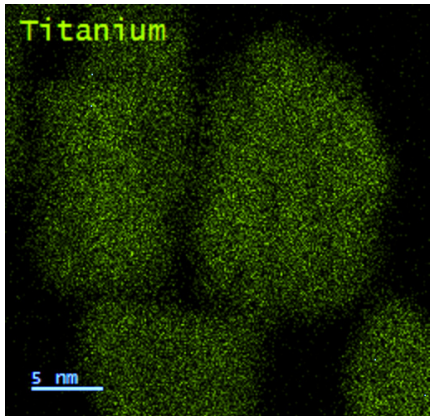


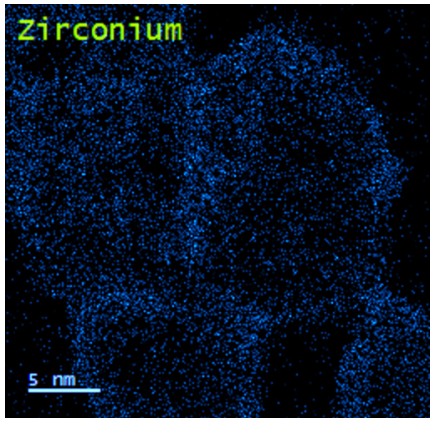
Q-Sun (AM1.5, 400nm filter, 500 hrs.), 20 µm FT



TiO_2 core

ZrO_2 shell





Ti and Zr on the same particle.

The PixClear® , PixNIL® & PixJet® Advantage

Nanocrystal Synthesis → Capping Process / Property Tuning → PixClear® Titania & Zirconia Dispersions → Base Formulations → Final Formulations → PixNIL® / PixJet® Applications

Market Leading Properties:

- ✓ HRI 1.7 – 2.0+
- ✓ 95%+ Transparency
- ✓ <0.1% haze
- ✓ Loadings up to 80%
- ✓ Uniform Dispersions

Varied Processing Conditions:

- ✓ Solvent-Free
- ✓ Solvent-Containing
- ✓ Nanoimprintable
- ✓ Spin-Coating
- ✓ Inkjet Printing & Jet Coating
- ✓ Bake / No Bake

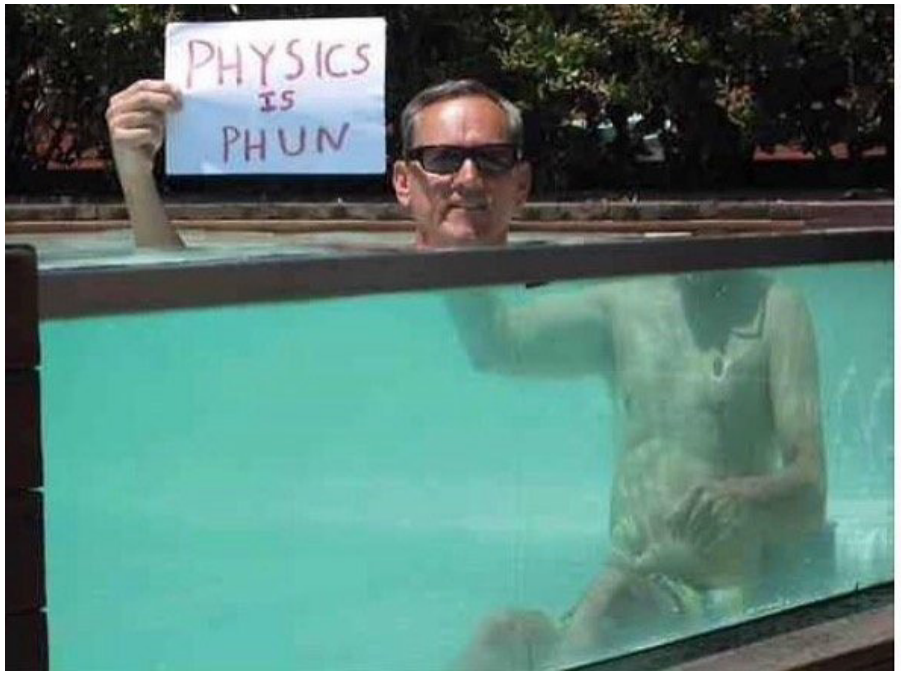
Formulations are tunable to suit application needs:

- ✓ Viscosity
- ✓ Film RI
- ✓ Film thickness & NIL residual layer thickness
- ✓ Optimal RI to RLT Ratios
- ✓ Reliability/ Absorption Requirements
- ✓ Drop-in Ready

Tunable Properties

Thank You

Questions?



pixelligent

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https://twitter.com/Pixelligent