pixelligent

The Clear Solution®

Novel Metal Oxide Nanocrystals and Nanocomposites Enabling Next Generation Opto-Electronic Devices

Strategic Materials Conference, San Jose
Sept. 2017

Presentation Overview

I. Introduction

II. Leading challenges in commercializing advanced materials and Pixelligent Technologies approach:

- Value proposition related challenges
- Value/supply chain related challenges
- Uncertainty Due To Scaling challenges

III. Products & Technology enabling next generation optoelectronic devices

IV. Conclusions

I. Introduction

Company Overview

Disruptive Technology

- Technology leader in Next Generation High- RI Nanocomposites
- IP: 43 Active & Pending

Key Markets Served

- OLED Display, HD Display, OLED Lighting, LED Lighting

Customers & Partners

- Leading Device, Advanced Materials, & Consumer Electronics Companies

Manufacturing

- 5 MT Pilot Baltimore, MD
- 40 MT Full-scale, PA, Q4 2017

Locations

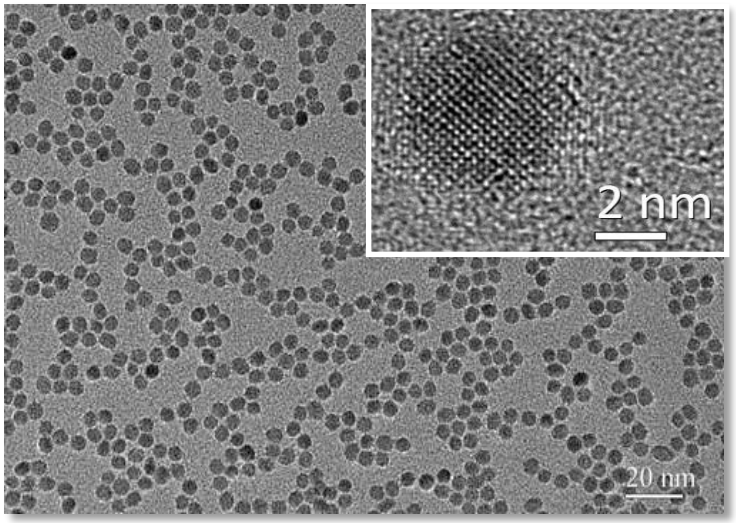
- Baltimore, MD - HQ
- Midwest Sales Office
- Taipei, Taiwan Sales Office

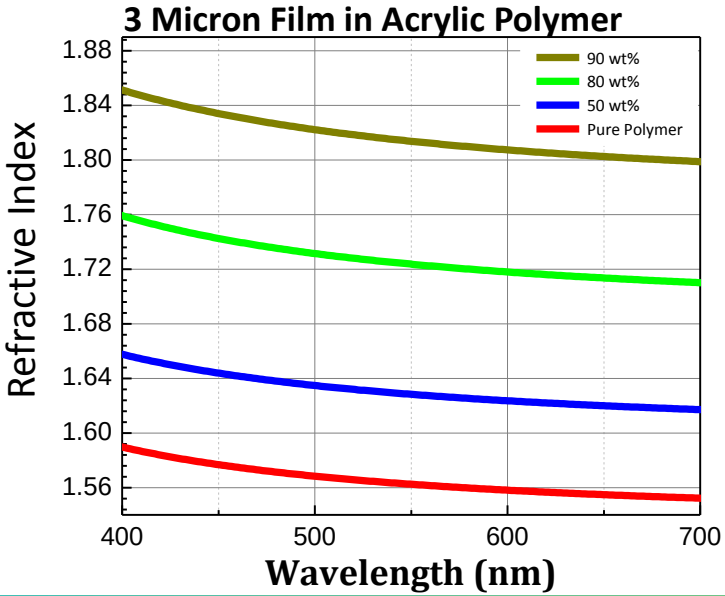
Distributors

- Korea, Japan, Taiwan

Disruptive Technology Platform

- Technology leader in high RI nanocomposites:
  - 5nm-10nm ZrO_2 spheres
  - Fully uniform (monodisperse)
  - High loadings (>80wt%)
  - 95% transmittance
  - High RI >1.8
  - Broad compatibility
- Significant customer benefits:
  - Highest possible light extraction
  - Low Haze <0.5%
  - Increased mechanical strength
  - Dramatic improvements in overall operating efficiencies

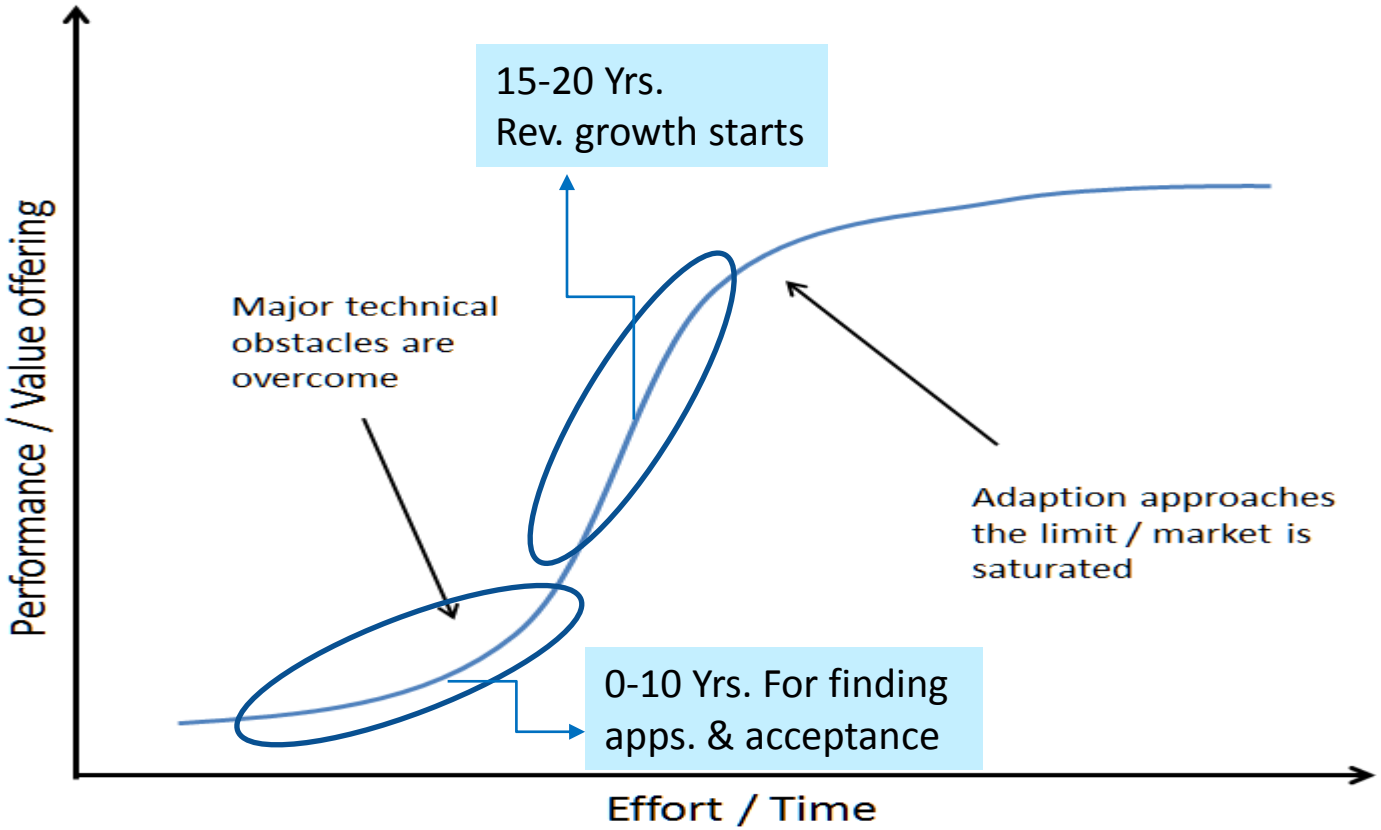




II. Challenges In Commercializing Advanced Materials* and Pixelligent Approach

*"Path to improved Returns in materials commercialization", Chemical Practice, McKinsey & Co., Aug. 2012
* "Accelerating Advanced Materials Commercialization" Nature Materials, Apr. 2016

Challenge of Long Timeline To Peak Revenue For New Materials Products :



Long time to peak revenue for new materials products a function of many factors:

- Lack of focus by materials companies, Technology scaling risk
- Value chain complexity, Value proposition not clear, Adoption cycle, etc.

Challenges In Commercialization of Advanced Materials:

Value Proposition Related Challenges

- Market Segmentation: Finding the Best Match
  - Older products will be completely replaced by my new product:
  - "Why wouldn't every consumer (every market segment) want a more energy efficient light bulb enabled by my new product"
- Utopian Illusion
  - Companies think that materials developed based on a distinct set of properties in early R&D can be a "panacea"
  - Fact: Customers value only 1 or 2 properties of the new material in their applications

Value Chain Related Challenges

- Stifled By The Loser:
  - Upstream position in the value chain
  - Benefits to end-user do not equate to benefits to value chain players
- "Drop-in Solution":
  - Integration and reliability
  - Need for complementary innovation

Technology Uncertainty For End Users and Value Chain Partners

- Lab to full scale manufacturing

Value Proposition Related Challenges:

- Market Segmentation
  - Belief that "older products will be completely replaced by my new product"
  - "Why wouldn't every consumer want a more energy efficient light bulb enabled by my new product"
- Utopian Illusion:
  - Companies think new materials developed based on a distinct set of properties in early R&D can be a "panacea"
  - Fact is customers value only 1 or 2 properties of the new material in their applications

Pixelligent Approach and Timeline

2012

Metal Coatings
Optically Components & Films (OCF)
OLED Displays
Dielectric Coatings
Lubricants & Greases
Paints & Coatings
Dental Composites
LED Lighting
Lithography Hard Mask
Gradient Index Lenses

Customer engagements with early prototypes

2013

LED Lighting
OLED Lighting
Displays

Q2: Standard PixClear™ products launched
Value proposition understood in light extraction

2014

OLED Lighting
LED Lighting
Displays OCF

Q1: First JDA engagement in SSL
Q1 Pilot mfg. began
Focus market segments identified

2015

OLED Lighting
LED Lighting
HD Displays OCF

Q2: First POR Win in SSL Lighting
OLED Lighting
LED Lighting
HD Displays
OCF

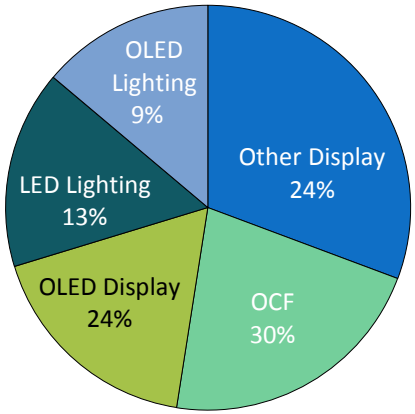
2016

OLED Displays
OLED Lighting
LED Lighting

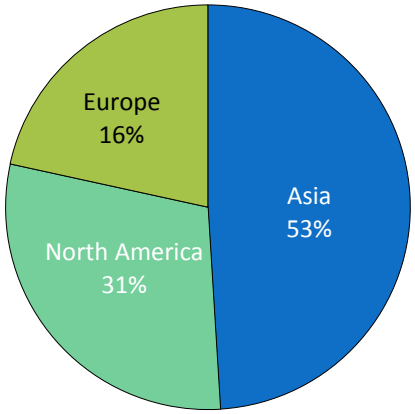
Prioritized focus
High Priority Segments:
OLED Displays
OLED Lighting
LED Lighting

2017 Pixelligent Focused Markets:

Active Customers by Market Segment



Active Customers by Region



Pixelligent Approach: Key Take Away

- Engaged with customers early: Do not wait to have a perfect product to go to market
- Helped understand the value of PixClear™ in customer applications and determine target market segments early:
  - Segments that value materials with combination of high R.I., high %T, and low haze
- Understanding market segments helps in prioritization & resource allocation to accelerate high potential commercial opportunities

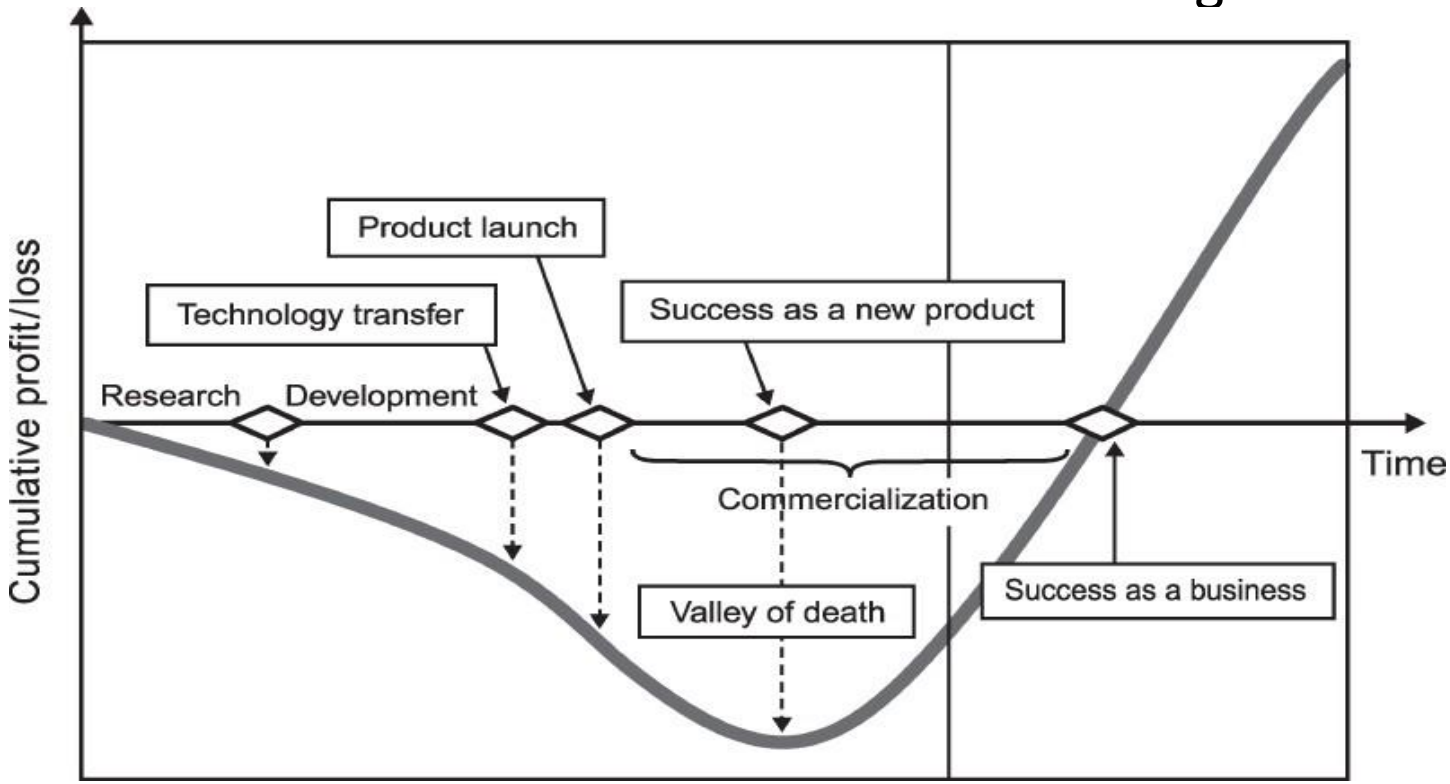
Value Chain Related Challenges:

- Stifled By The Loser:
  - Upstream position in the value chain
  - Benefits to end user do not equate to benefits to value chain players

Pixelligent Approach:

- **End Users:** Engage with leading end users and key stakeholders in value chain to demonstrate benefits and value of PixClear® and create a market pull
  - End users help drive engagement with leading material suppliers in the market
  - Engagement with end device mfrs. led to JDAs with material suppliers
- **Materials Suppliers**: Engage with key formulators and materials suppliers to develop a finished product for end users
- **Equipment Suppliers:** Engage with key equipment suppliers to lower barriers to integration & adoption

Technology Uncertainty For End Users and Value Chain Partners From Lab to Full Scale Manufacturing



- Many advanced materials/nanomaterials companies fall into "Valley of Death":
  - Tried to scale too many materials platforms/products without understanding the real market pull
  - Scaling from lab to large scale manufacturing proved to be very challenging, expensive, etc.

Technology Uncertainty For End-Users and Value Chain Partners Going From Lab to Full Scale Manufacturing

Pixelligent Approach: PixClearProcess™ for fully scaled ZrO2 Nanocomposites

ZrO_2 Nanoparticle

- Same ZrO_2 nanoparticle for all products

Capped ZrO_2 Nanoparticle

- Application specific surface modification
- Same equipment and process for all products

Nanodispersions and Formulations

- Broad materials compatibility
- Wide range of applications

PixClearProcess™ *Frost & Sullivan 2017 Manufacturer of the Year*

Volume

- 5 MT pilot line today
- >40 MT on line 4Q17
- Further scaling without constraints

Quality

- Quality maintained during scaling
- Consistent Lot to lot quality, over multiple years

PixClearProcess™

ZrO_2

Compliance

- Fully compliant with all US and International EH&S and standards.

Cost

- >95% Mfg cost reduction from lab to MP
- Driving compelling value propositions

Focused on one core material system	Experts in nanoparticle synthesis and surface chemistry
Developed large portfolio of proven surface modifiers	Fully integrated PD and manufacturing processes

III. Products and Technology Enabling Next Generation Optoelectronic Devices

PixClear® Drives Significant Customer Benefits in Rapidly Growing Markets

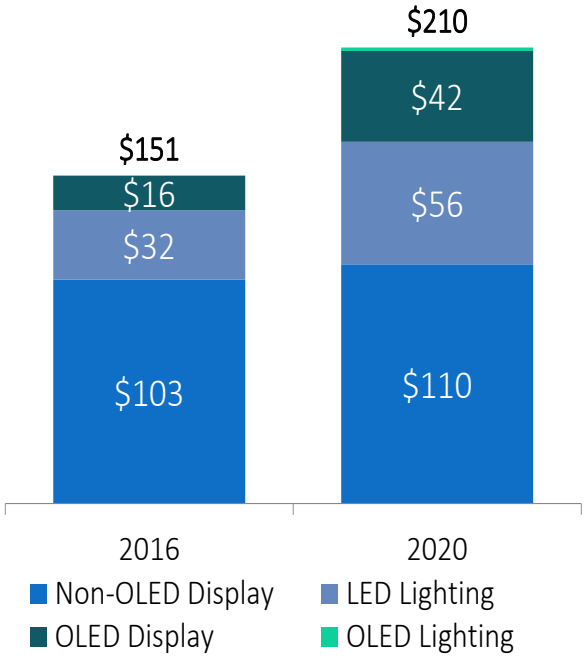
OLED Display

Increases OLED display brightness 50% to 200%

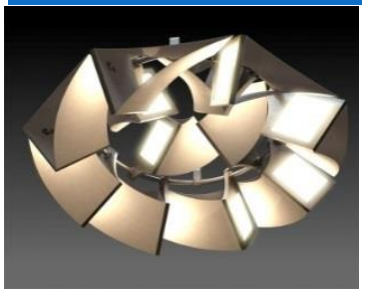
LED, LCD,QD, and Reflective Displays

Provides substantial operating efficiencies across all display technologies

Total Available Market ($B)



OLED Lighting



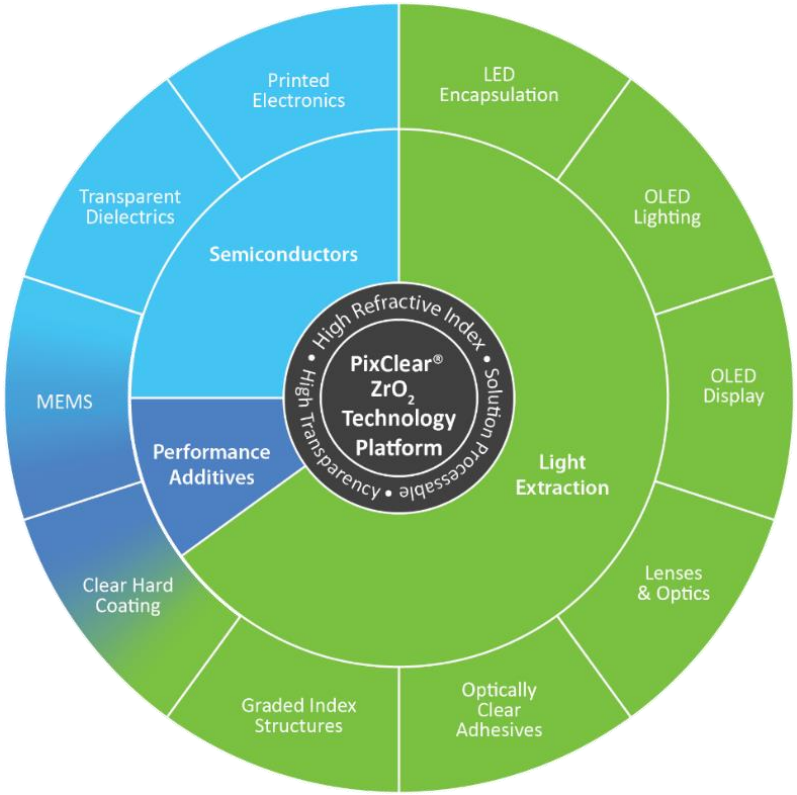
Increases OLED lighting efficiency by >100%

LED Lighting

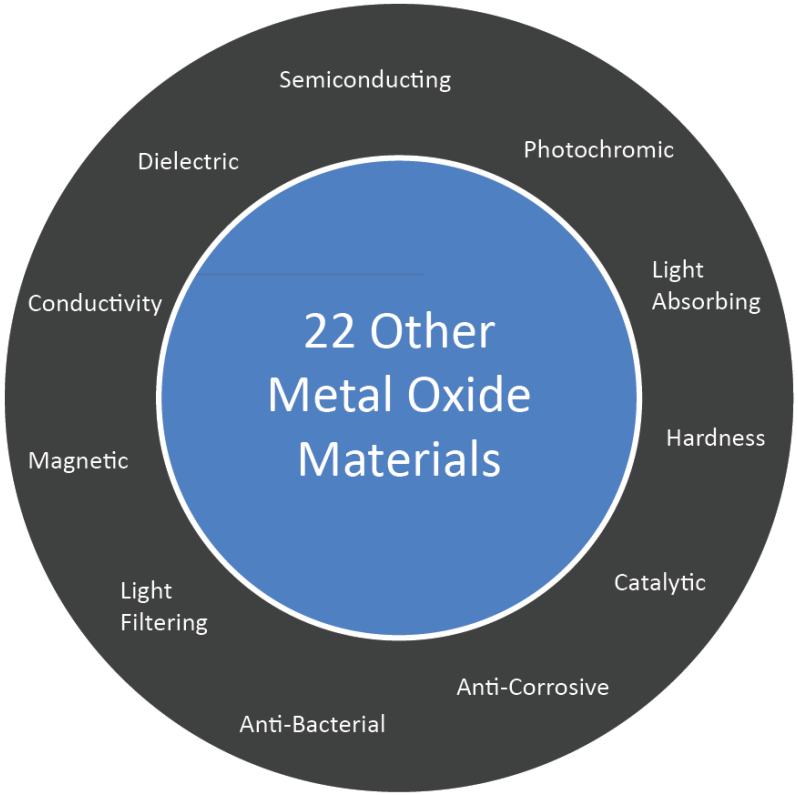
Releases up to 35% of trapped light in LEDs

Extending the PixClearProcess™

Today



Future



Broad Compatibility

Zirconia Nanocrystals

Dispersion Medium | Polar Solvents | Non-Polar Solvents | Solvent-Free Monomers

Customer Target Material

Silicone | Siloxane | Epoxy | Acrylics | Future

TBD

Benefits

High RI | Transparency | Dielectric | Hardness | Thermal Stability | Light Stability | Solution Processible

Manufacturing

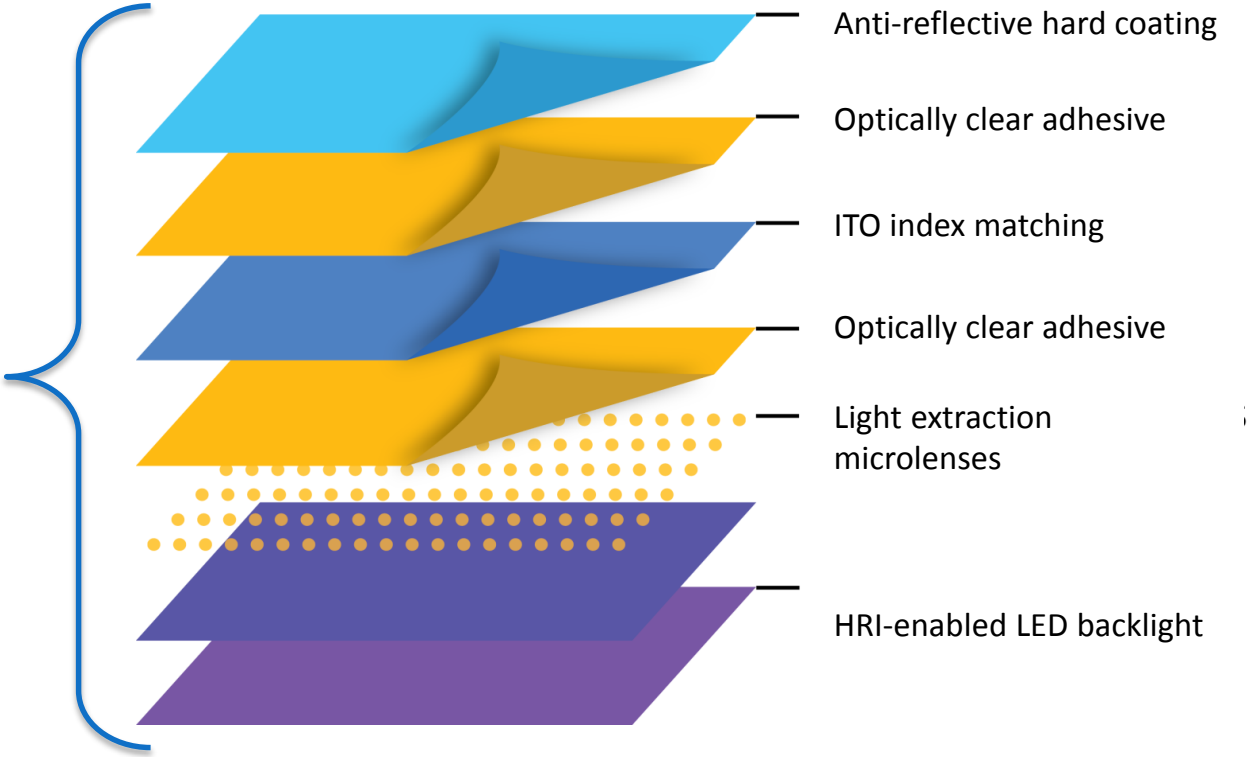
Inkjet | Slot Die | Imprint | Dispense

LED | **OLED Display** | **OLED Lighting** | **Display** | **OC&F**

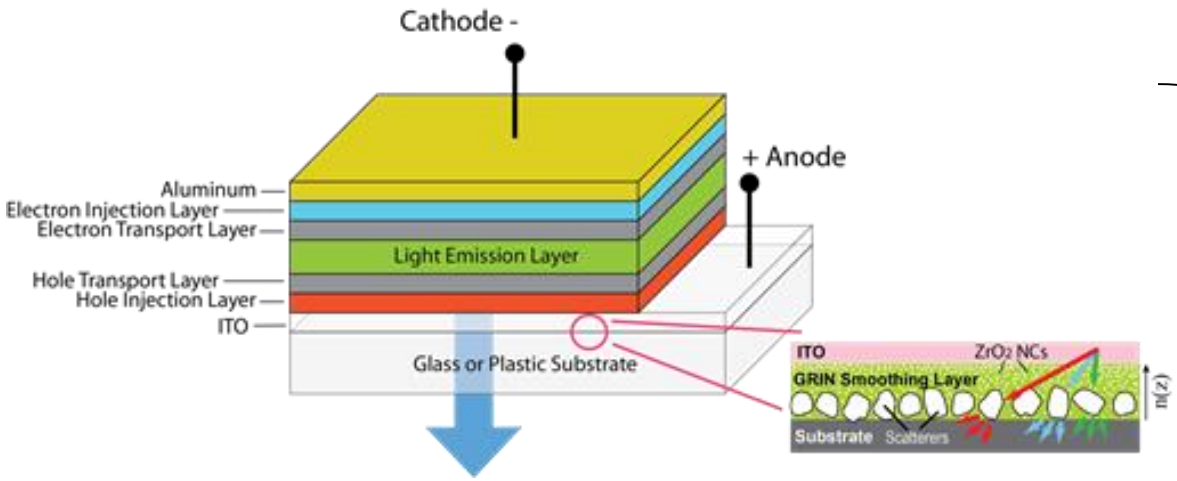
PixClear® Display Applications

PixClear® delivers:

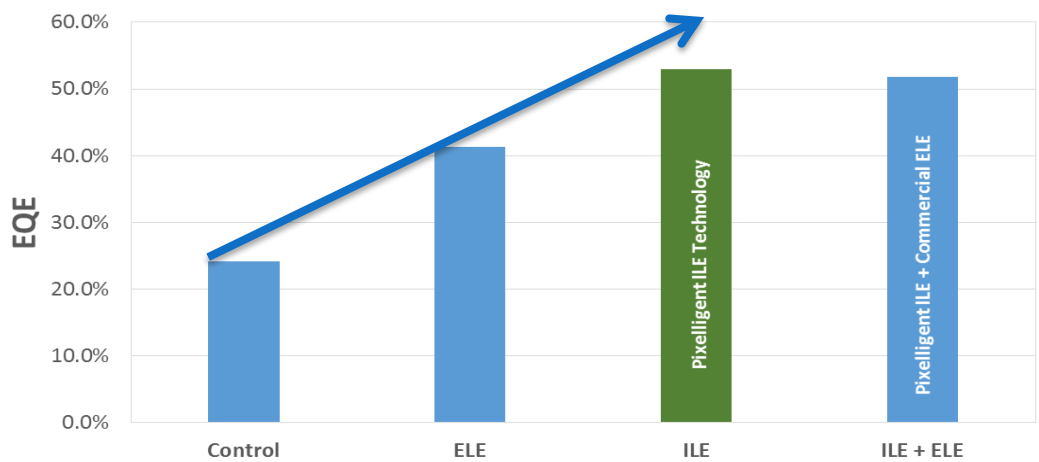
- 1.75+ RI
- 95% transparency
- Flexible or rigid
- 100%+ light efficiency improvement
- Improved scratch resistance



PixClear® OLED Lighting Applications

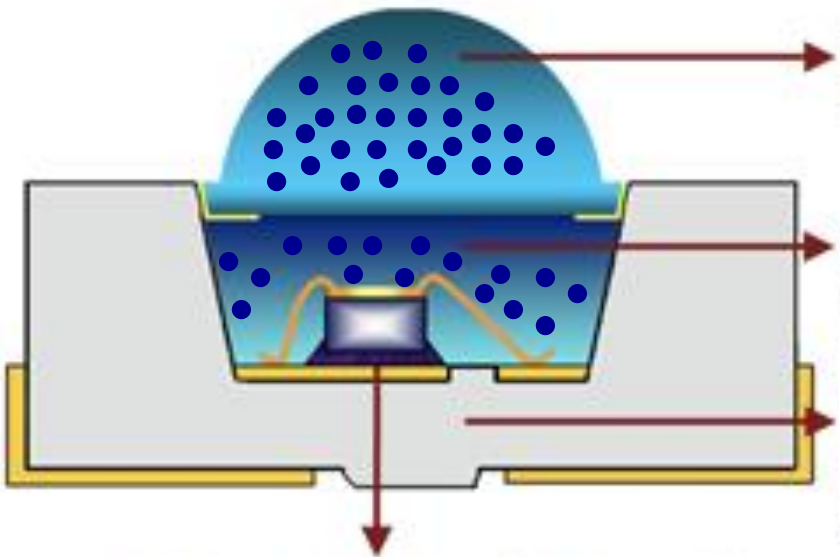


PixClear® Gen 1 internal light extraction ("ILE") materials provide a smoothing layer; Gen 2 will include scatters; part of 4 generation product roadmap



PixClear® Gen 1 ILE materials provide more than 100% increase in light output compared to control

PixClear® LED Applications



Pre-molded PixClear® containing silicone Fresnel lens

Solvent-based and solvent-free PixClear® containing silicone encapsulation materials

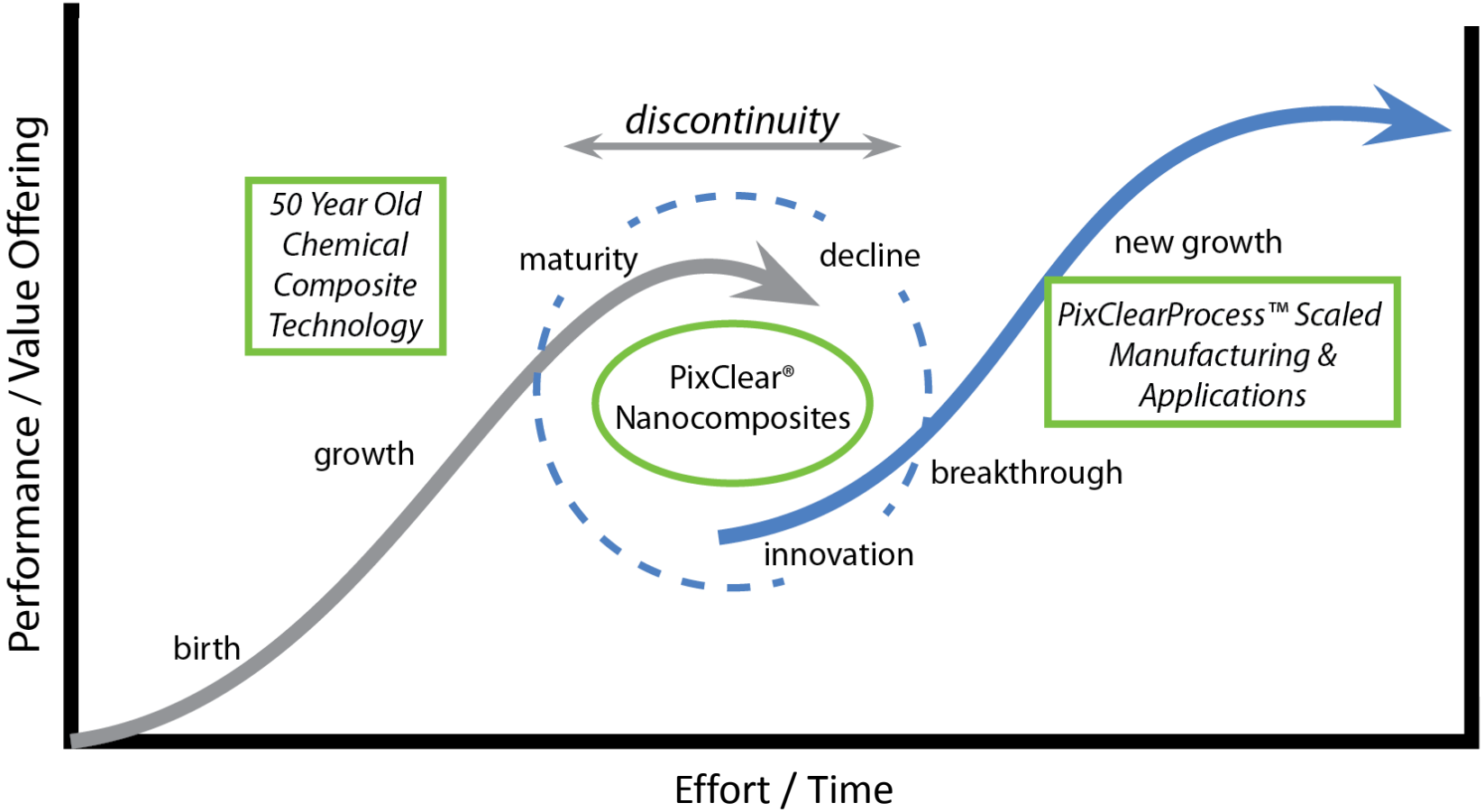
Pre-molded silicone reflector

Silicone die attach material

PixClear® silicone nanodispersions increase refractive index of silicones from 1.4 to 1.65, improving performance by releasing 15% - 35% of the trapped light

IV. Conclusion

PixClear® Disruptive Product & Process Technology



Summary

- PixClear® delivers dramatic cost and performance improvements in OLED Display, OLED Lighting, Non-OLED Display, and LED Lighting markets:
  - Improves OLED displays by increasing display brightness, improving operating efficiencies and extending battery life – features critical to both the mobile computing and TV markets
  - Increases OLED light output by 100%+, accelerating the adoption of OLED lighting
  - Delivers significant performance improvements and cost reductions in LED chips by releasing 15% - 35% of the trapped light in each chip
  - Built on proprietary PixClearProcess™ for Mass Production
  - Supported by one of the most experienced and sophisticated nanocomposite teams in the world

Thank You!!

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Meet us @ 2017 OLED World Summit, San Francisco Sept. 21, 22
Pixelligent Presentation on OLED Technology