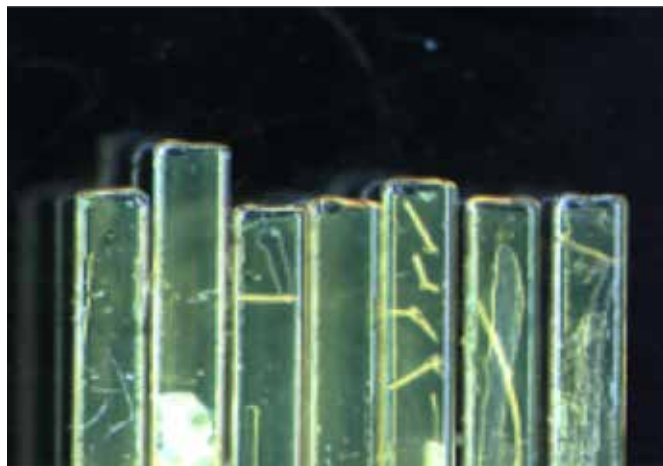




QUANTUM DOT TECHNOLOGY NEW FRONTIERS

Jason Hartlove, Nanosys CEO & President | March 20, 2019

QUANTUM DOTS IN 2013...



UNPROVEN RELIABILITY



CADMIUM



HIGH COST

FAST FORWARD TO 2019 TODAY



PROVEN & SCALED TECHNOLOGY



HEAVY METAL FREE



LOW COST

QUANTUM DOTS EVERYWHERE



Samsung Q900 8K QLED TV
Samsung 49" CRG90 QLED Gaming Monitor



Vizio P-Series Quantum X
Vizio P-Series Quantum
Vizio M-Series Quantum



HP Pavilion 27



HP Omen X Emperium



Hisense H9F



Hisense U9F



TCL X10 8K QLED TV

CES 2019: QUANTUM DOTS EVERYWHERE



HIGHLIGHTED PRODUCTS

Brand	Model	Size
HP	Pavilion 27	27"
	Omen X Emperium	65"
Vizio	P-Series Quantum X	65" & 75"
	P-Series Quantum	65" & 75"
	M-Series	43" - 65"
Hisense	H9F (starting at \$699)	55" & 65"
	U9F	75"
	ULED XD	65"
TCL	X10 QLED 8K TV	75"
	8-Series	65"
	TCL QD Bezel-Less Glass TV	65"
Samsung	2019 QLED TV Lineup	43" - 85"
	Q900 8K TV	65", 75", 82", 85" & 98"
	The Frame	43", 49", 55" 65"
	Serif TV	43" 49" 55"
	CRG9 Monitor	49"

68

Total Products on Display

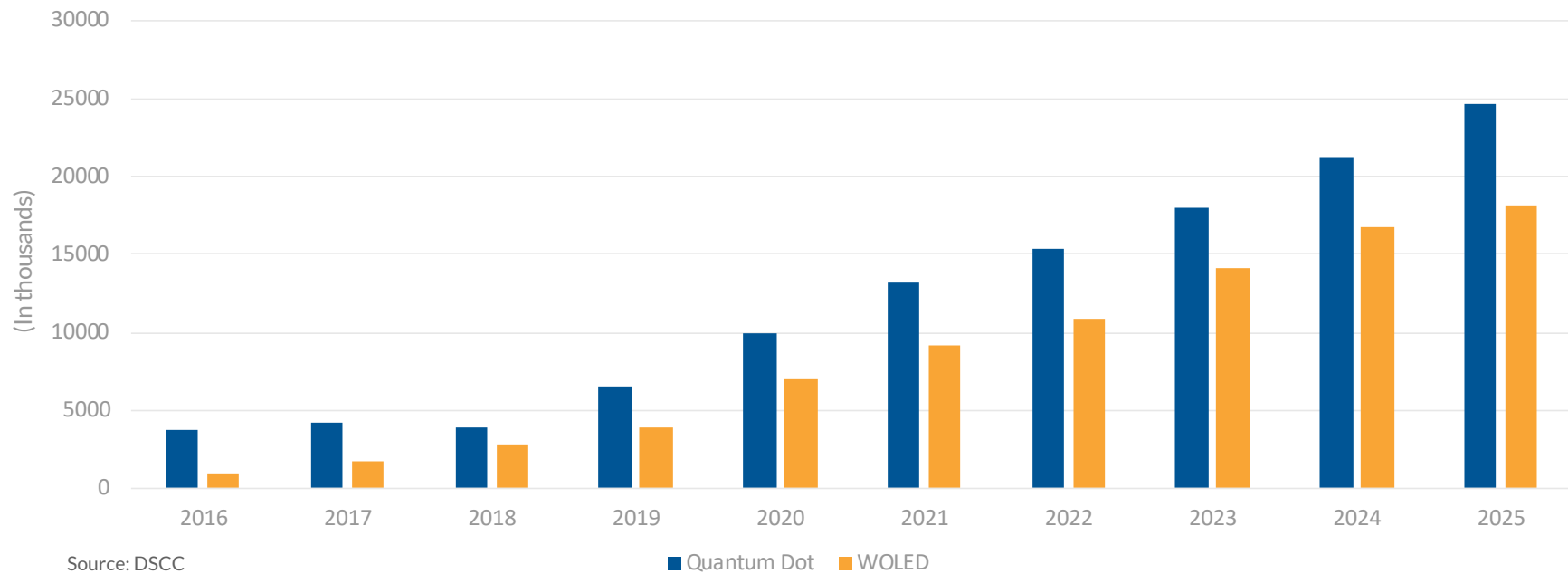
1.83X

More Products on Display vs. 2018

11

CE Brands Showing QD

QUANTUM DOTS TO CONTINUE TO OUTSELL WOLED IN COMING YEARS



- According to Bob O'Brien, Co-Founder & President of Display Supply Chain Consultants, "Quantum Dot LCD TVs are projected out-sell those using rival White-OLED technology for the next five years. Additional demand for Quantum Dots will come from Quantum Dot OLED TVs."

QUANTUM DOT: THE PERFECT EMITTER



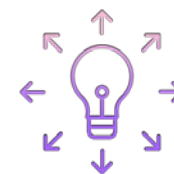
SPECTRUM ENGINEERING

Quantum Dots emit light with narrow spectral peaks. A wide range of colors can be created just by tuning synthesis conditions at manufacturing.



HIGH STABILITY

Quantum Dots do not face the fast bond cleavage issue of the host materials used in other devices like PHOLEDs.



HIGH EFFICIENCY

Quantum Dots are nearly perfect light energy converters. They absorb and emit light with high efficiency.



COST

Quantum Dots are lower-cost per gram than current phosphors.



SOLUTION PROCESSABLE

QDs are versatile. They have been formulated with solvents, monomers, polymer films, inks, photoresists; attached to biomolecules, cells, and more.

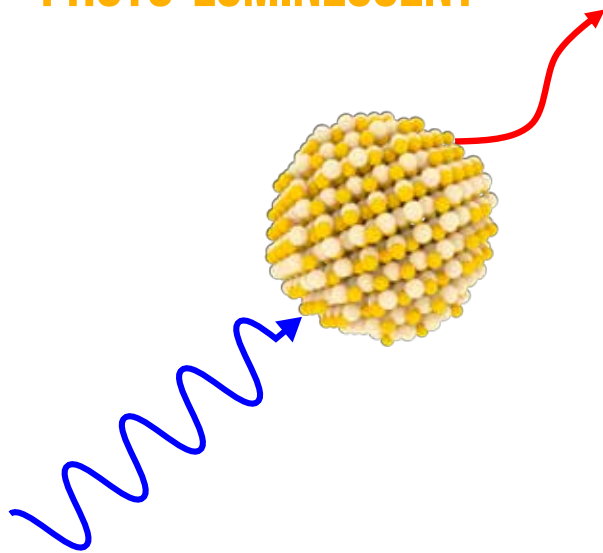


BRIGHT

Existing OLEDs with either fluorescent or phosphorescent emitters cannot achieve such high luminance because of significant efficiency roll-off problems at high current density.

QD USABLE IN MULTIPLE MODES

PHOTO-LUMINESCENT



ELECTRO-LUMINESCENT

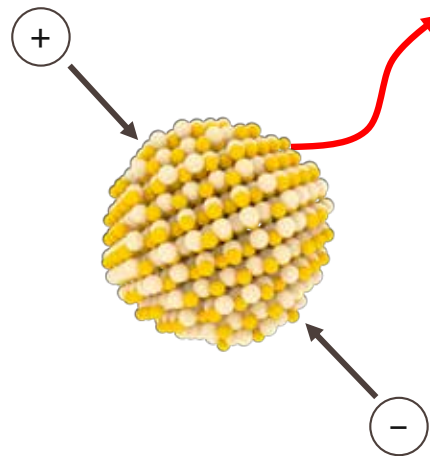
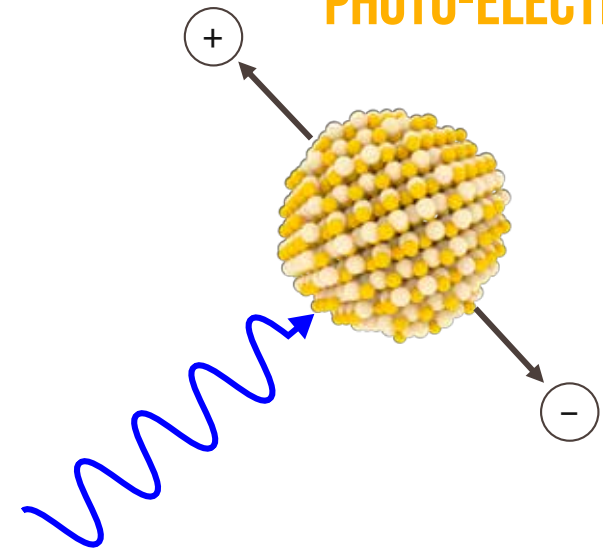


PHOTO-ELECTRIC





BEYOND DISPLAYS

SOLAR POWER: SMART WINDOWS



SMART WINDOWS

Quantum Dots can turn tinted windows into power sources. This enables technologies like building-integrated sunlight harvesting and could revolutionize urban architecture.



REDUCE URBAN GHGS EMISSIONS

With Quantum Dot smart windows, buildings may eventually realize net zero energy consumption or even end up supplying the grid with electricity, helping to reduce urban greenhouse gas emissions.



HIGH EFFICIENCY

"[Quantum Dots] are so efficient that existing measurements were not capable of quantifying just how good they are... [They] may someday enable applications that require materials with luminescence efficiency well above 99 percent, most of which haven't been invented yet."

- Dr. Paul Alivisatos



END MARKET ENABLED

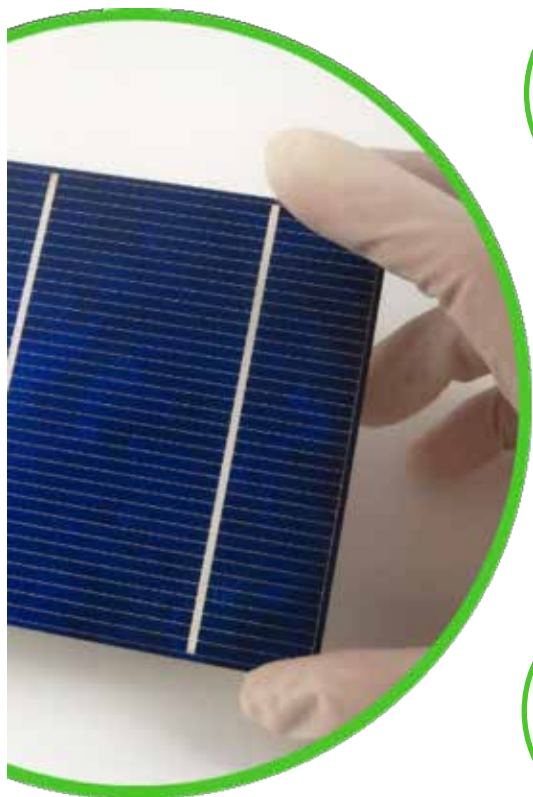
\$950 Million in 2023



FIRST MP PRODUCTS

2021

SOLAR POWER: TANDEM/MULTI JUNCTION PANELS



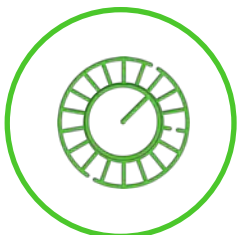
QUANTUM DOT SOLAR

Solar cell design using quantum dots as the absorbing photovoltaic material in conjunction with bulk materials such as silicon, copper indium gallium selenide (CIGS) or cadmium telluride (CdTe).



LOWER COST SOLAR ENERGY

Cost-effective way to highly improve the efficiency of harvesting solar energy.



SPECTRUM ENGINEERING

Quantum Dots are perfectly suited to absorb light from multiple parts of the spectrum and can be paired for maximum photo-conversion efficiency.



END MARKET ENABLED

>\$5 Billion in 2026



FIRST MP PRODUCTS

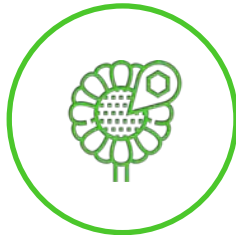
2025

BIOLOGICAL TAGGANTS : SPECIMEN TRACKING (POLLEN)



POLLEN TRACKING

Because Quantum Dots are tiny and have the ability to emit bright light in a range of possible colors, they can be used to track pollen grains and other biological phenomenon.



REVOLUTIONIZE FARMING

Quantum Dots have the potential to solve the challenge of the past 200 years in pollination research and other fields where researchers do not have the data for where the specimen actually comes from prior to study.



SOLUTION PROCESSABLE

Solution processed Quantum Dots are easy to deploy by spraying on bugs or other specimens.



END MARKET ENABLED

>\$100 Million in 2021



FIRST MP PRODUCTS

Already Commercial

SMART FARMING: GREEN HOUSE FILMS



GREENHOUSE FILMS

Quantum dots can be coated on various structures such as glass, rigid plastic and flexible film to modify the solar spectrum.



INCREASE CROP YIELD

Trigger early fruiting and shorten crop cycle, leading to increased annual crop yields.



STABILITY

Greenhouse films must be stable under sunlight for multiple years in a low cost film.



END MARKET ENABLED

>\$50 Million in 2022



FIRST MP PRODUCTS

2020

SMART LIGHTING : GREEN HOUSE ILLUMINATION



GREEN HOUSE ILLUMINATION

Quantum Dots can be fabricated to shift blue light energy from high efficiency GaN LEDs to red light, resulting in an ideal magenta spectrum for growing green plants.



LOWER ENERGY CONSUMPTION

Quantum Dot illumination consumes far less energy for the same production output than traditional green house lighting, reducing the costs needed to control growing environments.



HIGH EFFICIENCY

Ultra high efficiency quantum dots convert the spectrum without optical losses, consuming far less and producing less heat than traditional greenhouse lighting.



END MARKET ENABLED

>\$100 Million in 2022



FIRST MP PRODUCTS

2021

SMART LIGHTING : CIRCADIAN ILLUMINATION



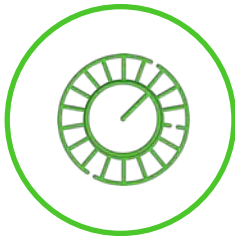
SMART LIGHTING

Quantum dots are the only low cost and high efficiency way to achieve the create a continuous, variable spectrum which can match the lighting requirements for circadian illumination applications



IMPROVED HUMAN HEALTH

Lighting which matches our evolutionary circadian program enables reduced sleep deficit and associated improvement in physical health.



SPECTRUM ENGINEERING

Quantum dots can be fine tuned to emit different wavelengths to meet the requirement of circadian illumination applications and other specialty lighting requirements.



END MARKET ENABLED

>\$200 Million in 2022



FIRST MP PRODUCTS

2021

PHOTO MEDICINE: PHOTO-DYNAMIC THERAPY



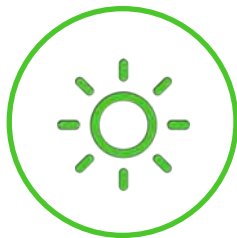
UNLOCKS HEALING PROPERTIES

Quantum Dots can be made into sheets of light emitting material with high intensity and precise wavelengths which activate certain otherwise inert compounds for treatment



HEALTHIER SKIN

Non-invasive treatment for pre-cancerous lesions as well as rosacea, facial wrinkles, sun damage, and age spots. Targets specific cells and leave surrounding tissue unharmed.



BRIGHTNESS

High brightness light source required to make this application work. Quantum Dots are uniquely able to provide light output needed.



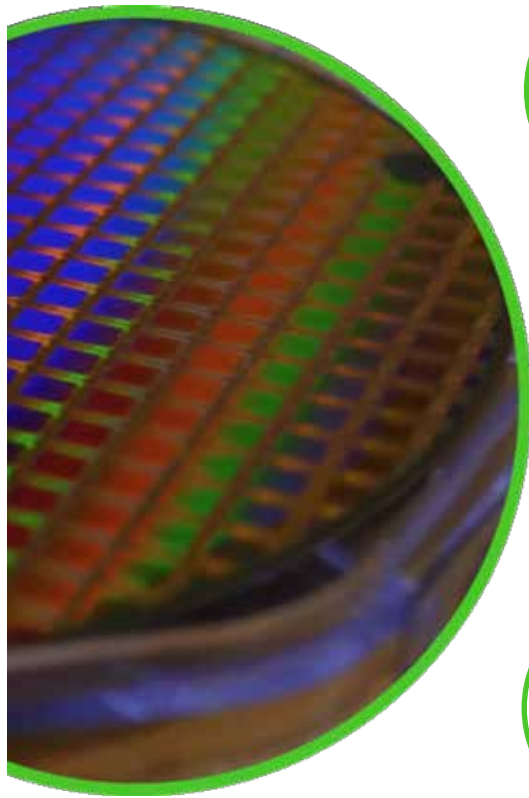
END MARKET ENABLED

>\$1B Million in 2027



FIRST MP PRODUCTS

2025



QUANTUM DOT SENSOR

Quantum Dot sensors are able absorb light 8x faster than Silicon Sensors eliminating the challenges of silicon sensors like the rolling shutter effect, limited dynamic range and low light sensitivity. Increased resolution and sharpness for infrared light.



NEW SENSOR APPLICATIONS

Quantum Dot sensors enable a new generation of sensors for applications such as time-of-flight sensing and others.



SOLUTION PROCESSABLE

Quantum dots can be spin coated as the photo-detecting layer onto silicon wafer substrates which contain circuit elements for imaging.



END MARKET ENABLED

>\$100 Million in 2023



FIRST MP PRODUCTS

2022

The image features a vibrant blue nebula or star field as a background. A dark, semi-transparent horizontal band runs across the center, providing a clear space for the text. The blue tones range from deep indigo to bright, almost white highlights, suggesting a rich, multi-colored gas cloud or a field of distant stars.

WHAT'S NEXT?

RESPONSIBLE DEVELOPMENT



112.411 48
[Kr]4d¹⁰5s²

Cd

Melting point: 321.07°C
Boiling point: 767°C

CADMIUM

200.592 80
[Xe]4f¹⁴5d¹⁰6s²

Hg

Melting point: -38.8290°C
Boiling point: 356.73°C

MERCURY

51.9961 24
[Ar]3d⁵4s¹

Cr

Melting point: 1907°C
Boiling point: 2671°C

CHROMIUM

207.2 82
4f¹⁴5d¹⁰6s²6p²

Pb

Melting point: 327.5°C
Boiling point: 1740°C

LEAD

Latin name: *Plumbum*

74.92160 33
[Ar]3d¹⁰4s²4p³

As

Melting point: 937.4°C
Boiling point: 2830°C

ARSENIC

Latin name: *Arsenicum*

204.3833 81
4f¹⁴5d¹⁰6s²6p¹

Tl

Melting point: 303.5°C
Boiling point: 1457°C

THALLIUM

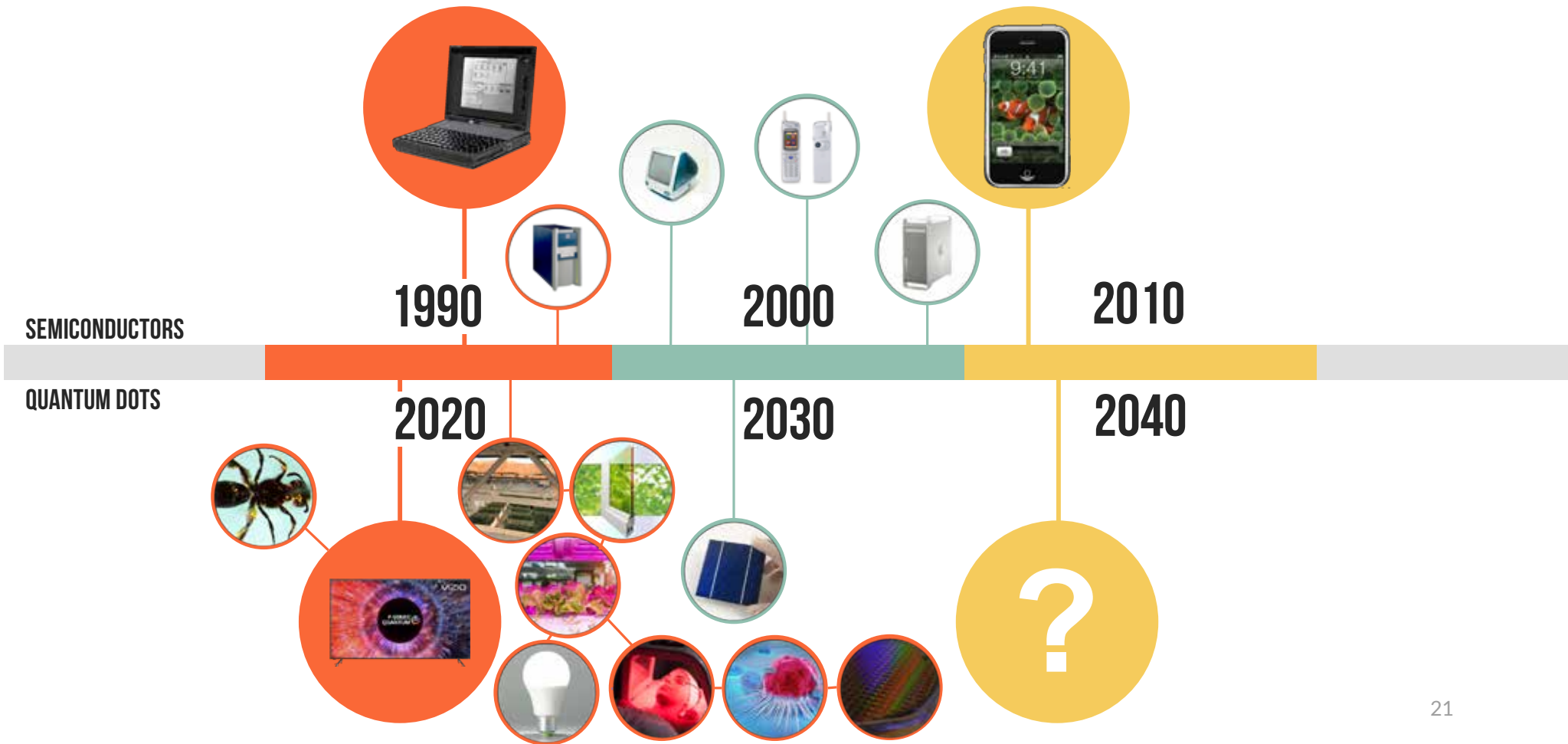
QUANTUM DOTS: UNLIMITED POSSIBILITIES



Characteristic	1992	1995	1998	2001	2004	2007
Feature size (microns)	0.50	0.35	0.25	0.18	0.12	0.10
Gates per chip (millions)	0.3	0.8	2.0	5.0	10.0	20.0
Bits per chip						
DRAM	16M	64M	256M	1G	4G	16G
SRAM	4M	16M	64M	256M	1G	4G
Wafer processing cost (\$/cm ²)	\$4.00	3.90	3.80	3.70	3.60	3.50
Chip size (mm ²)						
logic	250	400	600	800	1,000	1,250
memory	132	200	320	500	700	1,000
Wafer diameter (mm)	200	200	200-400	200-400	200-400	200-400
Defect density (defects/cm ²)	0.10	0.05	0.03	0.01	0.004	0.002
Levels of interconnect (for logic)	3	4-5	5	5-6	6	6-7
Maximum power (watts/die)						
high performance	10	15	30	40	40-120	40-200
portable	3	4	4	4	4	4
Power supply voltage						
desktop	5	3.3	2.2	2.2	1.5	1.5
portable	3.3	2.2	2.2	1.5	1.5	1.5

SIA Roadmap 1993

NEXT 20 YEARS OF INNOVATION



QUANTUM DOT ROADMAP



CHARACTERISTIC	2013	2019	2022	2026	2030	2034
Core Material	CdSe	InP				
Core-Shell Structure	C-S	C-S-S				
Spectrum Engineering						
FWHM (nm) (G)	35	33				
Wavelength Range (nm)	520-622	519-645				
Solution Processable						
Minimum Layer Thickness (μm)	100	5				
Patternability (μm)	None	< 0.1				
Inkjet Patternability (μm)	None	20				
High Stability						
PL Device Lifetime at 1X Display Flux (hrs)	30,000	>50,000				
EL LT50 at 500 nits (hrs) (R)	ND	200				
High Brightness						
EL Peak Luminance @ 7V, nits	ND	25,000				
High Efficiency						
Absolute QY	ND	93%				
PL BFE (white)	70%	83%				
Blue Absorption (OD/mass, Red)	0.9	0.8				
Color Conversion Efficiency (Red)	ND	35%				
Cost						
\$/gram	\$300.00	\$12.15				
Sqm/gram (white, PL)	1.6	2.9				
Supply Chain						
Shell Reactor Scale	5L	1,250L				
Gamut coverage	100% sRGB	>99% DCI-P3				
QDEF Barrier film permissible permeability (OTR)	0.0001	0.1000				
QDEF Barrier film requirement cost (\$/m ²)	\$20.00	\$2.00				



THANK YOU

For more information, visit: www.nanosysinc.com