RoHS Exemption Request 2013-5 Meeting

December 13, 2013





December 13, 2013 Stakeholder Discussion

Goal: To further illustrate that

- The use of Cd containing quantum dots in display applications to improve color performance results in a net positive environmental, health and consumer safety impact
- The reliability of substitute technologies to achieve more energy efficient displays is not ensured

Scope

- Short 3M overview
- Brief quantum dot (QD) film technology overview
- Range of color performance achievable in liquid crystal displays (LCDs) with QD film
- Efficiency QD film systems in terms of energy consumption
- Review of how QDs can be applied in an LCD system
 - "on-chip", "on-edge" and "on-surface"
- Amounts of Cd used in actual products
- Availability of QD film containing products







Our Vision

3M Technology Advancing Every Company 3M Products Enhancing Every Home 3M Innovation Improving Every Life





3M Inventing Tomorrow – Sustaining Our Future

Sustainability is part of 3M's DNA

- Our sustainability strategies are built upon three key principles:
 - Environmental stewardship
 - Social responsibility
 - Economic success
- 3M has stated environmental goals and we publicly track our progress

	Progress to Date	Current Goal
Waste	68% reduction in waste indexed to net sales (1990-2011)	Reduce Waste <i>indexed to net sales</i> 10% (2010-2015)
Greenhouse Gas Emissions	72% reduction in absolute greenhouse gas emissions (1990-2010)	Reduce Greenhouse Gas Emissions <i>indexed to net sales</i> 5% (2006-2011)
Energy Use	59% improvement in energy efficiency (2000-2011)	Improve Energy Efficiency 25% (2005-2015)
Volatile Air Emissions	98% reduction in volatile organic air emissions indexed to net sales (1990-2011)	Reduce Volatile Air Emissions <i>indexed</i> to net sales 15% (2010-2015)
Water	40% reduction in water use indexed to net sales (2005-2011)	Develop Water Conservation Plans for 3M sites Located in Areas With Scarce or Stressed Water Resources



3M's Early History with Pollution Prevention



Dr. Ling launched 3M's Pollution Prevention Pays program in 1975

- First year savings of over 3.5 billion pounds of pollution prevented
- In 1976, Dr. Ling first presented his ideas at a Conference sponsored by the United Nations.
 - Developed booklet for the UN Environmental Program
- Served as advisor to 3 sitting US presidents and the Environmental Protection Agency

Today 3P is a fundamental 3M philosophy (Eliminate Pollution at the Source = Economic Benefit)



Electronics & Energy

Enabling Tomorrow's Lifestyle Today with Power, Communications and Electronics

- Optical Systems Division (OSD) is part of the Electronics and Energy Business Group at 3M
- We sell energy saving brightness enhancement film solutions to the display industry
- 3M developed first enhancement film solutions at the start of the LCD industry
- OSD is the leading supplier of brightness enhancement film with capacity to support the entire industry demand





3M Optical Systems Division – LCD Industry Leading Supplier

- 3M is a reliable, high volume supplier to all major display manufacturers and electronic device brands
 - 20+ years in the business
 - Several billion parts converted and shipped each year
 - Can meet high capacity requirements at a high quality level
- Global supply chain reach and support network
- Investment in future
 - Development of innovative LCD products to meet efficiency and quality needs
- Ethical supplier
 - 3M abides by all US and international business laws and practices



3M OSD Received Alliance to Save Energy Award in 2009



George Buckley CEO accepting innovative Star of Energy Efficiency" award

"Power consumption has become an increasingly important issue in today's electronic devices. We are honored to receive this award from the Alliance to Save Energy and feel it is indicative of our efforts to enable energy efficient electronic devices without sacrificing performance"

Using 3M DBEF film decreases overall energy consumption of LCD monitors and TVs by as much as 32%.

It is estimated that in 2012 3M DBEF saved an average of ~2.25TWh in TV applications globally



Liquid Crystal Displays





Range of Products Where QD Film can be Applied

Televisions



- QD film easily integrates into the existing LCD supply chain
- It can be immediately applied to any sized LCD device
 - Hand held smartphones \rightarrow +85" TVs

Monitors





LCD Industry Trends – Improved Visual Experience



- System efficiency is paramount
 - Mobile battery life (>10 hours)
 - TV and monitor meet global energy standards
- 3M offers technology to enable these trends through improving efficiency



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High Resolution



Quantum Dot Film

- Efficiently increases color performance of LCD displays by improving backlight spectrum
- Integrates into existing LCD supply chain
 White LEDs are replaced with blue LEDs







Quantum Dot (QD) Background What is a Quantum Dot?



- Nano semiconductor
 - An inorganic highly efficient phosphor crystal
- Contains core and shell
 - Material constraints: Photonic bandgap and matched crystal lattices
 - Core (CdSe or InP based)
 - Optically active
 - Shell (ZnS)
 - Protects core increases efficiency



Quantum Dot Background What Does a QD Do?



- Absorbs short wavelength light and reemits longer wavelength light
 - Similar to a phosphor
- Emission wavelength is determined by QD size tunable
- Spectral distribution is narrow
- Tuneability and narrow distribution result in efficient high color displays







Increased Color Gamut with Color Filters Only



3M

Increased Color Gamut with Quantum Dots



LCD System Efficiency



- QD film is the most efficient method to achieve high color gamuts for LCD systems^{1, 2}
 - ~10-50% more efficient than standard LCDs
 - Higher efficiency leads to lower electricity consumption, less power generation, and fewer pollutants emitted
- Cd-Free QD film results in 20-40% lower system efficiency than the standard QD film solution^{3,4}
 - Lower light conversion efficiency (QY of 80 vs. 90)
 - Wider spectral distribution (~10nm)
- 1. Statement supported in letters by: Dr. Holstalek of Merck on 11/6/2103, Jason Hartlove of Nanosys on 10/29/2013, Dr. Colegrove from Touch Display Research Inc. on 9/20/2013, Jurgen Strum from Lighting Europe on 11/9/2013, and 6 other lighting companies on 11/7/3013.
- 2.3M has received positive supporting feedback on QD film sample evaluation from over 40 industry leading LCD suppliers and OEMs
- 3. Joint development analysis of Cd-Free QD film with Nanosys (permission granted)
- 4. Cd-Free QD properties discussed at HIS E&M Quantum Dot Seminar, Seoul, October 2013.



Use-Phase Environmental Impact 100% NTSC Color Gamut 55" LCD TV Example

	CF100 (CFs Only)	CF72 QD Film	CF72 Cd-Free QD Film
Cd Content (mg)	0.0	20.0	0.0
Efficiency	0.69	1.00	0.75
Energy Consumption (Watts)	240	129	223
Power Saved Per TV Per Year* (kWh)	0	167	26
Total Power Saved in EU per Year (GWh)**	0.0	173	27

* Based on 4 hours operating time per year **Estimated on 55" TVs sold in EU per year (~1M)

- Using a report by OneSource¹ on energy consumption it can be calculated that:
 - ~175GWh of electricity is saved per year by the use of a QD film as compared to denser color filters
 - Consumption of less electricity will also result in significantly lower emissions of toxic metals such as lead and mercury
 - Additionally, the emission of greenhouse gasses will be reduced
 - 72,000 metric tons of avoided CO₂-e emissions the equivalent of approximately 16,000 cars removed from the road for one year
 - Further, the Cd in a QD display is bound in a polymeric matrix and does not leach into the environment²
- Eliminates Cd air emissions by (~20 mg EU / 150 mg US) per TV
- 1. Quantum Dot Enhancement Film Cadmium Emissions Analysis, SourceOne, Inc., http://www.sourceone-energy.com/
- 2. Pace Analytical Services. 2012. QD Film Leaching Study

Integrating QDs into an LCD System











Integrating QDs into an LCD "On-Chip"

- Quantum dots placed directly on the blue LED die
- Smallest surface area
 - Fewest total number of total quantum dots needed
- Single pass configuration (blue flux only goes through QDs once)
 - Higher concentration of quantum dots needed
- QDs exposed to extreme light flux and temperature conditions
 - Unacceptably reduced life and performance levels
- Not a viable technology option for the next 5-10 years
 - Remains an active research area



Integrating QDs into an LCD "On-Edge"

- QDs placed between LEDs and the edge of the light guide plate
- Medium surface area
 - More total QDs needed than "on-chip" but less than "on-surface"
- Single pass configuration higher concentration of quantum dots needed
- Not scalable to smaller screen sizes due to bezel constraints





Integrating QDs into an LCD "On-Surface"

- Quantum dots placed on top of the light guide plate
 - e.g., a QD film product (Quantum Dot Enhancement Film or QDEF)
- Greatly reduced temperature and flux exposure
 - Improved system lifetime
- Largest surface area
- Multiple pass configuration (light "recycling")
 - Significantly lower concentration of quantum dots needed due to multiple light reflection
 - More QDs needed than "on-edge" configuration but not a simple area ratio
- Highest system efficiency all QD flux emitted into the back light system





Amount of Cd in QD Film

- Cadmium-containing materials are used to efficiently convert blue light to red and green
 - System design (single pass vs. high "recycling")
 - White point (bluish vs. yellowish)
 - Display color gamut target
- Typical Cadmium mass per part
 - Total Cd / part = Cd per QD Film Area [µg/cm²] x QD Film Area [cm²]
 - i.e., For a 7" diagonal tablet device (16:9 Aspect Ratio)
 Total Cd = 3 µg/cm² x (15.5 cm x 8.7 cm) ≈ 400 µg ≈ 0.0004 g
- Maximum Cadmium Concentration (2014 2019)
 - Single-pass LCD / Yellowish white point (D65) / 100% NTSC
 - 20 μ g/cm² of display area
 - 55" TV = 0.17 g Cadmium

QD Film Availability

- A QD Film (QDEF) is currently in mass production and is incorporated into a commercially available tablet
 - QDEF effort initiated within 3M in early 2011 Approximately 3 years for product development
- Due to its easy inclusion into to LCD supply chain, QDEF is rapidly being incorporated into LCD devices across screen sizes
 - Working with customers to incorporate into various applications ranging from 3" diagonal hand held smartphones to +65" diagonal televisions in 2014





Cd-Free QD Availability

- 3M is actively working with its technical partner Nanosys, and across the QD manufacturing industry, to develop and commercialize as soon as feasible a Cd-Free QD film solution
 - 3M's commitment to continually improve environmental impact
 - In response to customer requests
- To date 3M has not received, nor learned about from the literature of, any Cd-Free QD raw material components that meet efficiency and environmental stability requirements to commercialize
 - Efficiency issues: Lower quantum yield and wider spectral distribution
 - Lifetime issues: Instability of Cd-Free dots in a film construction



Cd-Free QD Film Development

- When an acceptable Cd-Free QD raw material is developed, significant scientific and engineering work will still be needed to successfully commercialize a film product
 - Performance equivalent to current Cd based QD materials
- The reliability of Cd-Free quantum dots as a substitute technology for displays is not ensured and is technically impracticable within 5 years
- QDEF is currently under development for medical devices, which may necessitate a 7 year validity period

Timeline for Cd-Free QD Film Introduction



AMOLED as a High Color Gamut Substitute for QD Enhanced LCD

- AMOLEDs are not a reliable near term substitute technology
 - Consume more power than do LCDs^{1,2}
 - Insufficient industry capacity to supply broad market
 - AMOLED volume +7.1M SQM by 2017 (<5% total industry)
 - LCD volume +36.7M over same period
 - Inappropriate for many segments
 - Color shift with angle and image sticking ("burn in")
 - Too costly for mass adoption
 - Current: 55" OLED thousands US\$/SQM vs LCD US\$641/SQM
 - 2017: 55" OLED US\$1320/SQM vs. LCD US\$485/SQM



*iSuppli Q3'14 forecast. OLED Display Market Tracker, LCD Market Tracker, Small & Medium Display Market Tracker

- 1. DisplayMate, Soneira, R. M. Flagship Smartphone Display Technology Shoot-Out. 2012.
- 2. Statement supported by letters from: Dr. Holstalek of Merck on 11/6/2103 and Dr. Colegrove from Touch Display Research Inc. on 9/20/2013



Conclusions

- Due to higher system efficiency, the use of Cd containing QD film technology in display applications results in a net positive impact on environmental, health and consumer safety
- The reliability of substitute technologies for displays is not ensured and they are technically impracticable within 5 years
- Request 2013-5 fulfills each of the three conditions stated in Article 5.1(a) of the 2011 RoHS Recast for granting an exemption



Questions



