How the Rise of MicroLEDs Will Affect the Display Industry

In the final part of our quantum dots series with nanotechnologist Peter Palomaki, PhD, we take a look at how quantum dots and MicroLEDs could work together to change display technology.

Why is the display industry so excited about microLEDs?

One of the main driving forces for creating a display purely out of microLEDs is that they could be far more efficient than a traditional LCD display or a LED display. Similar to OLED, this is an emissive technology, where there's no additional filtering and selection required as you're emitting pure color directly from the sub-pixel.

So you get the high viewing angle, high efficiency, high color and high brightness that everyone in the display world wants.

If they're more efficient, would that make them cheaper to run as well?

Yes, in terms of energy consumption, they would be cheaper to operate although there's always a tradeoff between efficiency and brightness. So in current-generation TVs, if you make it more efficient, you can either reduce the number of LEDs you use and get the same amount of brightness or you can increase the number of LEDs, or drive them harder, and get an even brighter display, but use the same amount of energy.

Brightness is what consumers want now, so manufacturers are opting to increase the LEDs or add more LEDs. As screens are becoming more efficient, it allows manufacturers to do that, but you don't gain anything in terms of efficiency; you just gain brightness.

For mobile applications, the increase in efficiency that MicroLEDs bring would enable longer battery life. Right now, the display on our phones account for a large portion of the battery usage, so any improvement to efficiency will allow for smaller batteries/longer time between charges.

Could you tell us a bit more about the MicroLED technology itself?

MicroLEDs, as the name implies, are just really small LEDs. The concept behind using them in displays is that each individual LED would be sub-pixel for a pixel. So every pixel would have three LEDs: one that emits red, one that's green, and one that's blue.

You need these LEDs to be very, very small and you need to find a way to generate those three different colors. Almost all the LEDs in display products are blue so the industry knows very well how to make blue LEDs, but it's far less common to make a red or a green LED.

How do you create red and green LEDs?

With this technology, you have two options. You can either make a semiconductor that emits red naturally and that emits green naturally. Or you can use three blue LEDs with a down-converting phosphor or a quantum dot to convert that blue wavelength to red and green. This is exactly what is done now in TVs, just with normal-sized LEDs. They use a phosphor or quantum dot to take the blue light and generate red and green.

On the MicroLED side the challenge of doing this down-conversion process, is MicroLEDs are smaller than the phosphers! If you were to look on a microscale, you would have, basically, this boulder of a phosphor particle, and then this really tiny LED. So that is not a viable technology to use for down-conversion for these MicroLEDs.

Quantum dots, on the other hand, are much smaller than the size of a MicroLED, which themselves are predicted to go down to less than 10 microns in size. If that can be achieved, then quantum dots are a really attractive candidate for doing that down-conversion process of blue to red and green for a few reasons.

What makes quantum dot technology so attractive?

Their physical dimensions are such that it would allow them to be compatible with a MicroLED and they have high efficiency and narrow bandwidth, which is always useful for the display applications. So they're a nice fit with this up-and-coming technology.

This sounds impressive but what are the challenges with developing MicroLED technology?

There are a lot of challenges associated with it. Firstly it takes very complex electronics to control each individual sub-pixel independently, but then you need all the pixels to communicate, which is even more complex, but achievable. We have that knowledge base.

But with this size LED and each individual pixel having three of them, you're using literally millions of LEDs on a single 65" TV. So there's the sheer number of components and they all have to be placed perfectly.

These are very small length scales. They have to be located in groups of three, and they have to be in a high-yield place in those locations, and they all have to work well. Because if you have one or two pixels where one of the colors is defective, you'll see a few pixels that are dead on the display. If you've ever looked at an older TV that has some damaged pixels, your eye immediately picks up on that.

This sensitivity makes the yield challenge the hardest to overcome.

You have to figure out a way to take these millions of LEDs, place them in very well-controlled fashion over a panel, and make sure they all work well with no defects. One of the technologies people are using to do that right now is called ‘pick and place’, where a machine picks up one or hundreds of these MicroLEDs from the wafer in which they were created, and then transfer that over to a large-area display.

This is, of course, is only necessary when you have larger displays, for really small displays, maybe a square inch or smaller, this might not be required. You would need to have, again, near-perfect performance from that technology to make it viable. This is something that the industry is constantly working on and trying to improve. Right now, it's just not mature enough and not cheap enough. Either it takes too long, or the equipment is too expensive, or it's too low-yielding to become a manufactural process right now.

The last challenge is that of color. If you want to make a wafer of just blue LEDs, that's easy. But if you want to make one individual wafer that has both blue and red and green LEDs all next to each other, that's difficult to do. It’s possible to make the three different colored LEDs on three different wafer processes in parallel, but then you are back to the problem of placing them in the right location with high yield.

Luckily there are a couple of ways to address this. You can create all blue LEDs and use either photolithography or very fine printing techniques to deposit a down converter, like a quantum dot, on top of two-thirds of those blue LEDs, so that you get blue, red and green, and can actually make a color image out of it.

So quantum dots could be essential for the color conversion for MicroLED displays.

What would be the advantages of a MicroLED screen to the consumer?

When it comes to your own devices, MicroLEDs make for very bright and colorful screens. The colors will be even better than the quantum dot TVs right now. You're going to have a better experience due to the viewing angle and the fact that these LEDs emit in all directions.

Then there's always the potential that these things can be put on transparent substrates. So it could look like a piece of glass or plastic on your wall when it's turned off, or it's semi-transparent, and it's not until you turn it on that you actually see it. This will be possible because these LEDs are going to be so small with space in between them that it could appear transparent if it's put on glass, ITO or plastic substrates.

This also means it could be flexible if you put it on plastic. So this could be one of those technologies that start to enable flexible displays of some sort. To be honest, there are probably things that we can't even predict what might happen with this because it's so outside of what we're used to.

How could this change digital signage?

Firstly you’re going to be able to see signage clearly in any setting, even in bright sunlight. But then the most exciting thing is this sheer potential to do new types of signage - you could even potentially have portable digital signage that can be rolled up and transported to different locations.

Which do you think will be the first industries to adopt MicroLED?

It's going to be a little bit easier to accomplish for the really small area sizes first - you’ve probably heard all the buzz around this technology being used for Apple Watches.

The other one is the AR/VR space, for heads-up displays and these near-eye viewing systems, either for gaming or military applications, where you can start to have an image very close to your eye and get a really high-resolution image.

What price points do you think this might come in at?

This is a wild guess, but manufacturers are certainly sensitive to what consumers can afford. So it won't make sense to release a $5,000 watch because they'll sell so few of them that it's probably not worth it unless it's a PR stunt.

If you wanted to see real market penetration and generate excitement, I think for a watch you're talking about $1000 or less, and the tech isn't there right now.

The other question is: can you produce these in mass quantities in high quality? Even if it's cheap to manufacture, it's got to be high quality enough for consumers to trust that it's going to last for a few years.

How will MicroLED technology evolve in the near future?

This is not going to be an overnight transformation from our existing size LEDs to LEDs that are a fraction of that; it's going to be a progression of continuously smaller and smaller and smaller LEDs. We're already seeing this in this industry.

In terms of time frames, I think it will be a few years yet before the consumer will have MicroLED products.

We'd like to thank Peter for sharing his knowledge about quantum dots with us in this series. You can read the first two parts here: Quantum Dots: Challenges and Opportunities and The Evolution of Quantum Dot Technology.

Read Peter's blog here and sign-up to his newsletter to keep up to date with the latest quantum dots news.

To find out more about quantum dots read our guide and sign-up to our mailing lists for display industry news, research and expert interviews.