



Making the Case for Transparent OLED Displays

Transparent displays have been around for a very long time in the form of heads-up displays (HUDs) in aircraft and (to a limited extent) in retail displays, markets seen as too tiny by the large display makers and largely left to smaller firms and niche technologies. In the past two or three years, however, NanoMarkets notes that transparent display technology has been edging towards the mainstream, thanks to both a push from the supply side and a pull from the demand side:

- Keenly aware of the maturing liquid-crystal display (LCD) market's slowing growth trajectory, display makers are desperate to add new kinds of functionalities, even if it means pursuing and adopting another technology with higher-growth promise.
- New trends in consumer electronics, including the widening category of wearable computing devices, seem to call out for transparent displays. Companies jostling for position include all the well-known consumer electronics firms (Samsung, LG, Sony, Apple, Google, Microsoft, etc.) and suppliers would be foolhardy to ignore any potential market that includes them.

Transparency should be seen as one of a number of ways that the display industry is attempting to add dramatic new kinds of functionality to displays, alongside the addition of touch control and flexible substrates. Considerable progress has been made in each of these areas, though a truly transparent, flexible touch-screen display is a long way off due to various technical reasons and a lack of mature end-markets demanding the capability right now.

Limitations With Transparent Display Technologies

Two kinds of transparent display have already been commercially available for several years. The oldest and most primitive kind (and really "transparent" in name only) uses LEDs glued to some kind of transparent plastic substrate, so that when the LEDs light up they can be seen from both sides of the display. The other kind of transparent display is the electroluminescent display, a relatively stable technology but with inherent limitations that has relegated it to a niche business. It is unclear how far either of these could be progressed into mass-manufactured commercial products with competitive performance. There is also a collection of somewhat disparate display technologies grouped under the generic moniker "e-paper," defined by functionality and appearance i.e. flexible and can be read outdoors. Initially e-paper was hoped to be a revolutionary new direction for displays and particularly e-readers, but now it seems to be just one more display type crushed in the marketplace by high-quality LCDs.

The ubiquity of transparent thin-film transistor (TFT) LCD displays makes them the obvious platform to attempt to convert into transparent displays, and we see this segment



representing being the main area of focus (and revenues) over the next few years. In their simplest form they consist of an LCD matrix with a backlighting unit (BLU), color filter, and some kind of (active or passive) backplane. To make a transparent LCD display, however, requires everything that sits behind the matrix to be transparent -- in particular, there is the problem of how to create "invisible" backlighting and color filters. Simply relying on ambient light is a serious drawback and not easily overcome; when there is no light the display doesn't work. And removing color filters represents a huge sacrifice, and likely to be severely penalized in the marketplace where solutions must visibly stand out.

Why Transparent OLEDs Make Sense

Due to the serious limitations with producing transparency in other display technologies, the industry is gradually shifting to organic light emitting diode (OLED) technology, which is easier to turn into transparent displays because of two key advantages. First, OLEDs are emissive and provide excellent color without backlighting or color filters, though there is still a need to hide the TFTs. We note that most of the activity in the transparent display space is OLED-based, which suggests just how tricky the transparent display makers see the whole BLU issue. Second is a relative ease of manufacturing compared with LCDs, though large OLED's poor yields often offset the supposed manufacturing advantages (we expect this to continue to improve, however).

Truly making OLEDs transparent, however, is perhaps better qualified as "easier" than the other options rather than "easy," with several areas needing to be solved:

- Replacement of the usual metallic cathode with indium tin oxide (ITO) or some other transparent conductive oxide (TCO)
- Compensate for excessive light loss, controllable to a degree by introducing slight asymmetry in electrodes' local transmittance
- Disruption of displayed images caused by light coming from the background
- Replace the metal cathode with a transparent conductor, though this is a minor problem

Gradually these issues are being solved, and NanoMarkets expects progress to accelerate. Over the past two years OLED technology has begun to feel much more mainstream, primarily because of one factor (and benefactor): Samsung and its use of OLED in its cell phones. Yet we note there has been no great consumer clamor for OLED displays in popular products (cell phones, tablets, and TVs), so further OLED penetration depends on its promised cost-savings to manufacturers (presumably passed along to consumers to sweeten the pot). What the transparent OLED display really needs is some kind of broad strategy around architecture and applications with put some weight behind it.



Where We See Markets for Transparent OLED Displays

Generally, our expectation is that at least at first, OLEDs will not completely overtake LCD displays in most applications where transparent displays are options; in some cases it will lag far behind, if it makes any inroads at all. Nonetheless, we identify five categories where we see opportunities for transparent OLED displays:

Consumer/Mobile Electronics The big incentive here are massive addressable markets where even small penetrations for transparent displays can lead to large revenues. We believe smartphones and tablets will be the primary targets of the transparent panel manufacturers in the near- to medium-term. Transparent laptops and notebooks are still in the conceptual stage after failed commercialization attempts by established firms such as Samsung and Sony. This category involves far more business-use-case criteria than phones or tablets; novelty in design is less desirable, and there seems to be a lack of other truly desirable features for business users e.g. security.

Wearable Computing We narrow this down to segments that would (or could) use transparent displays: non-military head-mounted displays (HMD) and heads-up displays (HUD), smart glasses, and smart watches. In HUDs (i.e. helmets), AMOLED technology offers attractive luminance enhancing and weight-reduction capabilities. Initial signals from the developing category of smart glasses suggests this could be a serious challenge to smart phones, and thus move microdisplays into a position of prominence, which could include pursuit of OLEDs; several smart-glasses companies have been developing around (or rumored to be considering) OLED in their devices. And then there are the budding crop of smart watches now hitting the market or soon to do so, from everyone from Samsung to LG to Apple and other suppliers, and transparent OLED displays seem to be emerging as front-runners in these products.

Retail applications Amid a slow growth phase for the global retail industry, retail store owners are scouting for ways to engage and draw consumers to the stores. These obviously include high-quality interactive display solutions, as well as in-store display cases and vending machines. There is a potential market here for transparent OLED display technology, with emphasis on display cases, advertising windows, and touchscreens -- though less so in outdoor retail display environments due to current OLED performance issues.

Automotive NanoMarkets believes that transparent windshields and dashboard displays can be a possibility in the distant future, assuming collaborative research efforts between car OEMs and the scientific community leads to commercially viable options. Several major automakers are involved with projects in this area, including Ford, GM, BMW, and

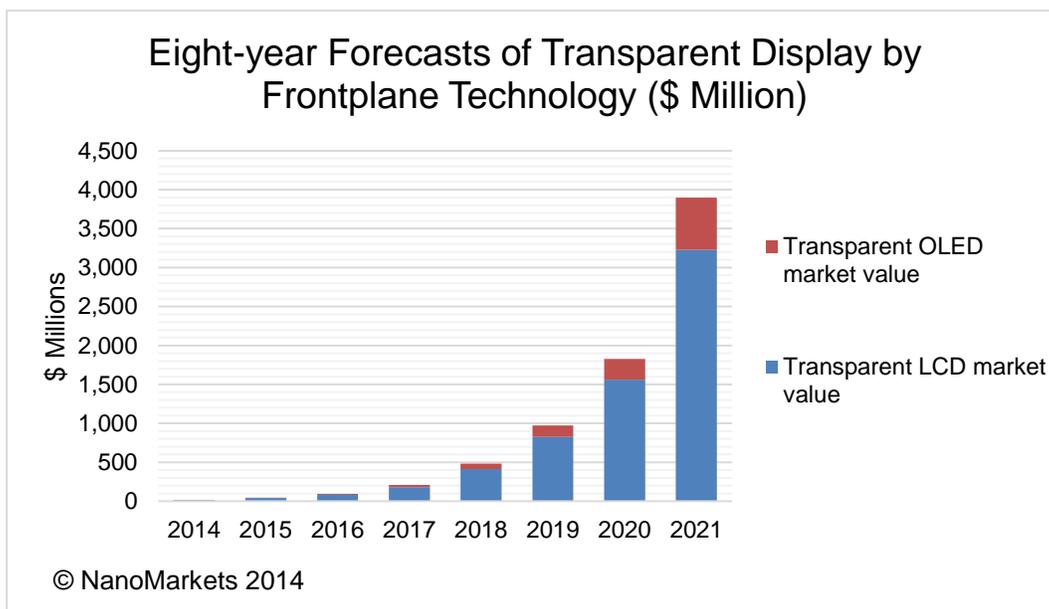


Kia Motors, working with suppliers including SuperImaging, Panasonic, Futaba, and NeoView Kolon.

Military Research is underway to develop prototypes that employ transparent AMOLED displays for military applications, most notably HUDs/HMDs. This is a truly niche market, but military end-users have keen appreciation of functionality over style (and is famously far less price-sensitive), so the aforementioned OLED benefits resonate well within this market segment.

Bottom Line Numbers

While we see the transparent display market as dominated by LCDs throughout the next several years, by 2019 or so, OLED participation in the transparent display market will reach almost \$150 million, and rapidly pick up steam toward the end of our forecast period to nearly \$700 million.



From the NanoMarkets report, [“Transparent OLED Displays – 2014”](#)