Daiwa Capital Markets

Special Report

Information Technology / Asia ex Japan

29 August 2013

The 10-second briefing

Get ahead of the curve

- In this MadeEasy report, we explain and explore the OLED-display technology now being used in an array of gadgets
- We expect OLED displays to rise in prominence given their superior image quality and potential to be cheaper than LCDs
- Find out about the next wave of flexible OLED displays and which companies stand to benefit as the market expands

OLED DISPLAYS

made easy

Jae H. Lee
(82) 2 787 9173
jhlee@kr.daiwacm.com

Joshua Oh, CFA
(82) 2 787 9176
joshua.oh@kr.daiwacm.com

See important disclosures, including any required research certifications, beginning on page 34

Please also see:

Korea OLED-display Sector: Initiation: catch the next wave in OLED displays

29 August 2013

Jae H Lee(82) 2 787 9173 (jhlee@kr.daiwacm.com)
Joshua Oh (82) 2 787 9176 (joshua.oh@kr.daiwacm.com)

Get ahead of the curve

OLED displays: what they do today, how they do it, and what is next in the pipeline

In this report in Daiwa's *MadeEasy* series, we explain, in layman's terms, OLEDs – organic light-emitting diodes – along with their development and drivers. We examine how companies are embracing OLED displays in their latest products, and what the future holds for OLED displays of all shapes and sizes as the underlying technology is refined and production yields improve.

As of today, the main manufacturers of OLED displays are Korea's Samsung Display and LG Display. Samsung Electronics (SEC) and Sony were the first companies to launch commercial products featuring OLED displays. SEC first rolled out OLED displays in its mobile phones in 2007, and in the same year Sony launched an 11-inch OLED-TV. However, Sony discontinued its OLED-TV in 2010, primarily because the device was expensive (retailing for USD2,500) and the screen was too small compared with conventional TVs.

From smartphones to TVs, many makers of electronic products globally are facing slowing market demand and falling product prices, and thus are seeking ways to differentiate their products. For some applications, the current generation of OLED displays serves as a useful differentiating factor.

In January 2013, LG Electronics (LGE) (066570 KS, KRW71,900, Hold [3]) was the first company to launch a large (55-inch) OLED-TV. Nokia has adopted OLED screens in some of its line of smartphones, in preference to LCD displays, while Motorola's new flagship phone, the Moto X, sports a 4.7-inch OLED screen. Clearly, the adoption of OLED technology is accelerating.

■ **Electronic devices currently using OLED displays**

Source: GSMarena, Daily Tech, Instash.com

Smartphones: what's next?
Smartphone specifications continue to evolve, with the latest cutting-edge technologies, but innovation seems to have slowed. Displays are getting larger and image resolution is improving, but where is the 'wow' factor?

Imagine having a smartphone with a foldable display that can double as a tablet PC when the screen is unfolded. We believe future-generation OLEDs will emerge as a game-changing technology for smart devices, making them bendable and rollable, and allowing companies to innovate once more with fresh product designs.

TVs: what's next?
In the TV segment, compared with conventional LCD TVs, OLED-TVs offer better picture quality, higher contrast ratios (the blacks are really dark and whites are really bright), and lower power consumption. Both SEC and LGE already offer OLED-TVs featuring curved displays and super-thin designs. Product retail prices are still high, but we expect them to decline sharply as production yields improve. As we believe the LCD-TV market has matured, we expect an increasing number of LCD-panel makers to shift their production to OLED displays over the short to medium term.

Other applications
As well as for smartphones, OLED displays could be used in small devices such as cameras, music players and vehicle navigation systems. Moreover, we expect OLED lighting to gain a hold in the consumer market in the coming years, as future generations of the technology should have several advantages over existing solutions.

Major OLED players

The OLED supply chain is currently dominated by Korea companies, with Samsung Display (Not listed) accounting for more than 96% of global OLED production capacity for 2012. As investment in OLED technology is just taking off, we believe the key beneficiaries in the coming months will be related equipment companies, followed by materials companies.

Our top picks in the OLED space are Korea players:

- **Samsung Electronics** (SEC, 005930 KS, KRW1,309,000, Buy [1]) as the company is the largest user of OLED displays in its consumer devices, and because it has a major stake in Samsung Display (Not listed).

- **SFA Engineering** (SFA, 056190 KS, KRW50,700, Buy [1]) as it is an all-around equipment player and it is highly likely that it will provide the core deposition equipment used in OLED-TV production lines going forward.

- **Wonik IPS** (Wonik, 030530 KS, KRW6,570, Buy [1]) for its growing exposure to OLED-display equipment and to NAND flash.

- **Duksan Hi-Metal** (DHM, 077360 KS, KRW23,450, Buy [1]), on the back of the potential revenue growth that we see from the development of organic materials used to make OLED-TVs.

We trust that you find this *Made Easy* report a useful guide to the OLED industry, and look forward to receiving your feedback.

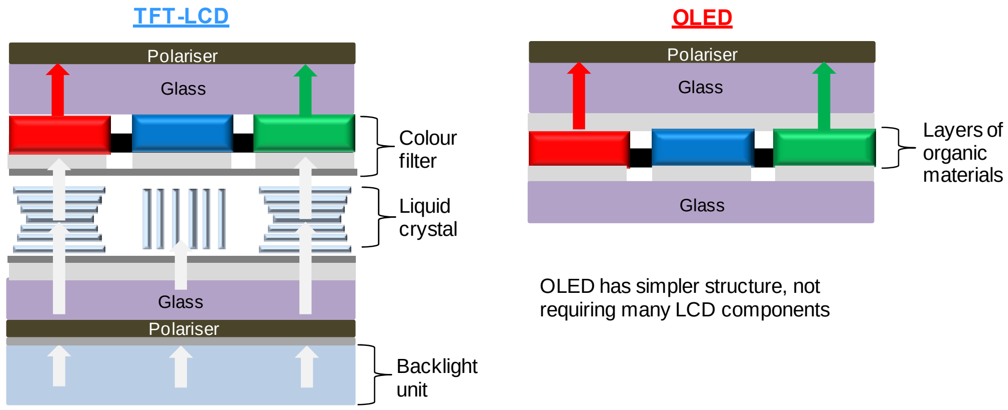
OLEDs explained

Unlike LCDs, OLEDs emit their own light

Simply put, OLED is a display technology in which organic materials are placed between two pieces of glass. When an electrical current is applied, a bright light is emitted from the display. The structure is somewhat similar to that of a conventional liquid-crystal display (LCD), which has liquid crystals between two glass substrates. However, the structure of an LCD is more complex because, unlike OLED, LCD requires backlighting and colour filters in order to emit light.

OLEDs have a simple structure

■ Comparison of the structure of OLED displays and LCDs



Source: Companies, compiled by Daiwa

Q. WHY IS IT CALLED ORGANIC?

A. This has nothing to do with organic food; it is because the core material is made up of carbon and hydrogen.

Q. HOW DO OLED DISPLAYS COMPARE WITH LCDS?

OLED displays consume less power and have a higher contrast ratio (the blacks are much darker and the whites much brighter) than LCDs, as OLEDs emit their own light. Therefore, they can simply turn pixels off and on, whereas with an LCD the backlight is constantly turned on and the liquid crystals are used to block or emit light. In addition, OLED displays have a broader colour spectrum, faster response time, and a lighter weight (as they have fewer components) than LCDs.

However, the current generation of OLED displays is not perfect. One major disadvantage is that they are more expensive than LCDs; OLED displays in handsets are typically priced at a 20% premium to LCDs, and the price premium is substantially larger for OLED-TVs (about 5-6x, according to our industry research). When OLED displays were first commercialised in 2007, their short lifespans and limited visibility in sunlight were also disadvantages. However, over the past few years we have seen steady improvements made in both aspects.

■ Comparison of today's OLED displays and LCDs

	OLED	LCD
Power consumption	Lower than LCD	Lower than plasma but higher than OLED
Backlight	No	Yes
Viewing angle	170 degrees	160 degrees (colour appears to shift when viewed from the side)
Contrast ratio	65,000:1 – 1,000,000:1	15,000:1
Production cost	High	Low
Flexible display	Yes	No
Lifetime	Up to 50,000 hours	50,000-100,000 hours
Thickness	4mm for OLED-TVs	8-15mm for LCD-TVs (with LED backlight)

Source: Companies, Daiwa

Q. WHAT ARE OLED DISPLAYS USED FOR TODAY?

A. OLED displays were initially used by SEC in its mobile phones in 2007. Since then, the company has expanded the use of the technology to all of its premium smartphone range, and we expect SEC to use OLED technology in its tablet PCs in 2014. Meanwhile, LG Electronics launched OLED-TVs in January 2013, selling at a retail price of USD10,000/unit.

Q. WHY DO SOME PEOPLE STILL PREFER LCDS OVER OLED DISPLAYS IN SMARTPHONES?

A. OLED displays have a much wider colour spectrum than LCDs. But bigger is not always better, as the colour in, say, photos, may seem over-saturated on OLED displays. Therefore, some people may feel that the colours produced by OLED displays differ too much from those in the actual image. Technical engineers we have spoken to tell us that as many people are used to watching LCD-TV screens at home and using LCD monitors at work, they may feel more comfortable with smart devices that feature LCD screens.

Q. WHY DOES MY SMARTPHONE WITH AN OLED SCREEN CONSUME AS MUCH POWER AS ONE WITH AN LCD?

A. Power consumption depends on the image, as OLEDs use power for each pixel that is illuminated. If the image has an all-white background, then the OLED display will consume more power than an LCD; the reverse applies for images with an all-black background.

Different types of OLED displays

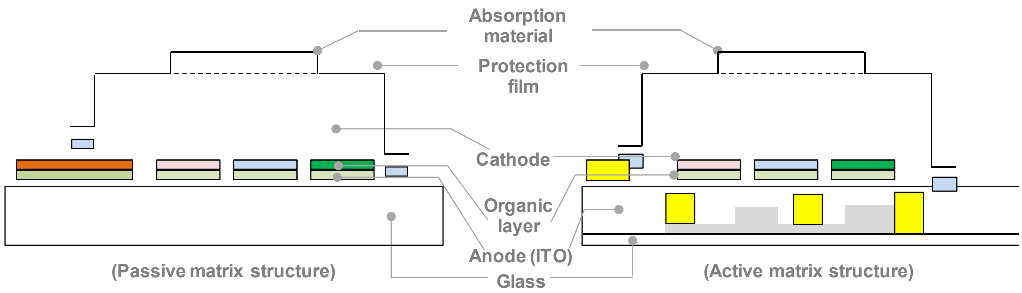
AMOLEDs vs. PMOLEDs

AMOLED displays use a TFT backplane

In pure technology terms, there are two types of OLEDs: active-matrix OLEDs (AMOLED) and passive-matrix OLEDs (PMOLED). The main difference between them is the driving electronics, ie, how the display is controlled.

With PMOLED, the display is controlled by switching on rows and columns, so there is no need for individual transistors. AMOLED displays, by contrast, require a thin-film transistor (TFT) backplane (shown in the chart below as bottom glass) to switch each individual pixel on or off, but they can be made into higher-resolution, larger-size displays than PMOLED.

■ Comparison of the structure of AMOLED and PMOLED



Source: Companies, Daiwa

Because PMOLED does not require a backplane, it is easier and cheaper to produce than AMOLED. However, the use of PMOLEDs is limited to small-size screens (normally less than 3”), which are used for displays in portable music players and as sub-displays for clam-shell type (folding) feature phones. With AMOLEDs, each pixel is controlled directly, so less power is consumed than with PMOLEDs, and therefore they are used in a wide range of displays, from 5” smartphones to 55” TVs.

■ AMOLED and PMOLED display technology in use today

Source: Luxatic, OLED-Info, GSMarena

What about Super AMOLED, Super AMOLED Plus, and HD Super AMOLED and full HD AMOLED?

Same OLEDs, but with different sub-pixels

Samsung Display has developed a number of variants on AMOLED technology, which collectively it terms Super AMOLED. With its Super AMOLED displays, touch sensors are integrated on the top glass layer of an AMOLED before encapsulation, in which the display is sealed in a vacuum to protect it from moisture and oxygen. This results in a thinner display that uses less power and reflects less light than standard AMOLED displays, resulting in better viewing outdoors.

■ Comparison of TFT-LCD, AMOLED and Super AMOLED displays

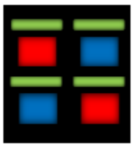
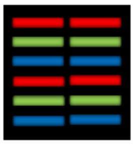
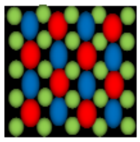
Source: Android Playa

The only practical difference between Super AMOLED, Super AMOLED Plus, and high-definition (HD) Super AMOLED display is the structure of sub-pixels in the display. Normally, within one pixel there are three sub-pixels – red, green, and blue – which are combined to create different colours. However, Samsung Display applied the PenTile method for the AMOLED display used in SEC's Galaxy S smartphone in 2010, which has a different sub-pixel layout compared with conventional LCD screens and previous OLED displays. Rather than having three (RGB) sub-pixels, Pentile uses alternating red-green and blue-green sub-pixels, which take advantage of the human eye's sensitivity to the colour green to display the same image using fewer sub-pixels.

The Pentile method is cheaper to produce but has inferior colour fidelity and text crispness than displays that use three sub-pixels for each pixel. Super AMOLEDs were used in SEC's first Galaxy S series smartphone. However, for the Galaxy S II smartphone, the company switched to Super AMOLED Plus, which uses all three (RGB) sub-pixels within each pixel to improve visual sharpness. For the Galaxy S III smartphone, Samsung Display developed HD Super AMOLED, which increased the display resolution to 1,280x720, from 800x480 previously.

For its latest Galaxy S4 smartphone, SEC uses full HD AMOLED, which uses the same underlying technology as HD Super AMOLED but has a resolution of 1,920x1,080. S4's full HD AMOLED has a 44% higher pixel-per-inch count than that of the Galaxy S III, and is 25% brighter and 20% more power-efficient. The screen for the Galaxy S4 smartphone also uses AMOLEDs utilising the Pentile method, but the layout of the sub-pixels is diagonal rather than in horizontal blocks (see the following pictures), so as to increase the pixel count, resulting in a substantial improvement in visual sharpness.

■ **Comparison of Super AMOLED displays in Galaxy-series smartphones**

	Galaxy S	**Galaxy SII**	**Galaxy SIII**	**Galaxy Note2**	**Galaxy S4**
					
Layout for pixels	PenTile	RGB stripe	PenTile	S-stripe (RGB)	PenTile (diamond pattern)
Deposition method	FMM	FMM	FMM	FMM	FMM
PPI	233	217	306	267	441
Resolution	800X480	800X480	1280X720	1280X720	1920X1080
Size	4.0-inch	4.3-inch	4.8-inch	5.5-inch	5.0-inch

Source: HDTV Magazine, Companies, Daiwa
Note: FMM = fine metal mask; PPI = pixels per inch

From a user's perspective, resolutions are fairly similar

How does OLED compare with IPS LCDs?

IPS, or in-plane switching, is technology used in some LCDs. IPS LCDs are typically found in high-end smartphones, tablets, and monitors, and offer better colour representation and viewing angles than conventional LCD panels. Apple's Retina Displays use LCD screens based on IPS technology. The term Retina Display refers to screens that have a high resolution and pixel density, such that users cannot distinguish individual pixels at a normal viewing distance.

As smartphone makers are increasingly using high-end components to differentiate their handsets, when it comes to displays, full-HD resolution and high-pixel density are becoming extremely important. Although many high-end smartphones now feature 1080p screens (full HD resolution), the HTC One (made by HTC Corp) has the highest pixel density currently of 468ppi, while the Galaxy S4 (SEC) and Xperia Z (Sony) have a pixel density of 441ppi, followed by the Lumia 920 (Nokia) with 332ppi, the iPhone 5 (Apple) with 326ppi, and the Galaxy S III (SEC) with 306ppi.

When comparing close-up images of the displays used in various smartphones, we notice that the resolution of the AMOLED display used in the Galaxy S4 has improved substantially compared with that used in the Galaxy S III, and that it is difficult to discern the Pentile layout of the pixels on the display of the Galaxy S4 – a common criticism of earlier models featuring Pentile layouts.

■ **Close-up comparison of displays in key flagship smartphones**

Source: phoneArena

Q. WHICH DISPLAY IS BETTER: AMOLED- OR IPS LCD-BASED?

A. Each display has its own strengths and weaknesses, and at similar resolutions we believe they are now quite comparable. LCDs currently offer sharper and more vibrant colours than AMOLED displays, and as a result, Apple's CEO Tim Cook argues that LCDs are a superior choice. However, AMOLED is an emerging technology and has the potential to challenge the best performance of the best LCD, in our view. In addition, the unbreakable and flexible features that AMOLED displays will offer in the future cannot be overlooked.

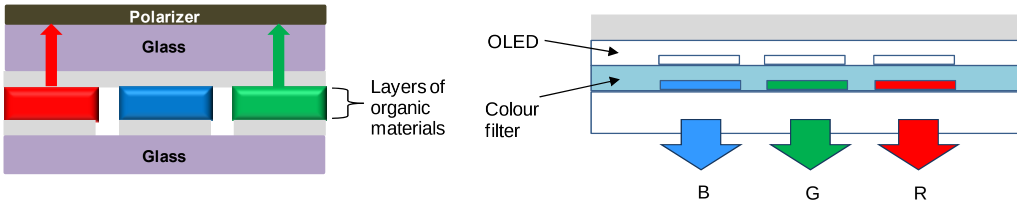
RGB and white OLED displays

White OLED displays use a colour filter

In the TV market, there are currently two different types of OLED-TV: RGB-OLED-TVs (manufactured by Samsung Display) and white-OLED-TVs (produced by LG Display). Although both types function similarly, RGB-OLED-TVs use separate red, green, and blue sub-pixels to emit colours, while white-OLED-TVs use white pixels with colour filters. White OLEDs are less efficient than RGB OLEDs, as some of the light is filtered out by colour filters and more emitting material may be required to improve its brightness.

However, white OLEDs are easier to produce, as an open mask is used to deposit white organic materials, rather than having a separate mask for each colour. Although white OLEDs could be cheaper to produce as they require less manufacturing investment, at the end of the day, we believe that having a high production yield is more important.

■ Comparison of the structure of RGB and white OLEDs



Source: Daiwa

Q. WHY ARE OLED-TVS SO EXPENSIVE?

A. LGE's 55" OLED-TV retails currently for KRW11,000,000 (USD10,000) in Korea, which is expensive in anyone's book. However, OLED companies expect OLED-TVs to sell at similar prices to those of existing high-end LED-TVs (the current retail price in Korea is about KRW3,000,000 [USD2,700]) within 2-3 years. The production yield for OLED-TV panels is only about 50% currently, pointing to significant room to improve production efficiency and bring down costs.

Q. WHICH OLED-TV IS BETTER: ONE MADE WITH RGB OLEDS OR ONE WITH WHITE OLEDS?

A. Many experts contend that the picture quality of an RGB-OLED-TV is superior to that of a white-OLED-TV. For its part, LGE argues that white OLEDs have greater colour accuracy than RGB OLEDs, as they have one extra white pixel in the colour filter compared with RGB OLEDs.

If the quality of two display technologies is similar, the production cost is likely to be a factor in determining which technology ultimately secures the biggest share of the market. Since white OLEDs are easier to manufacture currently, their cost is likely to be lower. However, the production yields for white OLEDs and RGB OLEDs are similar, at less than 50%, so the key factor, in our view, is which company can reduce manufacturing costs the fastest: producers of white OLEDs or RGB OLEDs.

Flexible displays

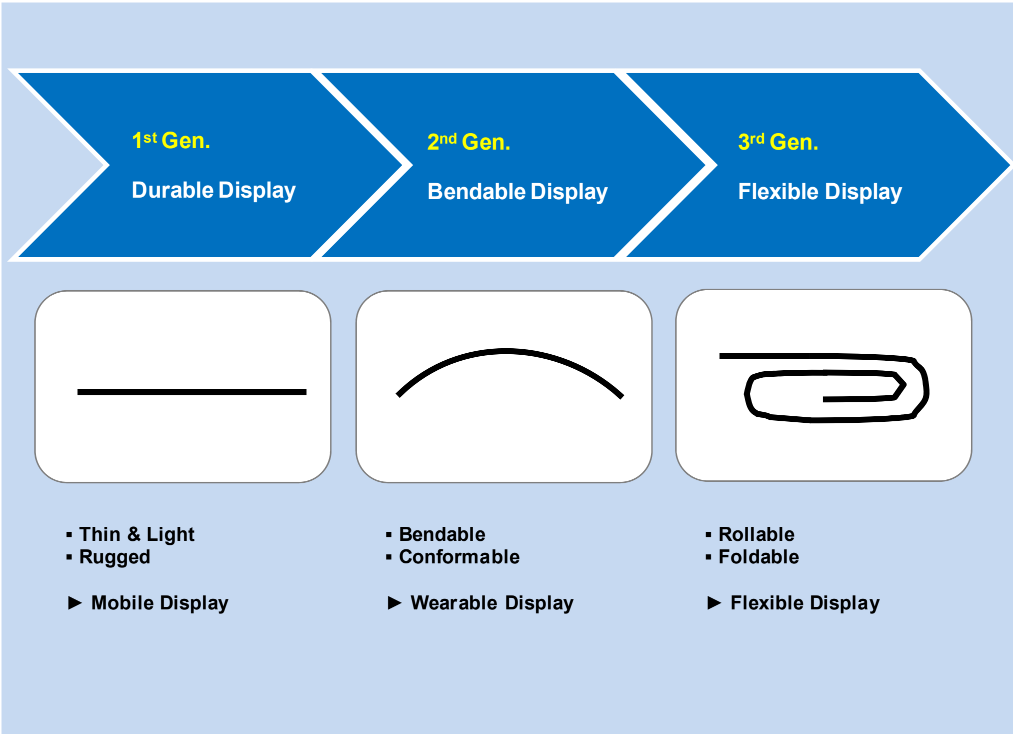
Flexible display: a game-changing feature

One of the exciting features of the OLED technology is the potential for end-products to be physically flexible. Although there are currently no products on the market that take advantage of this trait (due to difficulties in the manufacturing process), both Samsung Display and LG Display plan to launch first-generation products featuring a flexible substrate before the end of 2013.

Plastic-based substrates should allow for lighter, thinner and unbreakable products. We believe that the first-generation products are likely to be durable displays, ie, essentially unbreakable. Both Samsung Display and LG Display (034220 KS, KRW29,350, Hold [3]) are targeting to launch related products in 4Q13, though neither has offered further details.

Based on our research of the OLED makers, we believe that second-generation products will evolve into bendable or curved displays, and that later generations could ultimately take the form of a display that is foldable and/or rollable.

▪ The next steps in OLED's evolution



Source: Daiwa

Q. WHY IS IT SO DIFFICULT TO MAKE A FLEXIBLE DISPLAY?

A. Firstly, there are limitations to the current manufacturing process for non-glass (plastic or film) substrates that expand or change form at high temperatures. In addition, encapsulating (ie, vacuum-sealing) organic materials is challenging as these are extremely sensitive to water vapour and oxygen, causing rapid degradation.

Samsung Display is currently adopting a film-type encapsulation, in which seven layers of organic and inorganic materials are stacked together using an atomic-layer-deposition system in order to protect the product from vapour and oxygen.

How OLED technology will affect our lives

OLED displays have the potential to be used in exciting new applications

OLED technology is evolving rapidly and is likely to lead to many new exciting applications in the future. Although the technology is used mostly for the main displays in smartphones today, we will soon see it used more in TVs, information displays (in buildings and automobiles), and general lighting. We also believe mobile devices that have a flexible display will be a game-changer. Imagine unfolding a smartphone and it immediately becoming a tablet, or rolling out the display from a pen-like cylinder.

▪ Potential applications for OLED in mobile devices

Source: Companies

Meanwhile, as a light source, OLED lighting promises to be thinner, lighter, and more transparent than a piece of glass emitting light. This means your window could let in sunlight during the day, and at night, the same surface could turn into a light. It will likely be a few more years before OLED lighting makes it to the mass market.

▪ Potential OLED applications for general lighting

Source: Siemens, fubiz.net, oled-display.net

How OLEDs work

We have looked in broad terms at the technical differences between OLED displays and LCDs, and highlighted the advantages of OLED displays as the underlying technology continues to mature. For readers seeking an understanding of the technical underpinnings of OLED displays and the complex production processes needed to manufacture them, we now dig deeper.

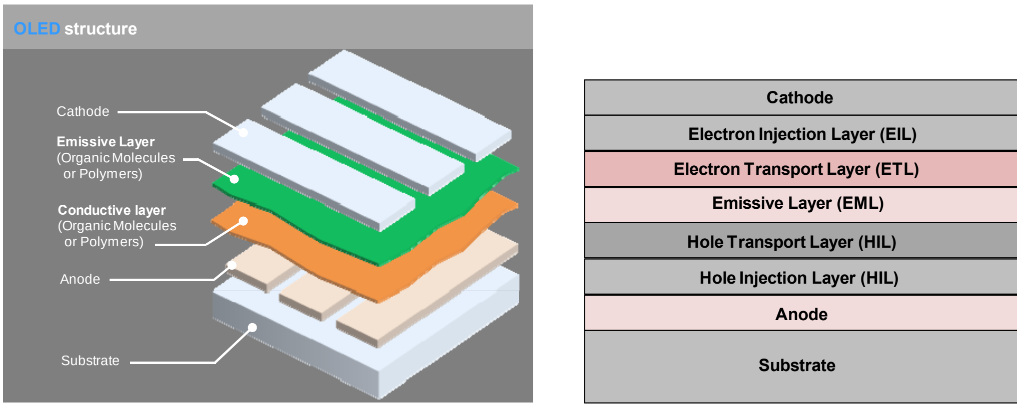
We have made this section as "easy" as we can, but readers who did not excel at physics in high school can skip to pages 23-25, on which we show where the major players fit into the OLED value chain and provide a glossary of terms.

Basic structure

Targeting more efficient devices, some companies now use 7-10 layers in their designs

The basic structure of an OLED comprises a **cathode** (which injects electrons when a current flows through the device), an **emissive layer** (where the light is made) and an **anode** (which removes electrons when a current flows through the device). However, in an effort to create more efficient devices, some companies apply 7-10 layers in their design. The chart below shows the OLED structure adopted by Samsung Display, which has 8 layers including the glass substrate.

■ OLED structure



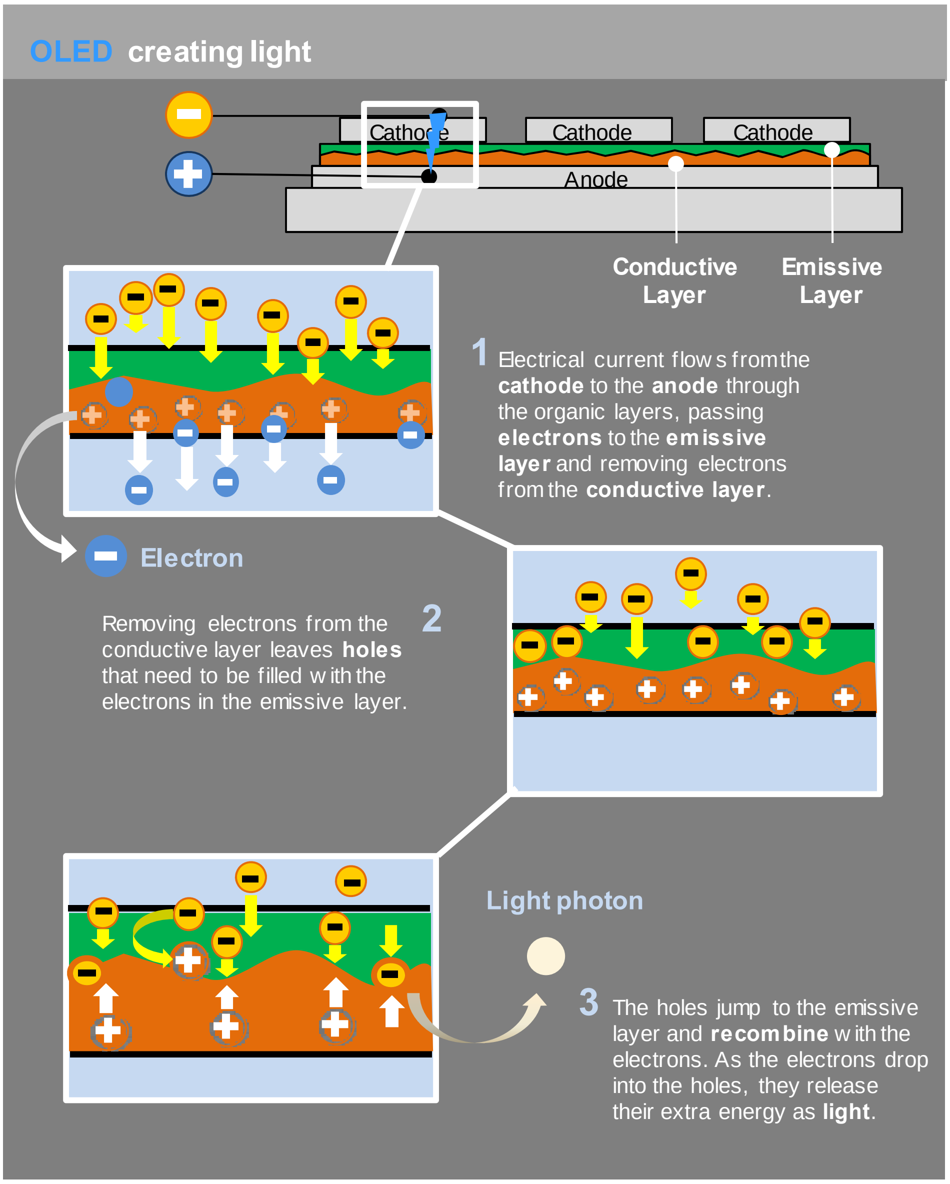
Source: HowStuffWorks, Daiwa

How light is created with an OLED

Electrons move from the cathode to anode through layers of organic material

With an OLED, electrical current flows from the cathode to the anode through several layers of organic material. The cathode passes electrons to the emissive layer, and the anode removes electrons from the conductive layer (creating holes in the conductive layer). At the boundary, between the emissive and conductive layers, electrons find electron holes and in the process create a photon of light.

■ **OLED: how light is created**



Source: HowStuffWorks, Daiwa

How OLEDs are made

Four major manufacturing processes for an OLED

Main manufacturing processes

Manufacturing OLEDs involves four major processes: backplane, deposition (evaporation), encapsulation and modularisation.

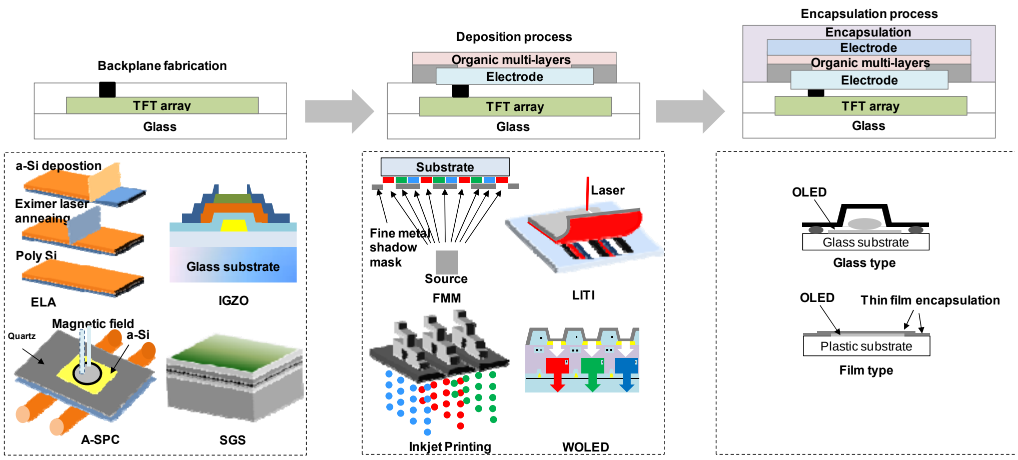
- The **backplane** process entails creating switches and a driving mechanism for the OLEDs.
- The **deposition** process is the formation of sub-pixels and depositing organic materials onto the substrate.
- **Encapsulation** involves placing an additional protection layer to seal and protect the OLED from water vapour and oxygen.
- Finally, the **module** process involves cutting substrates into smaller sizes, etching the glass to make it thinner, attaching electronic circuitry, and testing.

■ OLED manufacturing processes

Backplane	Deposition	Encapsulation	Module process
Semiconductor layer Pattering Gate electrode Pattering Source drain electrode Pattering Passivation Pattering Pixel electrode Patterning - Cleaning - PR coating - Exposure - Develop - Etch - PR remove - Inspection	Plasma/ UV treatment HIL deposition HTL depostion Blue layer deposition Green layer deposition Red layer depostion ETL deposition EIL depostion Metal electrode deposition - Alignment - Evaporation source - Glass handling	Canister/ cover glass Cleaning Attach getter Sealent dispensing Sealing (UV)	Aging Cell cutting Probe testing Pol. lamination COF bond

Source: YAS, Daiwa

■ OLED manufacturing processes: illustrated



Source: Daiwa

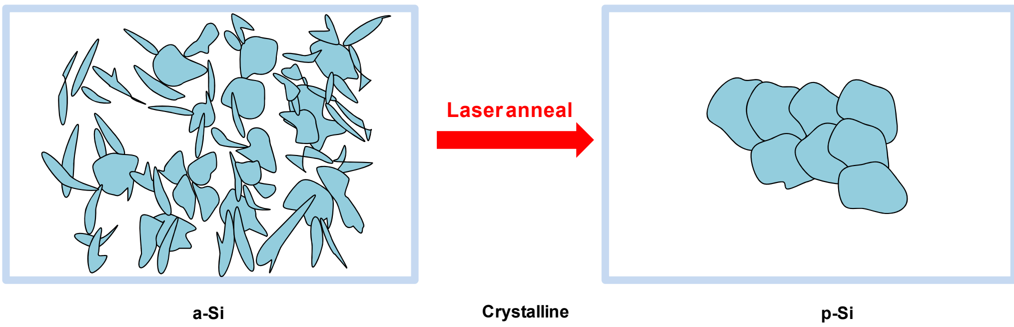
OLED backplane

Three major backplane technologies

The backplane is responsible for turning the individual pixels on the display on and off. It is composed of thin film transistors (TFT), which act as switches. There are three major backplane technologies: amorphous-silicon (**a-Si**), low-temperature poly-crystalline silicon (**LTPS**) and **oxide** (indium gallium zinc oxide [IGZO]).

a-Si TFT technology is widely used in the manufacture of TFT-LCDs. However, electron mobility, or the speed of electrons, is slow and is not appropriate for OLED backplanes. Meanwhile, LTPS allows for smaller, faster-switching LCDs, meaning that the electron mobility is 100 times greater than with a-Si TFT technology. The key difference between a-Si and LTPS is that LTPS uses a laser-annealing process to change amorphous silicon to poly-crystalline silicon, since poly-crystalline silicon has better carrier (electron and hole) mobility. Therefore, a user of OLED displays based on LTPS technology would not see ghosting on the display or become dizzy watching pictures moving at high speed.

■ Laser-annealing process for LTPS backplane



Source: Daiwa

However, LTPS is an expensive technology because of the large initial investment and ongoing maintenance costs. LTPS has higher manufacturing costs compared with a-Si due to its longer manufacturing process, extra masking steps required, and the additional laser-annealing process needed to crystallise the silicon. In addition, there are limitations on the laser-beam length, while the largest equipment available currently is applicable only to Gen6 (a glass substrate with a size of 1,500 x 1,850mm). Hence, the costs associated with LTPS may not decline as quickly as other processes, as companies need to work on larger glass substrates in order to cut more panels.

Oxide backplanes are better suited to large displays

Meanwhile, metal oxide, or simply a backplane that is made using the oxide technology, has properties somewhere between those of a-Si and LTPS. An oxide backplane is easier to manufacture than a LTPS backplane as it can utilise the existing a-Si facility in the LCD production line and fewer mask steps are required to create the transistors. In addition, the electron mobility is greater than that of a-Si, at 10-40cm^2/V-sec. Therefore, OLED displays with an oxide backplane could be cheaper to produce than OLED displays with a LTPS backplane.

However, an oxide backplane is not well-suited for the OLEDs used in small displays. Oxide transistors are not stable and may cause pixel-to-pixel variations. An additional transistor is needed to compensate for signal variations, but since each pixel in an OLED requires two transistors (one to switch the pixel on and off, and the other to control the current), there is not enough room on small displays to place three metal-oxide transistors per pixel. Therefore, OLED displays using an oxide backplane are more suited for use in TVs than mobile applications.

We believe oxide backplanes are well suited for use in displays for large-sized high-resolution TVs (LCD or OLED). In fact, LGD currently uses oxide backplanes to produce its OLED-TVs. However, for Samsung Display, LTPS is the preferred technology, even for OLED-TV backplanes, as the company believes LTPS is more stable for now. In addition, according to a few equipment companies, Samsung Display has managed to scale up LTPS for its Gen8 line substrates.

■ Comparison of backplane technologies

	a-Si TFT	LTPS	Oxide
Substrate	Gen8	Gen5.5	Gen8
Semiconductor	Amorphous silicon	Poly-crystalline silicon	Amorphous IGZO
Channel mobility	1cm^2/V-sec	100cm^2/V-sec	10-40cm^2/V-sec
Number of masks	4-5	5-11	4-5
Production cost	Low	High	Low
Circuit integration	No	Yes	Yes
TFT uniformity	Good	Poor	Good
Stability	Poor	Excellent	Poor

Source: Information Display

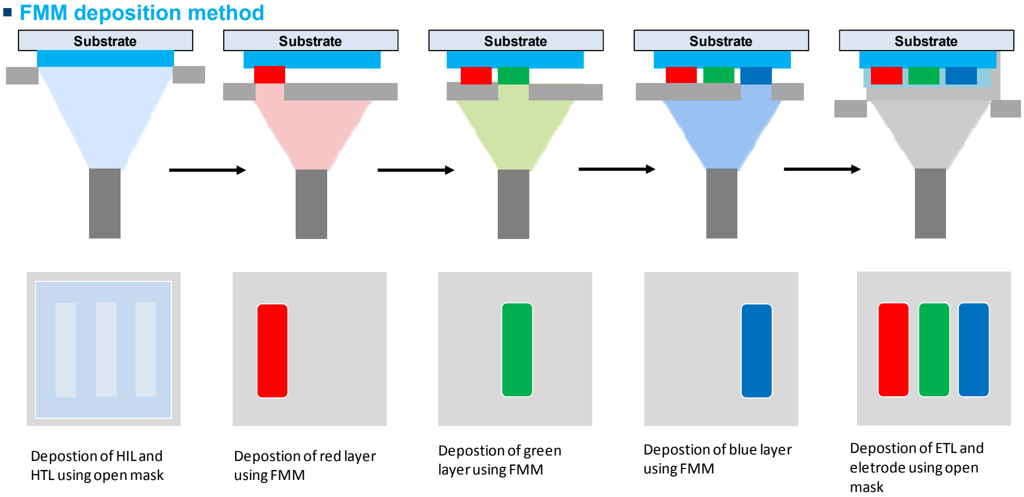
OLED deposition

Three major deposition technologies

In the OLED deposition process, organic materials are deposited or evaporated onto the backplane and individual sub-pixels are patterned. There are three major deposition technologies: using a fine metal mask (**FMM**) in vacuum evaporation, laser induced thermal imaging (**LITI**), and **inkjet printing**.

FMM is the deposition method most commonly used by OLED companies (particularly for small displays), and almost all of Samsung Display's Gen4 and Gen5.5 production lines are based on this technology. In the vacuum chamber, organic materials are heated, evaporated and then condensed on to the substrate. By using a metal mask with fine slits, organic layers are created on the substrate. However, it is difficult to form a superfine pattern, and difficult to apply it to large displays due to deformation of the mask. In addition, this method is expensive, as most of the organic materials end up on the walls of the vacuum chamber, rather than just small portion being evaporated directly on the substrate.

■ FMM deposition method

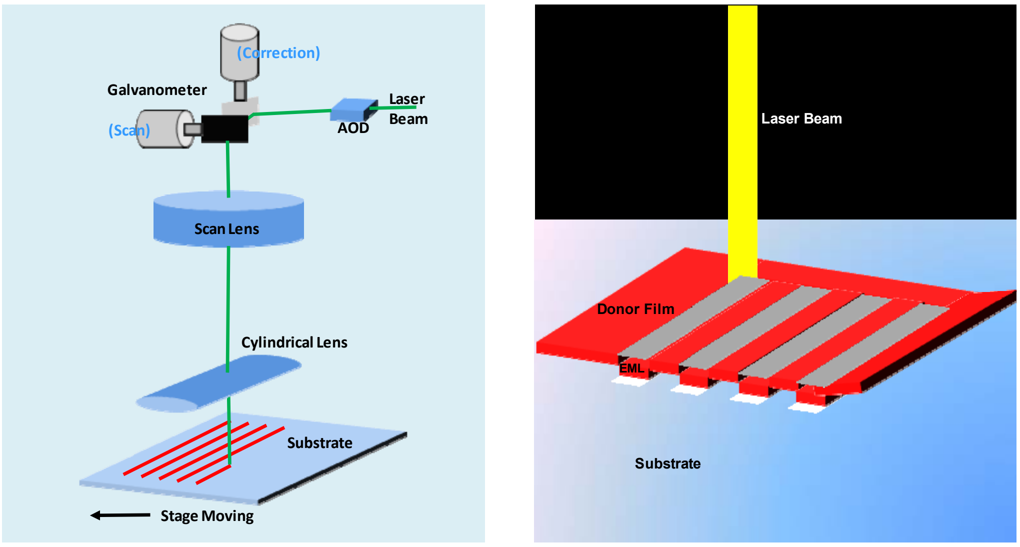


Source: Daiwa

LITI allows for high-resolution pattering of organic materials. In LITI, an imaging layer (a donor film with organic materials) is closely adhered to an acceptor substrate and then organic materials are transferred by scanning a laser to a donor film. However, LITI may induce thermal transfer defects within OLED materials. In addition, there are particle issues to deal with when laser is scanned to a donor film.

Using a laser beam to adhere organic material to a substrate

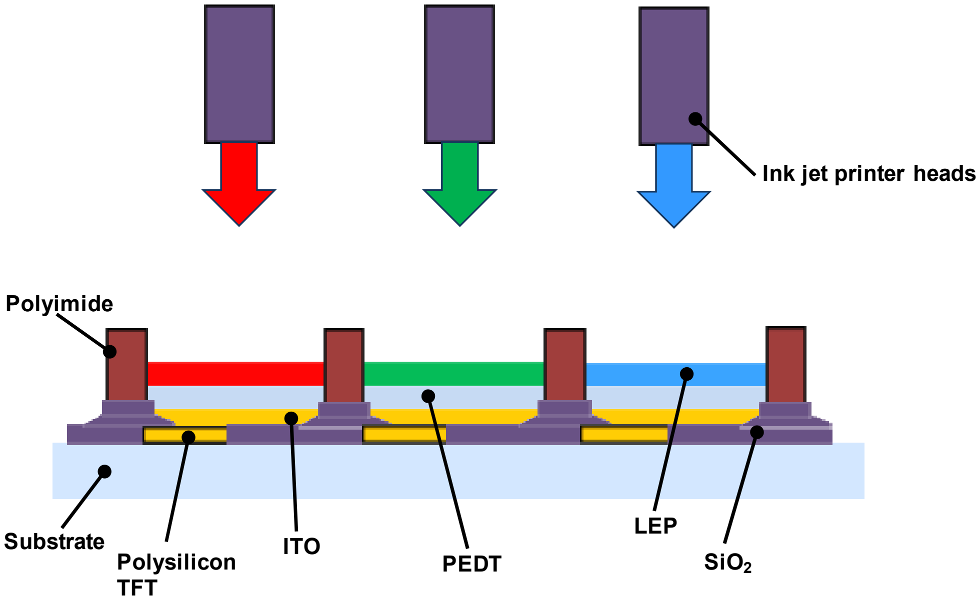
■ **LITI deposition technology**



Source: Daiwa

In the inkjet process, an organic layer is formed by discharging an organic solution from inkjet printer heads, similar to those used in inkjet printers. The discharged solution is produced by dissolving or dispersing a light-emitting material in a solvent. The inkjet process is relatively simple, but the major drawbacks are controlling the uniform thickness and the fact that it is difficult to apply this technology to a large-size display.

■ Inkjet printing for OLED materials



Source: Daiwa

Q. WHAT IS THE BEST DEPOSITION TECHNOLOGY?

A. FMM is currently the most reliable method. However, as OLED is a relatively new technology, we expect further improvements in production methods. As there are limitations with FMM technology, variations include white OLEDs (described earlier) and small mask system (SMS) technology, which is used to produce large displays.

SMS solves one issue with FMM – sagging, where a single large mask may not be uniformly level. Imagine you are spraying dots on a piece of paper. If you were to do this using a template the size of a daily newspaper, you would likely end up with sagging. But if you were to use a template the size of a business card, it would be easy to hold up the card, spray on top of it, and create circles on the paper without encountering sagging.

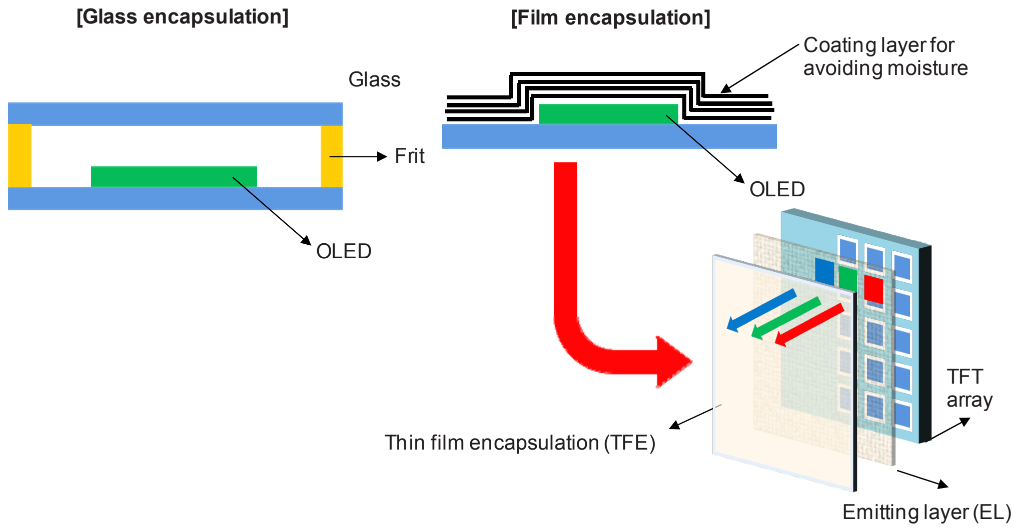
OLED encapsulation

It is important to protect OLED displays from air and moisture

For OLED displays, moisture and oxygen can cause material degradation (a decrease in the display's electroluminescence efficiency) and dark spots. In order to increase the lifespan of an OLED, encapsulation is required.

The most common method of encapsulation is using frit (a specially made ceramic composition) sandwiched between the substrate and cover glass. Although glass provides a strong barrier, it is rigid and thick. A film layer is a better alternative for use in a flexible display. We note that Samsung Display experienced production-yield issues with its flexible-display technology, but recently resolved this issue by using layers (organic and inorganic) of film encapsulation.

■ Comparison of glass and film-type encapsulation



Source: Daiwa

Your guide to the key players

The OLED supply chain is dominated by Korea companies

The OLED supply chain is dominated by Korea companies, with Samsung Display accounting for more than 96% of the OLED production capacity globally for 2012. LGD, on the other hand, has focused mainly on large displays and launched its first OLED-TV through LGE in January 2013.

As OLEDs, unlike LCDs, do not require any backlights or optical film, the supply chain is much simpler and is essentially limited to the processing-equipment and materials makers. As Samsung Display and LGD are the two companies in the world making commercial products using OLEDs, most of the small firms in the OLED supply chain are from Korea, supplying equipment and materials to these two OLED makers.

■ **OLED equipment supply chain by process**

	Samsung Display	LGD
Backplane process:		
Cleansing / wet processing	Semes (Not listed), DMS (068790 KS)	DMS (068790 KS) KC Tech (029460 KS)
Crystallisation	AP System (054620 KS) Tera Semicon (123100 KS), Viatron (141000 KS)	Unlisted local companies
Deposition (PE-CVD / sputter)	Ulvac (6728 JP), SFA (056190 KS) Applied Materials (AMAT US)	Ulvac (6728 JP) Jusung Engineering (036930 KS)
Photo lithography	Nikon (7731 JP), Canon (7751 JP)	Nikon (7731 JP), Canon (7751 JP)
Etching	ICD (040910 KS), Wonik IPS (030530 KS)	LIG ADP (079950 KS)
Deposition process:		
Evaporator	Canon Tokki (Not listed) Hitachi Hi-tech (8036 JP), SFA (056190 KS)	Canon Tokki (Not listed) YAS (Not listed)
Encapsulation process:		
Encapsulation system	AP System (054620 KS), LTS (138690 KS) SNU (080000 KS), Wonik IPS (030530 KS)	Avaco (083930 KS) Jusung Engineering (036930 KS)
Module process:		
Scriber / Grinder	SFA (056190 KS)	Top Engineering (065130 KS)
Bonder	SFA (056190 KS)	

Source: Companies, Daiwa

■ **OLED: material supply chain**

		Samsung Display	LG Display
Charged layer			
HTL		Duksan Hi-Metal (077360 KS), CS Elsolar (159910 KS)	Idemitsu Kosan (5019 JP), Merck (MRK GR), Hodogaya (4112 JP)
HIL		Duksan Hi-Metal (077360 KS)	Idemitsu Kosan (5019 JP), Merck (MRK GR), Hodogaya (4112 JP)
ETL		LG Chemical (051910 KS), Cheil Industries (001300 KS)	LG Chemical (051910 KS), Idemitsu Kosan (5019 JP) ,Merck (MRK GR), Toray (3402 JP)
EIL		LG Chemical (051910 KS)	LG Chemical (051910 KS), Idemitsu Kosan (5019 JP), Merck (MRK GR), Toray (3402 JP)
Emissive layer			
Red phosphorescent	Host	Dow Chemical (DOW US)	Dow Chemical (DOW US), Idemitsu Kosan (5019 JP)
	Dopant	Universal Display (OLED US)	Universal Display (OLED US)
Green phosphorescent	Host	Universal Display (OLED US)	Universal Display (OLED US)
	Dopant	Universal Display (OLED US)	Universal DIsplay (OLED US)
Green fluorescent	Host	CS Elsolar (159910 KS)	Universal Display (OLED US), Idemitsu Kosan (5019 JP)
	Dopant	Universal Display (OLED US)	Universal DIsplay (OLED US)
Blue fluorescent	Host	SFC (Not listed)	Idemitsu Kosan (5019 JP), Hodogaya (4112 JP)
	Dopant	SFC (Not listed)	Idemitsu Kosan (5019 JP), Hodogaya (4112 JP)

Source: Companies, Daiwa

Since, in our view, the OLED market has greater sales-growth potential than that of LCDs, we expect an increasing number of LCD panel makers to shift to OLED production. Moreover, we believe the current operating-profit margin for Samsung Display's OLED business of more than 20% could attract new entrants. This migration likely won't happen immediately, due to production-yield issues and the large investment required to build an OLED fab.

Given the likelihood that OLED displays will replace LCDs in the future, Samsung Display and LGD are committed to building additional OLED production lines as production yields improve. No other OLED makers have yet confirmed that they have mass production under way. Although we believe that most display companies have OLED R&D or pilot lines in place, production yields remain a major hurdle. Once yields stabilise, we expect these other players to commence volume production.

Glossary

AMOLED	The acronym for active-matrix organic light-emitting diode, a type of OLED requiring a thin-film transistor (TFT) backplane to switch each pixel on or off.
a-Si	Short for amorphous silicon, which is widely used in the manufacture of TFT-LCD backplanes. The manufacturing process is simpler than for other backplane technologies but the movement of electrons is slower.
Backlight	As LCDs do not emit their own light, backlights are used to illuminate an image and make it visible. The light source of the backlight is commonly made of cold cathode fluorescent lamps and light-emitting diodes.
Backplane	The backplane is composed of thin-film transistors, which are responsible for turning individual pixels on the display on and off.
Colour filter	This creates a colour image by transmitting or absorbing the white lights emanating from the backlight of the display. In producing a colour filter, a primary three-colour pattern of red, green, and blue is formed over a black matrix.
Contrast ratio	The difference in luminance between black and white shown on the display. A contrast ratio of 500:1 means that white areas are 500 times the brightness of black areas.
CVD	The acronym for chemical-vapour deposition. This is a common deposition method in the semiconductor manufacturing process, in which materials are deposited on the surface of a substrate through a chemical reaction.
Deposition	One of the core manufacturing process for OLEDs, in which organic materials are deposited or evaporated on to the backplane and individual sub-pixels are patterned.
EIL	The acronym for electron injection layer – an additive to speed up the transport of electrons to the emissive layer.
ELA	The acronym for excimer laser annealing, in which a 308nm excimer laser line beam disrupts the surface of a film of amorphous silicon, leading to the formation of poly-crystalline silicon.
EML	Short for emitting layer of organic material, in which electrons hit holes and emit light.
Encapsulation	In order to increase the lifespan of an OLED, the encapsulation process is used to seal OLED displays using glass or film to protect them from moisture and oxygen.
ETL	The acronym for electron transport layer, which transports the electrons to the emitting layer.
Flexible display	It uses plastic-based substrates in OLED production, allowing the product to be lighter, thinner, foldable, and rollable.
FMM	The acronym for fine metal mask. This is the most common deposition method used by OLED companies. In a vacuum chamber, organic materials are heated, evaporated, and then condensed on to the substrate.
Full HD-TV	Refers to a television that has a resolution of 1,920x1,080, compared with an HD-TV resolution of 1,280x720.
Gen5.5/Gen8	Describes the size of the glass substrate used for manufacturing flat panel displays. Gen5.5 glass is 1,300x1,500mm and Gen8 glass is 2,200x2,500mm.
HD-TV	A high-definition television produces an image that has a substantially higher a resolution than traditional television systems. CRT-TVs have 576 lines and HD-TVs have 720 or 1,080 lines (progressive scanned).
HIL	The acronym for hole injection layer – an additive used to speed up transporting the holes to the emissive layer.
HTL	The acronym for hole transport layer, which transports the holes to the emissive layer.
Inkjet printing	A deposition method in which organic layers are formed on the substrate by discharging a solution of organic material from the head of an inkjet printer.
IPS	The acronym for in-plane switching. This is the technology used in LCDs to improve the colour representation and viewing angle compared with conventional LCD panels. Apple's Retina Displays are based on IPS technology.
LITI	The acronym for laser-induced thermal imaging, which allows the high-resolution patterning of organic materials. In LITI, organic materials are adhered to a substrate through the scanning of a laser.
LTPS	The acronym for low-temperature poly-crystalline silicon, which allows for small, fast-switching LCDs, ideal for high-resolution small displays.
OLED	Short for organic light-emitting diode, which is a self-emitting display that has a higher colour contrast and thinner form factor than TFT-LCD.
Oxide backplane	A backplane that uses metal-oxide technology and shares the advantages of a-Si and LTPS. The manufacturing process is simpler than for an LTPS backplane.
Pixel	Short for picture element, which is the smallest element in a graphic image.
PPI	The acronym for pixels per inch. It refers to the number of pixels contained within a vertical or horizontal inch. A ppi of 300 means there are 300 pixels contained in each one-inch row.
PMOLED	The acronym for passive-matrix organic light-emitting diode, which is type of an OLED controlled by switching on rows and columns.
p-Si	Short for poly-crystalline silicon, which offers significantly higher carrier (electron and hole) mobility than a-Si. Using the excimer laser annealing process, a-Si is converted to p-Si.
Retina Display	Refer to IPS. Retina Display is a marketing term used by Apple to describe its LCDs based on IPS technology.
Resolution	Refers to the sharpness and clarity of an image. In display devices, the resolution is the number of pixels in each dimension that can be displayed.
RGB OLED	Uses separate red, green, and blue sub-pixels to emit colours. Samsung Display uses RGB OLEDs for its OLED-TV.
Super AMOLED	Samsung Display's OLED display for mobile handsets, in which touch sensors are integrated on the top glass layer, resulting in a thin display design.
TFT	The acronym for thin-film transistor, which is formed by sequentially depositing thin films of materials on glass substrates.
UHD-TV	Short for ultra-high-definition televisions or 4K TVs, which have four times the resolution of current full HD-TVs (3,820x2,160 pixels compared with 1,920x1,080 pixels).
White OLED	Uses white OLED pixels with colour filters, and is less efficient than RGB OLEDs as some of the light is filtered out by colour filters. LG Display uses white OLEDs for its OLED-TV.

Source: Daiwa

Daiwa
Capital Markets

Daiwa's Asia Pacific Research Directory

HONG KONG		
Hiroaki KATO	(852) 2532 4121	hiroaki.kato@hk.daiwacm.com
Regional Research Head		
John HETHERINGTON	(852) 2773 8787	john.hetherington@hk.daiwacm.com
Regional Deputy Head of Asia Pacific Research; Regional Head of Product Management		
Pranab Kumar SARMAH	(852) 2848 4441	pranab.sarmah@hk.daiwacm.com
Regional Head of Research Promotion		
Kevin LAI	(852) 2848 4926	kevin.lai@hk.daiwacm.com
Deputy Head of Regional Economics; Macro Economics (Regional)		
Christie CHIEN	(852) 2848 4482	christie.chien@hk.daiwacm.com
Macro Economics (Taiwan)		
Jonas KAN	(852) 2848 4439	jonas.kan@hk.daiwacm.com
Head of Hong Kong Research; Head of Hong Kong and China Property; Regional Property Coordinator; Property Developers (Hong Kong)		
Jeff CHUNG	(852) 2773 8783	jeff.chung@hk.daiwacm.com
Automobiles and Components (China)		
Grace WU	(852) 2532 4383	grace.wu@hk.daiwacm.com
Head of Greater China FIG; Banking (Hong Kong, China)		
Jerry YANG	(852) 2773 8842	jerry.yang@hk.daiwacm.com
Banking (Taiwan)/Diversified Financials (Taiwan and China)		
Leon QI	(852) 2532 4381	leon.qi@hk.daiwacm.com
Banking (Hong Kong, China)		
Joseph HO	(852) 2848 4443	joseph.ho@hk.daiwacm.com
Head of Industrials and Machineries (Hong Kong, China); Capital Goods –Electronics Equipments and Machinery (Hong Kong, China)		
Winston CAO	(852) 2848 4469	winston.cao@hk.daiwacm.com
Capital Goods – Machinery (China)		
Eric CHEN	(852) 2773 8702	eric.chen@hk.daiwacm.com
Pan-Asia/Regional Head of IT/Electronics; Semiconductor/IC Design (Regional)		
Felix LAM	(852) 2532 4341	felix.lam@hk.daiwacm.com
Head of Materials (Hong Kong, China); Cement and Building Materials (China, Taiwan); Property (China)		
John CHOI	(852) 2773 8730	john.choi@hk.daiwacm.com
Regional Head of Small/Medium Cap; Small/Mid Cap (Regional); Head of Multi-Industries (Hong Kong, China); Internet (China)		
Joey CHEN	(852) 2848 4483	joey.chen@hk.daiwacm.com
Steel (China)		
Kelvin LAU	(852) 2848 4467	kelvin.lau@hk.daiwacm.com
Head of Transportation (Hong Kong, China); Hong Kong and China Research Coordinator; Transportation (Regional)		
Jibo MA	(852) 2848 4489	jibo.ma@hk.daiwacm.com
Head of Custom Products Group; Custom Products Group		
Thomas HO	(852) 2773 8716	thomas.ho@hk.daiwacm.com
Custom Products Group		

PHILIPPINES		
Rommel RODRIGO	(63) 2 813 7344 ext 302	rommel.rodrigo@dbpdaiwacm.com.ph
Head of Philippines Research; Strategy; Capital Goods; Materials		

SOUTH KOREA		
Chang H LEE	(82) 2 787 9177	chlee@kr.daiwacm.com
Head of Korea Research; Strategy		
Sung Yop CHUNG	(82) 2 787 9157	sychung@kr.daiwacm.com
Pan-Asia Co-head/Regional Head of Automobiles and Components; Automobiles; Shipbuilding; Steel		
Jun Yong BANG	(82) 2 787 9168	junyong.bang@kr.daiwacm.com
Tyres; Chemicals		
Anderson CHA	(82) 2 787 9185	anderson.cha@kr.daiwacm.com
Banking/Finance		
Mike OH	(82) 2 787 9179	mike.oh@kr.daiwacm.com
Capital Goods (Construction and Machinery)		
Sang Hee PARK	(82) 2 787 9165	sanghee.park@kr.daiwacm.com
Consumer/Retail		
Jae H LEE	(82) 2 787 9173	jhlee@kr.daiwacm.com
IT/Electronics (Tech Hardware and Memory Chips)		
Joshua OH	(82) 2 787 9176	joshua.oh@kr.daiwacm.com
IT/Electronics (Handset Components)		
Thomas Y KWON	(82) 2 787 9181	yskwon@kr.daiwacm.com
Pan-Asia Head of Internet & Telecommunications; Software (Korea) – Internet/On-line Game		
SoYoung WANG	(82) 2 787 9133	soyoung.wang@kr.daiwacm.com
Transportation/Logistics		

TAIWAN		
Mark CHANG	(886) 2 8758 6245	mark.chang@daiwacm-cathay.com.tw
Head of Research		
Steven TSENG	(886) 2 8758 6252	steven.tseng@daiwacm-cathay.com.tw
IT/Technology Hardware (PC Hardware)		
Christine WANG	(886) 2 8758 6249	christine.wang@daiwacm-cathay.com.tw
IT/Technology Hardware (Automation); Cement; Consumer		
Kylie HUANG	(886) 2 8758 6248	kylie.huang@daiwacm-cathay.com.tw
IT/Technology Hardware (Handsets and Components)		
Lynn CHENG	(886) 2 8758 6253	lynn.cheng@daiwacm-cathay.com.tw
IT/Electronics (Semiconductor)		

INDIA		
Punit SRIVASTAVA	(91) 22 6622 1013	punit.srivastava@in.daiwacm.com
Head of Research; Strategy; Banking/Finance		
Navin MATTA	(91) 22 6622 8411	navin.matta@in.daiwacm.com
Automobiles and Components		
Saurabh MEHTA	(91) 22 6622 1009	saurabh.mehta@in.daiwacm.com
Capital Goods; Utilities		
Mihir SHAH	(91) 22 6622 1020	mihir.shah@in.daiwacm.com
FMCG/Consumer		
Deepak PODDAR	(91) 22 6622 1016	deepak.poddar@in.daiwacm.com
Materials		
Nirmal RAGHAVAN	(91) 22 6622 1018	nirmal.raghavan@in.daiwacm.com
Oil and Gas; Utilities		

SINGAPORE		
Adrian LOH	(65) 6499 6548	adrian.loh@sg.daiwacm.com
Head of Singapore Research, Regional Head of Oil and Gas; Oil and Gas (ASEAN and China); Capital Goods (Singapore)		
David LUM	(65) 6329 2102	david.lum@sg.daiwacm.com
Property and REITs		
Ramakrishna MARUVADA	(65) 6499 6543	ramakrishna.maruvada@sg.daiwacm.com
Head of ASEAN & India Telecommunications; Telecommunications (ASEAN & India)		

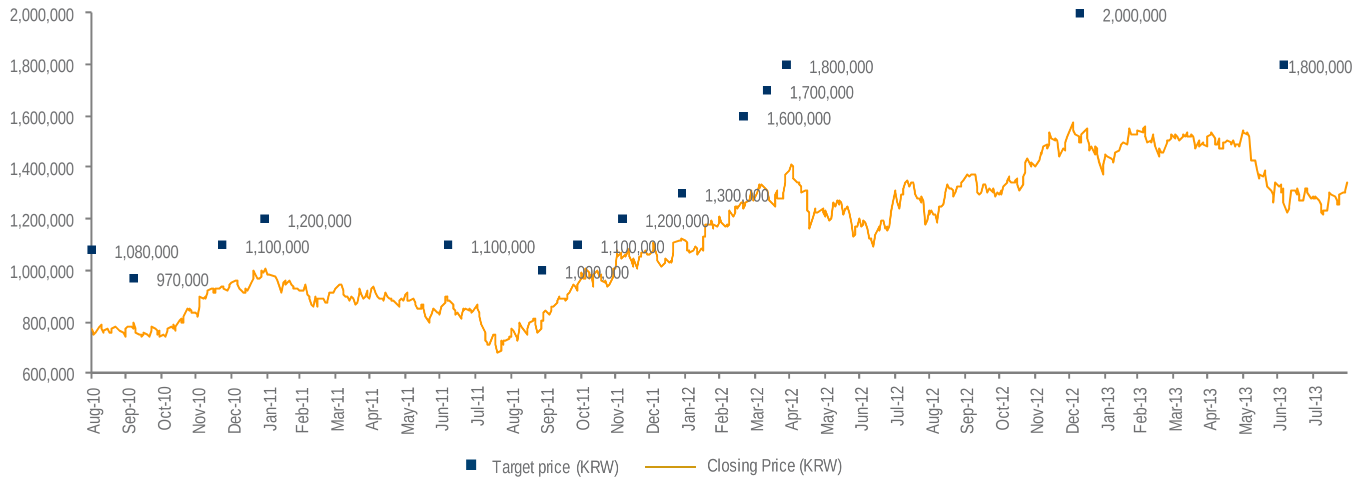
Daiwa's Offices

Office / Branch / Affiliate	Address	Tel	Fax
DAIWA SECURITIES GROUP INC			
HEAD OFFICE	Gran Tokyo North Tower, 1-9-1, Marunouchi, Chiyoda-ku, Tokyo, 100-6753	(81) 3 5555 3111	(81) 3 5555 0661
Daiwa Securities Trust Company	One Evertrust Plaza, Jersey City, NJ 07302, U.S.A.	(1) 201 333 7300	(1) 201 333 7726
Daiwa Securities Trust and Banking (Europe) PLC (Head Office)	5 King William Street, London EC4N 7JB, United Kingdom	(44) 207 320 8000	(44) 207 410 0129
Daiwa Europe Trustees (Ireland) Ltd	Level 3, Block 5, Harcourt Centre, Harcourt Road, Dublin 2, Ireland	(353) 1 603 9900	(353) 1 478 3469
Daiwa Capital Markets America Inc	Financial Square, 32 Old Slip, New York, NY10005, U.S.A.	(1) 212 612 7000	(1) 212 612 7100
Daiwa Capital Markets America Inc. San Francisco Branch	555 California Street, Suite 3360, San Francisco, CA 94104, U.S.A.	(1) 415 955 8100	(1) 415 956 1935
Daiwa Capital Markets Europe Limited	5 King William Street, London EC4N 7AX, United Kingdom	(44) 20 7597 8000	(44) 20 7597 8600
Daiwa Capital Markets Europe Limited, Frankfurt Branch	Trianon Building, Mainzer Landstrasse 16, 60325 Frankfurt am Main, Federal Republic of Germany	(49) 69 717 080	(49) 69 723 340
Daiwa Capital Markets Europe Limited, Paris Representative Office	36, rue de Naples, 75008 Paris, France	(33) 1 56 262 200	(33) 1 47 550 808
Daiwa Capital Markets Europe Limited, London, Geneva Branch	50 rue du Rhône, P.O.Box 3198, 1211 Geneva 3, Switzerland	(41) 22 818 7400	(41) 22 818 7441
Daiwa Capital Markets Europe Limited, Moscow Representative Office	Midland Plaza 7th Floor, 10 Arbat Street, Moscow 119002, Russian Federation	(7) 495 641 3416	(7) 495 775 6238
Daiwa Capital Markets Europe Limited, Bahrain Branch	7th Floor, The Tower, Bahrain Commercial Complex, P.O. Box 30069, Manama, Bahrain	(973) 17 534 452	(973) 17 535 113
Daiwa Capital Markets Hong Kong Limited	Level 28, One Pacific Place, 88 Queensway, Hong Kong	(852) 2525 0121	(852) 2845 1621
Daiwa Capital Markets Singapore Limited	6 Shenton Way #26-08, DBS Building Tower Two, Singapore 068809, Republic of Singapore	(65) 6220 3666	(65) 6223 6198
Daiwa Capital Markets Australia Limited	Level 34, Rialto North Tower, 525 Collins Street, Melbourne, Victoria 3000, Australia	(61) 3 9916 1300	(61) 3 9916 1330
DBP-Daiwa Capital Markets Philippines, Inc	18th Floor, Citibank Tower, 8741 Paseo de Roxas, Salcedo Village, Makati City, Republic of the Philippines	(632) 813 7344	(632) 848 0105
Daiwa-Cathay Capital Markets Co Ltd	14/F, 200, Keelung Road, Sec 1, Taipei, Taiwan, R.O.C.	(886) 2 2723 9698	(886) 2 2345 3638
Daiwa Securities Capital Markets Korea Co., Ltd.	One IFC, 10 Gukjegeumyung-Ro, Yeouido-dong, Yeongdeungpo-gu, Seoul, 150-876, Korea	(82) 2 787 9100	(82) 2 787 9191
Daiwa Securities Capital Markets Co Ltd, Beijing Representative Office	Room 3503/3504, SK Tower, No.6 Jia Jianguomen Wai Avenue, Chaoyang District, Beijing 100022, People's Republic of China	(86) 10 6500 6688	(86) 10 6500 3594
Daiwa SSC Securities Co Ltd	45/F, Hang Seng Tower, 1000 Lujiazui Ring Road, Pudong, Shanghai 200120, People's Republic of China	(86) 21 3858 2000	(86) 21 3858 2111
Daiwa Securities Capital Markets Co. Ltd, Bangkok Representative Office	18th Floor, M Thai Tower, All Seasons Place, 87 Wireless Road, Lumpini, Pathumwan, Bangkok 10330, Thailand	(66) 2 252 5650	(66) 2 252 5665
Daiwa Capital Markets India Private Ltd	10th Floor, 3 North Avenue, Maker Maxity, Bandra Kurla Complex, Bandra East, Mumbai – 400051, India	(91) 22 6622 1000	(91) 22 6622 1019
Daiwa Securities Capital Markets Co. Ltd, Hanoi Representative Office	Suite 405, Pacific Palace Building, 83B, Ly Thuong Kiet Street, Hoan Kiem Dist. Hanoi, Vietnam	(84) 4 3946 0460	(84) 4 3946 0461
DAIWA INSTITUTE OF RESEARCH LTD			
HEAD OFFICE	15-6, Fuyuki, Koto-ku, Tokyo, 135-8460, Japan	(81) 3 5620 5100	(81) 3 5620 5603
MARUNOUCHI OFFICE	Gran Tokyo North Tower, 1-9-1, Marunouchi, Chiyoda-ku, Tokyo, 100-6756	(81) 3 5555 7011	(81) 3 5202 2021
New York Research Center	11th Floor, Financial Square, 32 Old Slip, NY, NY 10005-3504, U.S.A.	(1) 212 612 6100	(1) 212 612 8417
London Research Centre	3/F, 5 King William Street, London, EC4N 7AX, United Kingdom	(44) 207 597 8000	(44) 207 597 8550

Share price and Daiwa recommendation trend

■ **Samsung Electronics: share price and Daiwa recommendation trend**

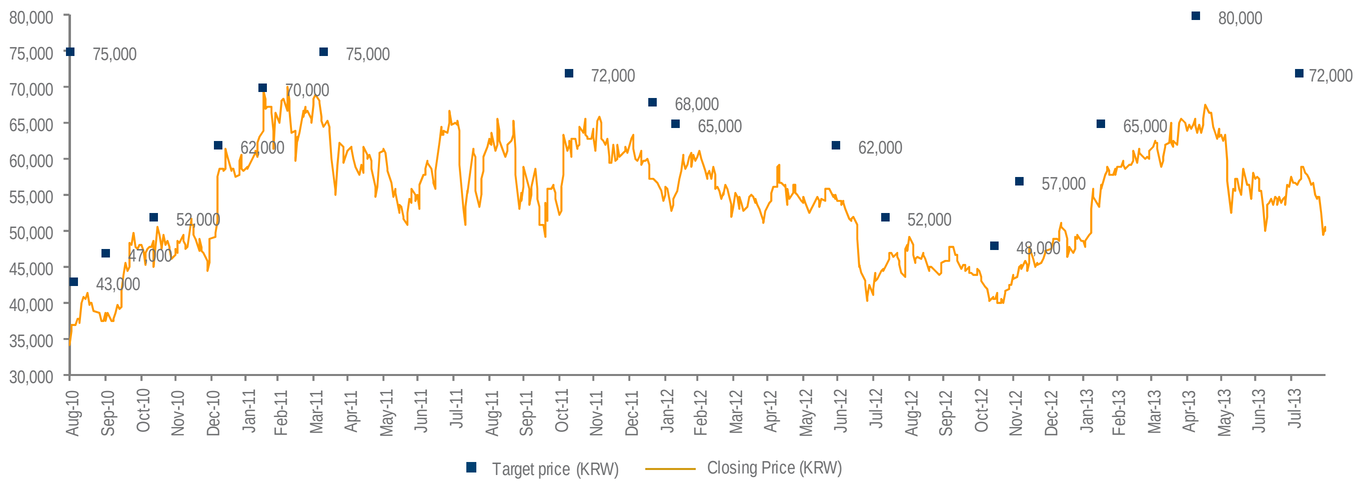
Date	Target price	Rating	Date	Target price	Rating	Date	Target price	Rating
22/12/10	1,100,000	Outperform	28/10/11	1,100,000	Outperform	10/04/12	1,700,000	Buy
28/01/11	1,200,000	Outperform	06/12/11	1,200,000	Outperform	27/04/12	1,800,000	Buy
07/07/11	1,100,000	Outperform	27/01/12	1,300,000	Outperform	08/01/13	2,000,000	Buy
27/09/11	1,000,000	Outperform	21/03/12	1,600,000	Buy	05/07/13	1,800,000	Buy



Source: Daiwa

■ **SFA Engineering: share price and Daiwa recommendation trend**

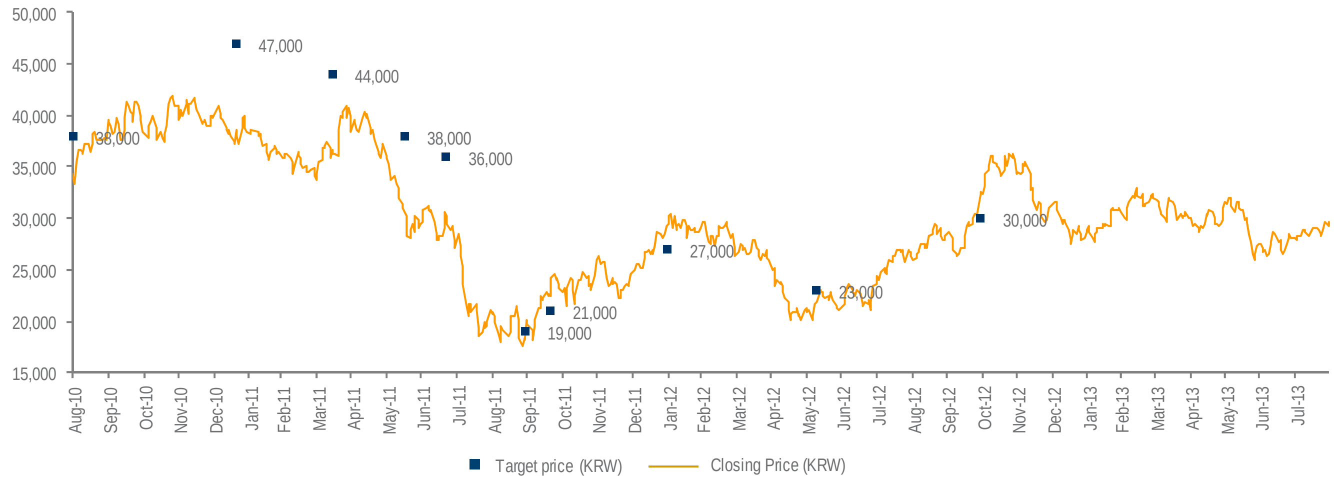
Date	Target price	Rating	Date	Target price	Rating	Date	Target price	Rating
30/09/10	47,000	Outperform	08/11/11	72,000	Outperform	13/11/12	48,000	Outperform
11/11/10	52,000	Outperform	20/01/12	68,000	Outperform	05/12/12	57,000	Buy
06/01/11	62,000	Outperform	09/02/12	65,000	Outperform	14/02/13	65,000	Buy
14/02/11	70,000	Outperform	28/06/12	62,000	Outperform	08/05/13	80,000	Buy
08/04/11	75,000	Outperform	10/08/12	52,000	Outperform	06/08/13	72,000	Buy



Source: Daiwa

■ LG Display: share price and Daiwa recommendation trend

Date	Target price	Rating	Date	Target price	Rating	Date	Target price	Rating
13/04/11	44,000	Outperform	28/09/11	19,000	Hold	08/06/12	23,000	Hold
15/06/11	38,000	Outperform	20/10/11	21,000	Hold	27/10/12	30,000	Hold
21/07/11	36,000	Outperform	30/01/12	27,000	Hold			



Source: Daiwa

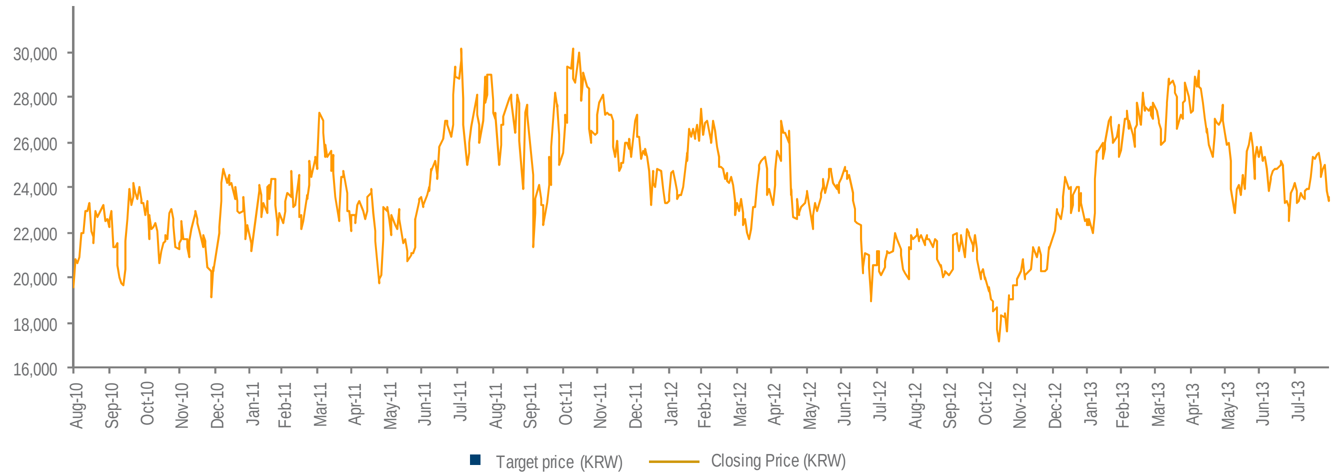
■ LG Electronics: share price and Daiwa recommendation trend

Date	Target price	Rating	Date	Target price	Rating	Date	Target price	Rating
07/01/11	130,000	Outperform	10/09/12	72,000	Hold	18/04/13	82,000	Hold
27/04/11	120,000	Outperform	11/10/12	70,000	Hold	12/06/13	78,000	Hold
04/07/11	90,000	Hold	20/02/13	75,000	Hold	24/07/13	75,000	Hold

Source: Daiwa

■ Duksan Hi-Metal: share price and Daiwa recommendation trend

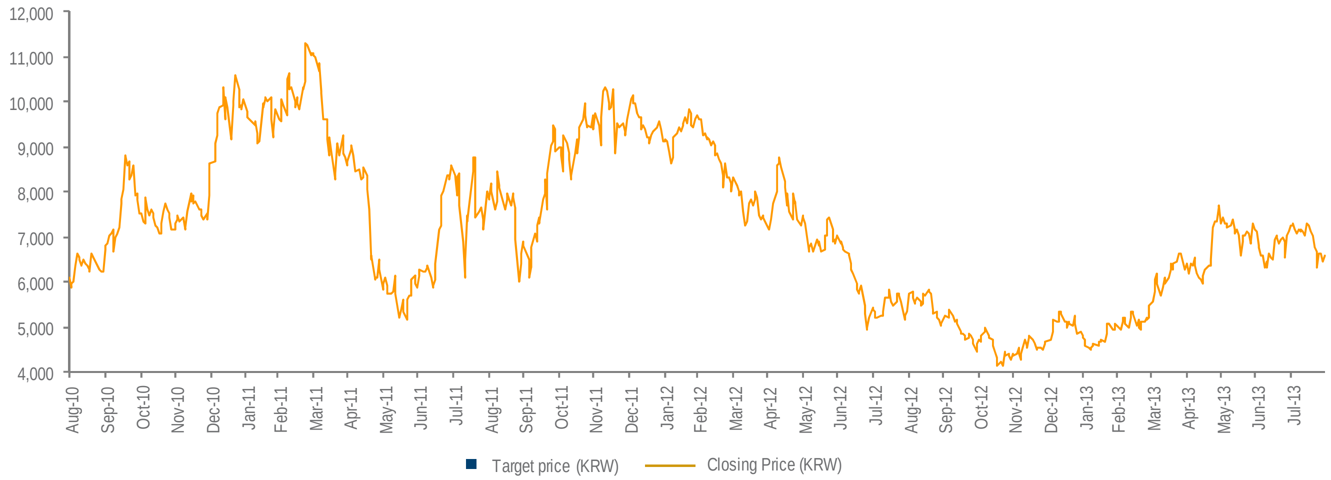
Date	Target price	Rating	Date	Target price	Rating	Date	Target price	Rating



Source: Daiwa

■ Wonik IPS: share price and Daiwa recommendation trend

Date	Target price	Rating	Date	Target price	Rating	Date	Target price	Rating



Source: Daiwa

Disclaimer

This publication is produced by Daiwa Securities Group Inc. and/or its non-U.S. affiliates, and distributed by Daiwa Securities Group Inc. and/or its non-U.S. affiliates, except to the extent expressly provided herein. This publication and the contents hereof are intended for information purposes only, and may be subject to change without further notice. Any use, disclosure, distribution, dissemination, copying, printing or reliance on this publication for any other purpose without our prior consent or approval is strictly prohibited. Neither Daiwa Securities Group Inc. nor any of its respective parent, holding, subsidiaries or affiliates, nor any of its respective directors, officers, servants and employees, represent nor warrant the accuracy or completeness of the information contained herein or as to the existence of other facts which might be significant, and will not accept any responsibility or liability whatsoever for any use of or reliance upon this publication or any of the contents hereof. Neither this publication, nor any content hereof, constitute, or are to be construed as, an offer or solicitation of an offer to buy or sell any of the securities or investments mentioned herein in any country or jurisdiction nor, unless expressly provided, any recommendation or investment opinion or advice. Any view, recommendation, opinion or advice expressed in this publication may not necessarily reflect those of Daiwa Securities Capital Markets Co. Ltd., and/or its affiliates nor any of its respective directors, officers, servants and employees except where the publication states otherwise. This research report is not to be relied upon by any person in making any investment decision or otherwise advising with respect to, or dealing in, the securities mentioned, as it does not take into account the specific investment objectives, financial situation and particular needs of any person.

Daiwa Securities Group Inc., its subsidiaries or affiliates, or its or their respective directors, officers and employees from time to time have trades as principals, or have positions in, or have other interests in the securities of the company under research including derivatives in respect of such securities or may have also performed investment banking and other services for the issuer of such securities. The following are additional disclosures.

Japan
Daiwa Securities Co. Ltd. and Daiwa Securities Group Inc.
Daiwa Securities Co. Ltd. is a subsidiary of Daiwa Securities Group Inc.
Investment Banking Relationship
Within the preceding 12 months, The subsidiaries and/or affiliates of Daiwa Securities Group Inc. * has lead-managed public offerings and/or secondary offerings (excluding straight bonds) of the securities of the following companies: REXLot Holdings Limited (555 HK); Huadian Fuxin Energy Corporation Limited (816 HK); Chaowei Power Holdings Limited (951 HK); CITIC Securities Company Limited (6030 HK); China Outfitters Holdings Limited (1146 HK); The People's Insurance Company (Group) of China Limited (1339 HK); China Precious Metal Resources Holdings Company Limited (1194 HK); Jiangnan Group Limited (1366 HK); Blackgold International Holdings Ltd (BGG AU); Tosei Corporation (8923 JP); Modern Land (China) Co. Ltd (1107 HK).

*Subsidiaries of Daiwa Securities Group Inc. for the purposes of this section shall mean any one or more of: Daiwa Capital Markets Hong Kong Limited, Daiwa Capital Markets Singapore Limited, Daiwa Capital Markets Australia Limited, Daiwa Capital Markets India Private Limited, Daiwa-Cathay Capital Markets Co., Ltd., Daiwa Securities Capital Markets Korea Co., Ltd.

Hong Kong
This research is distributed in Hong Kong by Daiwa Capital Markets Hong Kong Limited ("DHK") which is regulated by the Hong Kong Securities and Futures Commission. Recipients of this research in Hong Kong may contact DHK in respect of any matter arising from or in connection with this research.
Ownership of Securities
For "Ownership of Securities" information, please visit BlueMatrix disclosure Link at https://daiwa3.bluematrix.com/sellside/Disclosures.action.
Investment Banking Relationship
For "Investment Banking Relationship", please visit BlueMatrix disclosure Link at https://daiwa3.bluematrix.com/sellside/Disclosures.action.
Relevant Relationship (DHK)
DHK may from time to time have an individual employed by or associated with it serves as an officer of any of the companies under its research coverage.
DHK market making
DHK may from time to time make a market in securities covered by this research.

Korea
The developing analyst of this research and analysis material hereby states and confirms that the contents of this material correctly reflect the analyst's views and opinions and that the analyst has not been placed under inappropriate pressure or interruption by an external party.

Name of Analyst : Jae H. Lee / Joshua Oh, CFA

Disclosure of Analysts' Interests
If an analyst engaging in or a person who exercises influences on the preparation or publication of a Research Report containing recommendations for general investors to trade financial investment instruments with regard to which the analyst or the influential person has personal interests and if the recommendations contained in the Report may have impacts on the personal interests, Daiwa Securities Capital Markets Korea Co., Ltd.("Daiwa Securities Korea")shall ensure that the Analyst or the influential person notifies that he/she has personal interests with regard to:

1. The equity, the equity-linked bonds and the instruments with the subscription right to the equity issued by the legal entity covered in the Research Report (or the legal entity subject to the investment recommendations);
2. The stock option granted by the legal entity covered in the Research Report (or the legal entity subject to the investment recommendations); or
3. The equity futures, the equity options and the equity-linked warrants backed by the equity prescribed in the preceding Paragraph 1 as the underlying assets.

Legal Entities subject to Research Report Coverage Restrictions
Daiwa Securities Korea hereby states and confirms that Daiwa Securities Korea has no conflicts of interests with the legal entity covered in this Research Report:

1. In that Daiwa Securities Korea does NOT offer direct or indirect payment guarantee for the legal entity by means of, for instance, guarantee, endorsement, provision of collaterals or the acquisition of debts;
2. In that Daiwa Securities Korea does NOT own one-hundredth (or 1/100) or more of the total number of outstanding equities issued by the legal entity;
3. In that The legal entity is NOT an affiliated company of Daiwa Securities Korea pursuant to Sub-paragraph 3, Article 2 of the Monopoly Regulation and Fair Trade Act of Korea;
4. In that, although Daiwa Securities Korea offers advisory services for the legal entity with regard to an M&A deal, the size of the M&A deal does NOT exceed five-hundredths (or 5/100) of the total asset size or the total number of equities issued and outstanding of the legal entity;
5. In that, although Daiwa Securities Korea acted in the capacity of a Lead Underwriter for the initial public offering of the legal entity, more than one-year has passed since the IPO date;
6. In that Daiwa Securities Korea is NOT designated by the legal entity as the 'tender offer agent' pursuant to the Paragraph 2, Article 133 of the Financial Services and Capital Market Act or the legal entity is NOT the issuer of the equity subject to the proposed tender offer; this requirement, however applies until the maturity of the tender offer period; or
7. In that Daiwa Securities Korea does NOT have significant or material interests with regard to the legal entity.

Disclosure of Prior Distribution to Third Party
This report has not been distributed to the third party in advance prior to public release.

The following explains the rating system in the report as compared to KOSPI, based on the beliefs of the author(s) of this report.

"1": the security could outperform the KOSPI by more than 15% over the next six months.
"2": the security is expected to outperform the KOSPI by 5-15% over the next six months.
"3": the security is expected to perform within 5% of the KOSPI (better or worse) over the next six months.
"4": the security is expected to underperform the KOSPI by 5-15% over the next six months.
"5": the security could underperform the KOSPI by more than 15% over the next six months.

"Positive" means that the analyst expects the sector to outperform the KOSPI over the next six months.
"Neutral" means that the analyst expects the sector to be in-line with the KOSPI over the next six months
"Negative" means that the analyst expects the sector to underperform the KOSPI over the next six months

Additional information may be available upon request.

Singapore
This research is distributed in Singapore by Daiwa Capital Markets Singapore Limited and it may only be distributed in Singapore to accredited investors, expert investors and institutional investors as defined in the Financial Advisers Regulations and the Securities and Futures Act (Chapter 289), as amended from time to time. By virtue of distribution to these category of investors, Daiwa Capital Markets Singapore Limited and its representatives are not required to comply with Section 36 of the Financial Advisers Act (Chapter 110) (Section 36 relates to disclosure of Daiwa Capital Markets Singapore Limited's interest and/or its representative's interest in securities). Recipients of this research in Singapore may contact Daiwa Capital Markets Singapore Limited in respect of any matter arising from or in connection with the research.

Australia
This research is distributed in Australia by Daiwa Capital Markets Stockbroking Limited and it may only be distributed in Australia to wholesale investors within the meaning of the Corporations Act. Recipients of this research in Australia may contact Daiwa Capital Markets Stockbroking Limited in respect of any matter arising from or in connection with the research.
Ownership of Securities
For "Ownership of Securities" information, please visit BlueMatrix disclosure Link at https://daiwa3.bluematrix.com/sellside/Disclosures.action.

India
This research is distributed by Daiwa Capital Markets India Private Limited (DAIWA) which is an intermediary registered with Securities & Exchange Board of India. This report is not to be considered as an offer or solicitation for any dealings in securities. While the information in this report has been compiled by DAIWA in good faith from sources believed to be reliable, no representation or warranty, express of implied, is made or given as to its accuracy, completeness or correctness. DAIWA its officers, employees, representatives and agents accept no liability whatsoever for any loss or damage whether direct, indirect, consequential or otherwise howsoever arising (whether in negligence or otherwise) out of or in connection with or from any use of or reliance on the contents of and/or omissions from this document. Consequently DAIWA expressly disclaims any and all liability for, or based on or relating to any such information contained in or errors in or omissions in this report. Accordingly, you are recommended to seek your own legal, tax or other advice and should rely solely on your own judgment, review and analysis, in evaluating the information in this document. The data contained in this document is subject to change without any prior notice DAIWA reserves its right to modify this report as maybe required from time to time. DAIWA is committed to providing independent recommendations to its Clients and would be happy to provide any information in response to any query from its Clients. This report is strictly confidential and is being furnished to you solely for your information. The information contained in this document should not be reproduced (in whole or in part) or redistributed in any form to any other person. We and our group companies, affiliates, officers, directors and employees may from time to time, have long or short positions, in and buy sell the securities thereof, of company(ies) mentioned herein or be engaged in any other transactions involving such securities and earn brokerage or other compensation or act as advisor or have the potential conflict of interest with respect to any recommendation and related information or opinion. DAIWA prohibits its analyst and their family members from maintaining a financial interest in the securities or derivatives of any companies that the analyst cover. This report is not intended or directed for distribution to, or use by any person, citizen or entity which is resident or located in any state or country or jurisdiction where such publication, distribution or use would be contrary to any statutory legislation, or regulation which would require DAIWA and its affiliates/ group companies to any registration or licensing requirements. The views expressed in the report accurately reflect the analyst's personal views about the securities and issuers that are subject of the Report, and that no part of the analyst's compensation was, is or will be directly or indirectly, related to the recommendations or views expressed in the Report. This report does not recommend to US recipients the use of Daiwa Capital Markets India Private Limited or any of its non – US affiliates to effect trades in any securities and is not supplied with any understanding that US recipients will direct commission business to Daiwa Capital Markets India Private Limited.

Taiwan
This research is distributed in Taiwan by Daiwa-Cathay Capital Markets Co., Ltd and it may only be distributed in Taiwan to institutional investors or specific investors who have signed recommendation contracts with Daiwa-Cathay Capital Markets Co., Ltd in accordance with the Operational Regulations Governing Securities Firms Recommending Trades in Securities to Customers. Recipients of this research in Taiwan may contact Daiwa-Cathay Capital Markets Co., Ltd in respect of any matter arising from or in connection with the research.

Philippines
This research is distributed in the Philippines by DBP-Daiwa Capital Markets Philippines, Inc. which is regulated by the Philippines Securities and Exchange Commission and the Philippines Stock Exchange, Inc. Recipients of this research in the Philippines may contact DBP-Daiwa Capital Markets Philippines, Inc. in respect of any matter arising from or in connection with the research. DBP-Daiwa Capital Markets Philippines, Inc. recommends that investors independently assess, with a professional advisor, the specific financial risks as well as the legal, regulatory, tax, accounting, and other consequences of a proposed transaction. DBP-Daiwa Capital Markets Philippines, Inc. may have positions or may be materially interested in the securities in any of the markets mentioned in the publication or may have performed other services for the issuers of such securities.
For relevant securities and trading rules please visit SEC and PSE Link at http://www.sec.gov.ph/irr/AmendedIRRfinalversion.pdf and http://www.pse.com.ph/ respectively.

United Kingdom
This research report is produced by Daiwa Capital Markets Europe Limited and/or its affiliates and is distributed in the European Union, Iceland, Liechtenstein, Norway and Switzerland. Daiwa Capital Markets Europe Limited is authorised and regulated by The Financial Conduct Authority ("FCA") and is a member of the London Stock Exchange, Eurex and NYSE Liffe. Daiwa Capital Markets Europe Limited and/or its affiliates may, from time to time, to the extent permitted by law, participate or invest in other financing transactions with the issuers of the securities referred to herein (the "Securities"), perform services for or solicit business from such issuers, and/or have a position or effect transactions in the Securities or options thereof and/or may have acted as an underwriter during the past twelve months for the issuer of such securities. In addition, employees of Daiwa Capital Markets Europe Limited and/or its affiliates may have positions and effect transactions in such securities or options and may serve as Directors of such issuers. Daiwa Capital Markets Europe Limited may, to the extent permitted by applicable UK law and other applicable law or regulation, effect transactions in the Securities before this material is published to recipients.

This publication is intended for investors who are not Retail Clients in the United Kingdom within the meaning of the Rules of the FCA and should not therefore be distributed to such Retail Clients in the United Kingdom. Should you enter into investment business with Daiwa Capital Markets Europe's affiliates outside the United Kingdom, we are obliged to advise that the protection afforded by the United Kingdom regulatory system may not apply; in particular, the benefits of the Financial Services Compensation Scheme may not be available.

Daiwa Capital Markets Europe Limited has in place organisational arrangements for the prevention and avoidance of conflicts of interest. Our conflict management policy is available at http://www.uk.daiwacm.com/about-us/corporate-governance-and-regulatory . Regulatory disclosures of investment banking relationships are available at https://daiwa3.bluematrix.com/sellside/Disclosures.action.

Germany
This document has been approved by Daiwa Capital Markets Europe Limited and is distributed in Germany by Daiwa Capital Markets Europe Limited, Niederlassung Frankfurt which is regulated by BaFin (Bundesanstalt fuer Finanzdienstleistungsaufsicht) for the conduct of business in Germany.

Bahrain
This research material is issued/compiled by Daiwa Capital Markets Europe Limited, Bahrain Branch, regulated by The Central Bank of Bahrain and holds Investment Business Firm – Category 2 license and having its official place of business at the Bahrain World Trade Centre, South Tower, 7th floor, P.O. Box 30069, Manama, Kingdom of Bahrain. Tel No. +973 17534452 Fax No. +973 535113

This material is provided as a reference for making investment decisions and is not intended to be a solicitation for investment. Investment decisions should be made at your own discretion and risk. Accordingly, no representation or warranty, express or implied, is made as to and no reliance should be placed on the fairness, accuracy, completeness or correctness of the information and opinions contained in this document, Content herein is based on information available at the time the research material was prepared and may be amended or otherwise changed in the future without notice. All information is intended for the private use of the person to whom it is provided without any liability whatsoever on the part of Daiwa Capital Markets Europe Limited, Bahrain Branch, any associated company or the employees thereof. If you are in doubt about the suitability of the product or the research material itself, please consult your own financial adviser. Daiwa Capital Markets Europe Limited, Bahrain Branch retains all rights related to the content of this material, which may not be redistributed or otherwise transmitted without prior consent.

United States
This report is distributed in the U.S. by Daiwa Capital Markets America Inc. (DCMA). It may not be accurate or complete and should not be relied upon as such. It reflects the preparer's views at the time of its preparation, but may not reflect events occurring after its preparation; nor does it reflect DCMA's views at any time. Neither DCMA nor the preparer has any obligation to update this report or to continue to prepare research on this subject. This report is not an offer to sell or the solicitation of any offer to buy securities. Unless this report says otherwise, any recommendation it makes is risky and appropriate only for sophisticated speculative investors able to incur significant losses. Readers should consult their financial advisors to determine whether any such recommendation is consistent with their own investment objectives, financial situation and needs. This report does not recommend to U.S. recipients the use of any of DCMA's non-U.S. affiliates to effect trades in any security and is not supplied with any understanding that U.S. recipients of this report will direct commission business to such non-U.S. entities. Unless applicable law permits otherwise, non-U.S. customers wishing to effect a transaction in any securities referenced in this material should contact a Daiwa entity in their local jurisdiction. Most countries throughout the world have their own laws regulating the types of securities and other investment products which may be offered to their residents, as well as a process for doing so. As a result, the securities discussed in this report may not be eligible for sales in some jurisdictions. Customers wishing to obtain further information about this report should contact DCMA: Daiwa Capital Markets America Inc., Financial Square, 32 Old Slip, New York, New York 10005 (telephone 212-612-7000).

Ownership of Securities
For "Ownership of Securities" information please visit BlueMatrix disclosure Link at https://daiwa3.bluematrix.com/sellside/Disclosures.action.

Investment Banking Relationships
For "Investment Banking Relationships" please visit BlueMatrix disclosure link at https://daiwa3.bluematrix.com/sellside/Disclosures.action.

DCMA Market Making
For "DCMA Market Making" please visit BlueMatrix disclosure link at https://daiwa3.bluematrix.com/sellside/Disclosures.action.

Research Analyst Conflicts
For updates on "Research Analyst Conflicts" please visit BlueMatrix disclosure link at https://daiwa3.bluematrix.com/sellside/Disclosures.action. The principal research analysts who prepared this report have no financial interest in securities of the issuers covered in the report, are not (nor are any members of their household) an officer, director or advisory board member of the issuer(s) covered in the report, and are not aware of any material relevant conflict of interest involving the analyst or DCMA, and did not receive any compensation from the issuer during the past 12 months except as noted: no exceptions.

Research Analyst Certification
For updates on "Research Analyst Certification" and "Rating System" please visit BlueMatrix disclosure link at https://daiwa3.bluematrix.com/sellside/Disclosures.action. The views about any and all of the subject securities and issuers expressed in this Research Report accurately reflect the personal views of the research analyst(s) primarily responsible for this report (or the views of the firm producing the report if no individual analysts[s] is named on the report); and no part of the compensation of such analyst(s) (or no part of the compensation of the firm if no individual analyst[s)] is named on the report) was, is, or will be directly or indirectly related to the specific recommendations or views contained in this Research Report.

The following explains the rating system in the report as compared to relevant local indices, based on the beliefs of the author of the report.
"1": the security could outperform the local index by more than 15% over the next six months.
"2": the security is expected to outperform the local index by 5-15% over the next six months.
"3": the security is expected to perform within 5% of the local index (better or worse) over the next six months.
"4": the security is expected to underperform the local index by 5-15% over the next six months.
"5": the security could underperform the local index by more than 15% over the next six months.

Additional information may be available upon request.

Japan - additional notification items pursuant to Article 37 of the Financial Instruments and Exchange Law
(This Notification is only applicable where report is distributed by Daiwa Securities Co. Ltd.)

If you decide to enter into a business arrangement with us based on the information described in materials presented along with this document, we ask you to pay close attention to the following items.

- In addition to the purchase price of a financial instrument, we will collect a trading commission* for each transaction as agreed beforehand with you. Since commissions may be included in the purchase price or may not be charged for certain transactions, we recommend that you confirm the commission for each transaction.
- In some cases, we may also charge a maximum of ¥ 2 million (including tax) per year as a standing proxy fee for our deposit of your securities, if you are a non-resident of Japan.
- For derivative and margin transactions etc., we may require collateral or margin requirements in accordance with an agreement made beforehand with you. Ordinarily in such cases, the amount of the transaction will be in excess of the required collateral or margin requirements.
- There is a risk that you will incur losses on your transactions due to changes in the market price of financial instruments based on fluctuations in interest rates, exchange rates, stock prices, real estate prices, commodity prices, and others. In addition, depending on the content of the transaction, the loss could exceed the amount of the collateral or margin requirements.
- There may be a difference between bid price etc. and ask price etc. of OTC derivatives handled by us.
- Before engaging in any trading, please thoroughly confirm accounting and tax treatments regarding your trading in financial instruments with such experts as certified public accountants.
  *The amount of the trading commission cannot be stated here in advance because it will be determined between our company and you based on current market conditions and the content of each transaction etc.

When making an actual transaction, please be sure to carefully read the materials presented to you prior to the execution of agreement, and to take responsibility for your own decisions regarding the signing of the agreement with us.

Corporate Name:	Daiwa Securities Co. Ltd.
	Financial instruments firm: chief of Kanto Local Finance Bureau (Kin-sho) No.108
Memberships:	Japan Securities Dealers Association, Financial Futures Association of Japan
	Japan Securities Investment Advisers Association
	Type II Financial Instruments Firms Association