TOUCH SCREEN SENSOR TECHNOLOGY – HOW TO PENETRATE THE FLEXIBLE ELECTRONIC DEVICES MARKET WITH A TAILOR-MADE BUSINESS PLAN

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"Coming together is a beginning. Keeping together is progress. Working together is success." --Henry Ford

Erina Suzuki

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ABSTRACT

Nanomade is a start-ups company located in Toulouse, France which owns the touch screen sensors. They conduct the research and development about the sensor that can be used on the electronics devices screen such as tablet and smart phones. The company would like us to study the touch screen devices market and to perform the business model how to penetrate the possible market. Their products have high level of technology, but it was necessary to educate the market to understand the value and to be demanded by the customers who are in the business to business clusters. We created the short and long term recommendation in order to meet the company's requirements.

KEY WORDS: France/ Touchscreen/ Electronic devices/ Technology/ Startups

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CHAPTER I
INTRODUCTION

1.1 Background

The mission the team had assigned from IAE Toulouse - École de Management of Université Toulouse 1 Capitole as the junior consultant in the company called "Nanomade", were to study the touch screen devices market and to perform the business model how to penetrate this specific market with their patented technology.

The company has the technology that developed since 2010 as a prototype but now their technology was concreted and be able to be used in the consumer electronics, so they would like to reach the market to increase their sales and revenues, but because of the uniqueness of their product, the market need to be studied in deep perspective and make them be able to reach the targets.

Moreover, we also studied the competitors' barriers and the other technologies that were the substitute to the company's technology. We suggested the tangible and achievable business model to help them create the idea of how to penetrate the market and also how to increase the sales of the company.

1.2 Problem Statement

The Company, Nanomade, is the touch screen sensor technology provider who has developed the unique solutions for the market where the consumer electronics are provided in focusing on the mobile or tablets solution. Since their technology is the sensor to put behind the substrate of the mobile phone, tablets, televisions or any other materials with display to make the sensitive touch and flexible substrates, to penetrate the market they need to start from to educate the market and the users who are the consumer electronics market and also to study the flexible substrate market trends.

They came up with the idea of developing the technology and to trade their product to the current market where there is only prototype of bendable, foldable and forcible touch screen electronics devices. Believing that the requirement of the users should be created by the technology provider, they continue the research and development in Toulouse for seven years before they decided to reach the market yet they did not know how and when will be the optimum timing to reach the clients.

1.3 Research Objectives

There were three key issues that we got assigned to make the concrete study and plan for the company which are;

1. Perform a market analysis of the flexible display market
2. Identify the key competitors' barriers and key enablers for Nanomade on this market.
3. Propose a strategic plan for Nanomade to enter the flexible electronic devices market

CHAPTER II
LITERATURE REVIEW

2.1 Consumer Electronics Market

The global consumer electronics market is expected to grow at a CAGR of over 5% from 2016 to 2023, and is expected to reach a value of US$1.6 trillion by 2018. The main drivers for this growth are the Analog and Digital TV segment that accounts for 32.3% market share, and the Personal Computers segment worth 25.5% of the total market share. In addition there are the smaller segments such as tablet, digital cameras & camcorder and video/audio equipment.

Geographically, the highest growth in the global electronic market can be found in Asia-Pacific region (CAGR of 17.6%), followed by the Middle East (CAGR of 17%), Africa (CAGR of 16.9%) and Japan (CAGR of 13.9%).

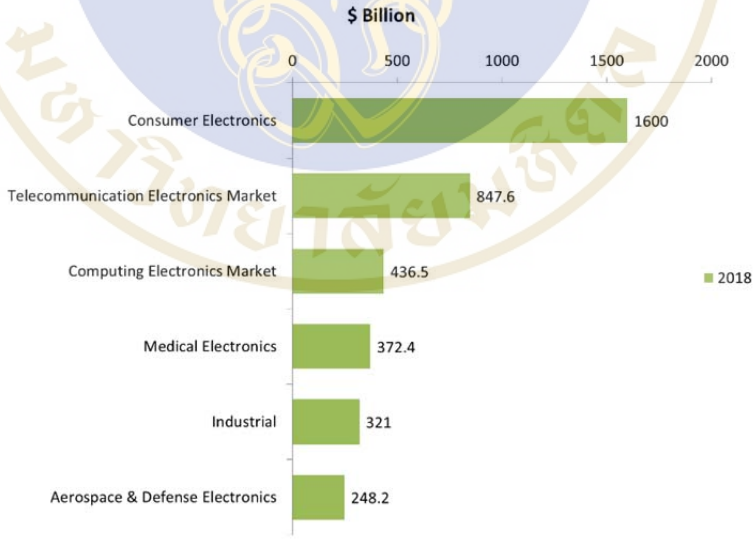


Figure 2.1 Global Electronics Market Revenues per industry in 2018

Source: Singh, A. (2015)

2.1.1 Analog and Digital TV

In the Analog and Digital TV segment, especially the AMOLED market growth is accelerating, and is expected to grow from $10.3 billion in 2014 to just over $23 billion in 2022 (Mertens, 2017). Most of the growth will be from the OLED TV market - which will grow from $400 million (2014) to over $9 billion in 2022. It is believed that the falling prices of LCD TVs make it very difficult for OLED TVs to penetrate the market.

2.1.2 Telecommunications

Telecommunication Electronics Application sector is anticipated to be worth US$ 847.6 billion by 2018 stating a clean CAGR of 12.8%

Asia Pacific will have more than 26.3% market share. Though US accounts for the largest share of market value, India is likely to surpass US in terms of growth rate in near future.

Among the application sectors, Mobile Phones account for the largest share of the entire market, driving a CAGR of 14.5% during the analysis period 2011-2018. Wireless LANs & WANs seen as the fastest growing end-user segment with a CAGR forecast of approximately 20.9% by 2018. With the growing trend in network and mobile satellite terminal technologies (dual-mode GSM cellular/satellite, handset and broadband data) the future of telecommunication electronics industry suggests for a positive growth (Electric Self-Balancing Scooters, n.d.).

Finally, the wearable technology segment is expected to grow from $ 15.74 Billion in 2015 to each $ 51.60 Billion by 2022, at a CAGR of 15.51% between 2016 and 2022

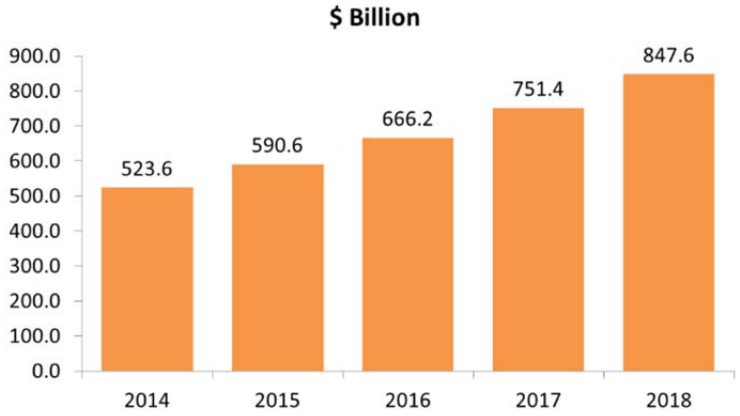


Figure 2.2 Telecommunication Electronics Revenue Forecast 2014-2018

Source: Singh, A. (2015)

2.1.3 Computing Electronics

With a CAGR of 10 %, global market value for computing electronics application sector is anticipated to be worth US$436.6 billion by 2018.

Asia Pacific will have more than 35% market share. Though US accounts for the largest share of market value, India is likely to surpass US & China in terms of growth rate in near future.

With a CAGR of 9.1%, Computer Peripherals account for the largest share of the entire market. Super Computers seen as the fastest growing application with a forecast CAGR of approximately 14.2% by 2018 (Singh, 2015).

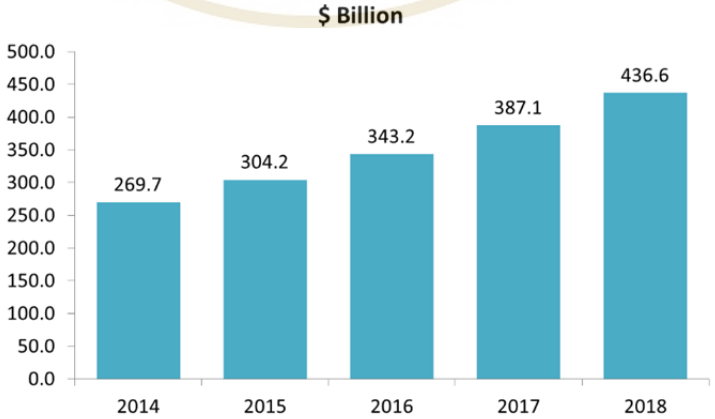


Figure 2.3 Computing Electronics Revenue Forecast 2014-2018

Source: Singh, A. (2015)

2.1.4 Medical Electronics

The medical electronics market is expected to reach US$372.4 billion by 2018. The growth drivers will be application sectors monitoring & surgical systems, imaging systems, diagnostics and medical therapeutics. Globally, medical therapeutics and imaging systems together account for approximately 52.9% of the market and are expected to support the medical electronics industry going forward.

2.1.5 Industrial Electronics

Industrial Electronics market is set to witness a value of US$321 billion by 2018. The growth drivers will be semiconductor capital equipment, test and measuring (T&M) instruments, automation systems and process control instrumentation.

2.1.6 Aerospace & Defense

The aerospace and defense market is expected to reach US$248.2 billion by 2018. The major growth drivers are likely to be application sectors such as engineering/ aeronautics (body), inflight entertainment, avionics and engine.

2.2 Display market

The global display market is expected to grow from $106.41 Billion in 2015, to $155.54 billion by 2020, to $169.17 Billion by 2022

The growth estimations for the Global Display Market vary between 6% CAGR (between 2015 and 2020) and 7.5% CAGR (Markets and Markets, 2017) (between 2016 and 2022). We believe that the average of these two estimations of 6.75% CAGR would be a good indication of the growth of the Global DIsplay Market. The high growth of the flexible panel market, rising demand for OLED-based devices, and development of energy-efficient, attractive, and high specification display products are expected to be the major drivers for the market (Markets and Markets, 2017).

The restraints for this market are lack of financial support, high cost of manufacturing different display technologies/types, R&D and commercial success, adaptability, and acceptance by consumers across the globe. Competitive pricing and design also challenge the scope of the technology and type of display.

Since technologies such as OLED, E-Ink and display type compromising 3D, flexible and transparent are at the nascent stage, there is a wide scope of opportunities for the overall market. The gradual shift from the conventional display type that includes flat panel display type to flexible displays has had a huge impact on the Display Market. Rise in demand for flexible display type based products and applications which are currently utilized in smartphones and tablets among others, have been noticed. The latest display type includes transparent and 3D displays which are in the developmental stage and yet to become commercially viable and profitable.

2.2.1 Key Players: Global Display Market

- Samsung Electronics (South Korea)
- LG (South Korea)
- E Ink Holdings (Taiwan)
- AU Optronics (Taiwan)
- Atmel (U.S.)
- Corning (U.S.)
- Plastic Logic (U.K.)
- DuPont Display (U.S.)
- Hewlett Packard (U.S.)
- Panasonic Corp. (Japan)
- Sony Corporation (Japan)
- Sony Corporation (Japan)
- Philips (The Netherlands)

2.3 Flexible Electronics Market

The global flexible electronics market revenue is estimated to grow from $3.4 billion in 2013 to $5.13 billion in 2015, to $13.23 billion in 2020 to $16.50 billion by end of 2021. The growth forecast of this market is varies widely in different sources; from a CAGR of 21.73% to a CAGR of 67%.

We believe that a CAGR of 21.73% between 2016 and 2021 is the most plausible prediction, and is also found in multiple sources. This growth is said to be driven by the increased deployment of wearable and mobile devices (Wearable Technology Market worth $51.60 Billion by 2022) Brainia (n.d.).

The Markets&Markets analysts, however, expect the Global Flexible Electronics Market to grow at a CAGR of 44.30%, and the Technavio analysts forecast the global flexible electronics market to grow at a CAGR of close to 67% during 2016-2020, which seems surprisingly high compared to the other two estimations.

Geographically, the global flexible electronic market has been segmented into (Businesswire: Technavio, 2017):

- North America → one of the largest markets for flexible electronic in the world
- Europe
- Asia-Pacific → Asia Pacific is expected to grow tremendously in the near future
- Middle East & Africa
- Latin America

2.3.1 Key Players: Global Flexible Electronics Market

- Samsung Electronics (South Korea)
- Solar Frontier (Japan)
- PARC, Inc. (U.S.)
- LG Corporation (Japan)
- Cymbet Corporation (U.S.)

2.4 Introduction to the Flexible Display Market

We have now seen the estimations and forecasts of the Consumer Electronics Market, the Flexible Electronics Market, and the Display Market (for information about the Printed and Stretchable Electronics see Appendix A). These different markets are all part of the Flexible Display market.

There are different factors that matter in the creation of flexible displays. Firstly, the screen size and radius of curvature, or the size and thickness of the display to support the design and function of the hardware. In addition, direction of the folded display – or whether the screen is facing out or in when folded (out-folding or in-folding) directly affects the design of an application. It also can determine the device's exposure to external tensions. An in-folding feature would require lower curvature than out-folding embodiment to keep the two sides of the display close, suggesting that the folded direction could affect the display's durability, internal structure, and materials. Another factor that can affect the device design depends on where and how many hinges (the number of points) go on the display in completely folded state. Along with the folded direction, the hinge location on the device can be mostly affected by repeated stress. Lastly, it is important whether to maintain the same pixel per inch (PPI) across the smartphone and tablet screens.

As of right now, different types of flexible displays are predicted; flat, curved, bendable, foldable, rollable and stretchable.

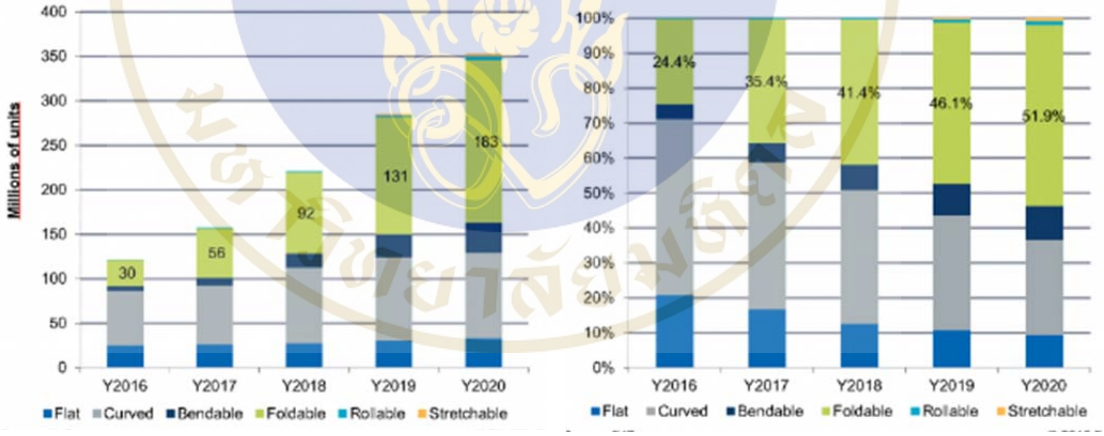


Figure 1.4 Flexible display Market Forecast by form factor

The estimations for the growth of the Flexible Display market vary significantly between the different market reports. EETimes is the most conservative, and expects the market to grow to $3.89 Billion by 2020 at a CAGR of 27% (Markets and markets, n.d.). This is very similar to Mordor Intelligence who estimate the market to reach USD 3.96 billion in 2020, at a CAGR of 27.40% (Mordor Intellige, 2018). Technavio's market research analysts, on the other hand, predict the global flexible displays market to grow

with a CAGR of more than 35% by 2021 (Business Wire, 2017). Finally, Occam Research expects the global flexible display market to hit $4.5 billion by 2022 with a CAGR of 105% in the forecasted period of 2016-2022 (Data Markets Analysis, 2016) (for detailed explanation of the prediction of this forecast see Appendix B).

In 2020 flexible displays will comprise 13% of the total display market, and by 2024 flexible displays (mostly OLEDs) will grab 15% of the total flat panel display market (Mertens, 2017).

Foldable displays will, however, take a 51.9% share in the entire flexible display market in 2020. Global shipments of foldable displays will grow at a Compound Annual Growth Rate (CAGR) of 58% from 2016 to 2020, reaching 180 million units in 2020.

We believe that the estimation of a CAGR of 35% is most likely, and this number is also sources by multiple analysts.

2.4.1 Key Players: Global Flexible Display Market

- AU Optronics
- BOE Technology Group
- EverDisplay Optronics (EDO)
- E Ink Holdings
- RiTdisplay
- Universal Display Corporation
- Visionox
- Hewlett Packard
- SONY Corporation
- Nokia
- Futaba
- LG Display
- Pioneer
- Samsung Display

We will now have a further look into the Flexible Display Market. In order to analyse this market it will be segmented in four different parts.

Firstly, we will look at the different Applications of flexible displays (Chapter 2). Secondly, we will analyze the different existing technologies to produce flexible displays (Chapter 3). Finally, we will have a look at the different components that are required in order to make a flexible display, and we will have a closer look on the materials used to create a substrate (Chapter 4).

2.4.2 Segmentation of the Flexible Display Market

2.4.2.1 By Application

- Mobile phone displays
- Tablet and notebook displays
- TV panels
- Automotive and aerospace
- Wearable electronics
- Industrial and professional displays
- Microdisplays
- Other applications

2.4.2.2 By Technology

- OLED/AMOLED
- LED-LCD: OLCD
- EPD-ink

2.4.2.3 By Components

- substrate
- conductive layer
- organic material
- backlight panel
- others

2.4.2.4 By (Substrate) Material (PR Newswire, 2014)

- Glass
- Flexible glass

2.5 Applications for Flexible Display

While currently the only devices that use flexible displays are phones and watches, this will expand to include tablet and notebook displays, automotive and aerospace displays, micro-displays and displays for industrial and professional use. In addition, the flexible displays will be applied into TV panels.

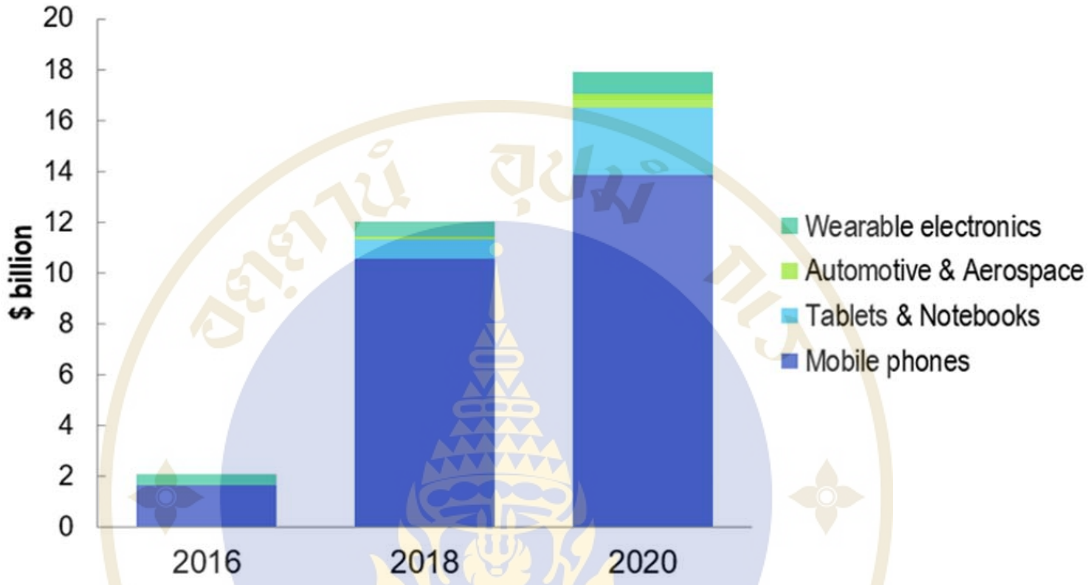


Figure 2.5 Plastic and Flexible AMOLED Electronics

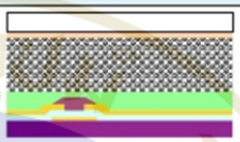
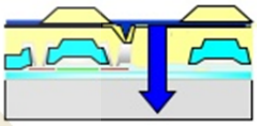
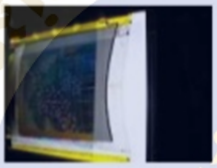
Source: Chansin, Ghaffarzadeh, & Zervos (2016)

According to IDTechEx, the flexible displays will mostly be used in mobile phones, with an expected market value of $14 Billion in 2020. Secondly, the most used application are expected to be tablets and notebooks, with a respective value of $2.4 Billion in 2020. Finally, the automotive & aerospace, and the wearable electronic applications are expected to have a market value of respectively $600 Million and $900 Million.

2.6 Technology for Flexible Displays

Flexible displays can be manufactured with QLED, (AM)OLED, LCD and EPD. However, flexible LCD's have not been commercialized yet. The differences between EPD, OLED and LCD are briefly explained in the Table 2.1.

Table 2.1 The Differences between EPD, OLED and LCD

Tech.	AM-LCD (Liquid Crystal Display)	AM-EPD (Electrophoretic Display)	AM-OLED (Organic Light Emitting Diode)
Structure			
Prototype	 ITRI, 2007	 AUO/ITRI, 2009	 ITRI, 2010
Flexibility	Poor	Good	Excellent
Performance (Video rate)	Excellent	Poor	Excellent

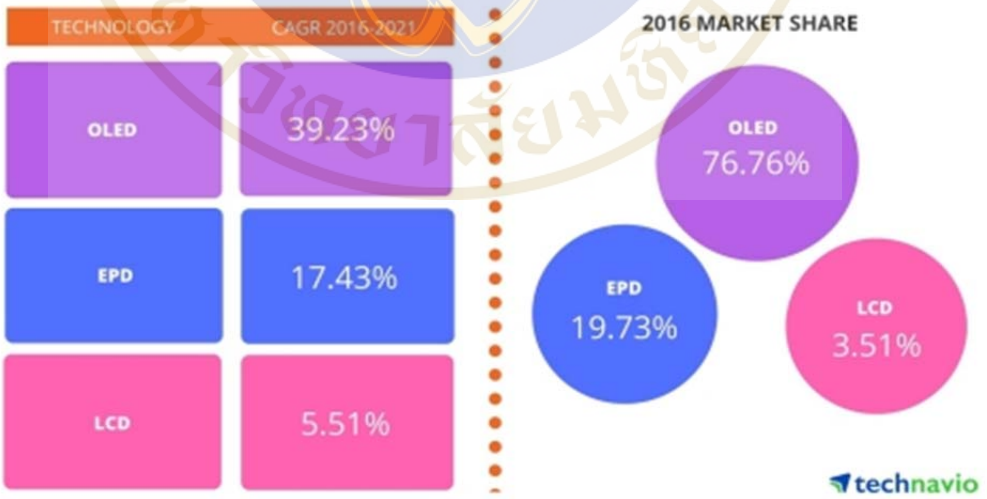


Figure 2.6 Flexible Display Market Forecast

Source: Business Wire (2017)

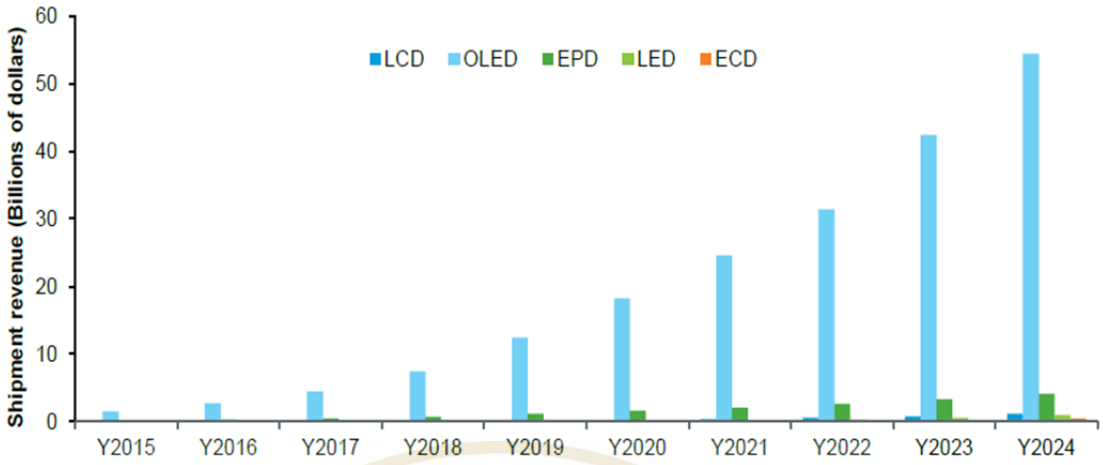


Figure 2.7 Flexible Display Market Forecast

2.6.1 OLED/ AMOLED

Currently, there are not many brands that are producing (AM) OLED displays, but due to the investments that are being made, we can see how in 24 month this technology has lower its costs. (AM)OLED displays can be thinner and flexible when they are applied with other class of materials. In addition, they consume less energy than the LCD displays.

Companies such as Samsung and LG Electronics adopted (AM) OLED displays in 2013 for use in their smartphones and have continued to use flexible (AM) OLED displays for smartphones, smartwatches and fitness trackers since they enable more curvilinear physical design.

LG Display leading the way in production (for TV's), it is currently the only company in mass production of (AM) OLED TV. Their displays use White (AM) OLED technology which enables them to go to the market faster. LG combines the ultra-thin (AM) OLED front plane with an inorganic backplane technology, such as LTPS substrates (Low Temperature Polysilicon). In addition. These displays offer some flexibility, which is limited by the inorganic ('ceramic-like') materials used in the LTPS backplane, which can crack if bent too far.

Samsung is currently the leading manufacturer (for cellphones) of flexible (AM) OLED and supply has been heavily constrained by demand from its own phones and a small selection of other manufacturers.

Adopters of (AM)OLED displays for smartphones include Samsung, Huawei, OPPO, Vivo, and Meizu.

Companies are working on alternatives that will be more flexible, as well as simpler to manufacture. For example, engineers at FlexEnable have been able to combine the (AM)OLED front plane with an organic thin film transistor (OTFT) array forming the backplane – enabling a truly flexible (AM)OLED display module (IEEE Xplore - Conference Table of Contents, n.d.).

2.6.1.1 Forecast

The potential applications of (AM) OLED displays are far reaching. This new market is set to explode, and analysts predict that the (AM)OLED market will grow from $16bn in 2016 to $57bn in 2026 (Chansin, Ghaffarzadeh, & Zervos, 2016). This is not surprising given that consumers will soon be seeing this form of display in wearables, mobiles and even television panels.

Market researchers, including IHS Markit and TrendForce, also expect Apple to adopt (AM) OLED displays in its upcoming iPhone models. Adoption of (AM) OLED displays will be a milestone for (AM) OLED in the display industry."

Analysts from IdTech expect the first flagship phone with a flexible display to ship in 2017. Based on this scenario, the market for plastic and flexible (AM) OLED displays will rise to $16bn by 2020 (Chansin, Ghaffarzadeh, & Zervos, 2016).

Government studies from Taiwan are also expecting a huge jump in flexible (AM) OLED shipments in 2017, estimated to be in the region of a 200% gain. The report estimates some 150 million flexible (AM) OLED panels to ship this year, up from 50 million last year. However, more conservative reports suggests that we could see close to a 50% jump in (AM) OLED shipments in 2017.

IHS forecasts global (AM) OLED manufacturing capacity to increase from 5 million square meters in 2014 to 30 million square meters in 2020. (AM) OLED display shipments are expected to grow 40 percent, year over year, to reach 395 million units in 2016, while revenue is forecast to increase by 25 percent, to reach $15 billion in 2016.

Senior director for IHS David Hsieh says several manufacturers, including "Samsung Display, LG Display, Sharp, JDI, BOE, Tianma, GVO, Truly, and

CSOT are also starting to ramp up their (AM)OLED manufacturing capacities and devote more resources to technology development," ."Samsung Display's enormous sixth-generation A3 (AM)OLED fabrique, for example, will enable even more (AM)OLED displays to reach the market."

Boyce Fan, senior research manager at WitsView says: "Products carrying (AM) OLED panels are projected to account for 70 percent of Samsung's smartphone shipments this year,". "SDC is also seeing a rise in the sales of (AM) OLED panels to other smartphone vendors, including Chinese brands. Over 50 percent of the respective smartphone shipments from OPPO and Vivo this year will be models with (AM) OLED screens."

Fan believes, LG Display (LGD) and Japan Display (JDI) will try to catch up with SDC by accelerating their timetables for the development and mass production of (AM)OLED panels, predicting the two companies becoming Apple's (AM) OLED panel suppliers in 2018 at the earliest. "LGD and JDI's efforts will eventually allow Apple to spread its orders out among multiple suppliers."

2.6.1.2 Future investments in (AM)OLED

- Foxconn-owned Sharp is mulling over a major 100 billion yen, about $864 million, investment into starting up an (AM)OLED production line, up from a $568 million investment announced in September 2016 (AppleInsider, 2017). The company has also been teasing a $7 billion US based display production facility to ramp up its supply for Apple, although this investment is far from confirmed (Wu, 2017). Speculation is still swirling about Apple finally making the switch from LCD to (AM) OLED with its next iPhone, but the industry would need additional capacity to cope with that demand.

- In China, local manufacturers are looking to diversity away from Samsung's hold on the (AM)OLED market by expanding their own production capacity (Huang, 2017). According to Digitimes Research, total annual capacity is estimated to increase from 272,000 square meters in 2016 to 1.584 million in 2018, 4.464 million in 2019, and 7.864 million square meters in 2020. For comparison, Samsung Display and LG Display offered 4.945 million square meters of production capacity for (AM) OLED in 2016, which is expected to increase to 15.13 million in 2020.

China is looking to close the gap, with BOE Technology, Tianma Micro-electronics, and Visionox expected to become the top three manufacturers in China come 2020.

1. BOE Technology

BOE technology is a Chinese Company. It's the first of this country that sums up to Samsung, LG, Sharp and Japan Display that works as Apple suppliers. To be able to confront the strong demand Apple requires, they are making a huge investment (14500 millions) in the construction of two plants in the province of Sichuan.

Despite BOE Technology effort to meet Apple's requested dates, they probably will not meet them for iPhone expected release date in 2017. To be precisely one of the two plants, located at Mianyang won't be fully functional for the next 2 years. However when both plants work at 100% they will be able to produce 1.6 millions of square meters of cristal (AM)OLED subtract a year

2. Tianma Micro-electronics

Tianma Micro-electronics Co., Ltd. (Tianma) specializes in providing display solutions and efficient support services worldwide. The company produces to the consumer and professional display industries that are used in applications to include smart phones, tablet PCs, smart wear, automotive instrumentation, industrial and medical instrumentation, avionic display, home automation, etc.

Tianma has a clear technological and production advantage in the small and medium sized display market where it has enjoyed a strong market presence over the years. Tianma has established a National R&D Laboratory on TFT-LCD Key Material and Technology, a National Enterprise Technology Center, and a post-doctoral workstation to enhance the knowledge and technical expertise of our employees. The possession of new technologies including LTPS-TFT, Oxide-TFT, (AM) OLED displays, Flexible displays, Transparent displays, 3D displays and In-cell/On-cell integrated touch technology lays the foundation for innovation and the development of new and exciting products.

They have a comprehensive production line combination including G4.5/G5 a-Si TFT–LCD, G5.5 LTPS TFT-LCD, plus one G5.5 (AM) OLED line and two new G6 LTPS TFT-LCD lines under construction. Tianma was the first to start mass production from a G5.5 LTPS production line in China.

3. Visionox

This is an (AM)OLED technology company, with 1,700+ patents and the world's largest (AM)OLED displays manufacturer. They have developed monotone, area color, full color, and flexible (AM)OLED displays. They produce a full suite of display solutions including: (AM) OLED, PMOLED and TFT LCDs (Resistive Touch Panel and Capacitive Touch Panel) (AMOLED, n.d.)

2.6.1.3 (AM) OLED Vs. LCD

The battle between (AM)OLED and LCD has been a long running, but the consensus is now leaning towards (AM)OLED as the technology that has made the greatest strides in improving display quality and pushing the boat out in terms of new form factors. Flexible (AM)OLED has been made popular by Samsung's Galaxy Edge flagships, but flexible LCD and other advancements could mean that this battle is soon to heat up once again.

OLED displays are thinner, lighter, and offer better color performances compared to LCD.

What we would see later are the two most important events that had taken place in 2017 which can force the balance to one side or the other;

- (AM) OLED became cheaper to produce than LCD
- LCD has developed new ways that enable the technology to become as flexible as the (am) oled displays can.

2.6.1.4 When (AM)OLED became cheaper to produce than LCD

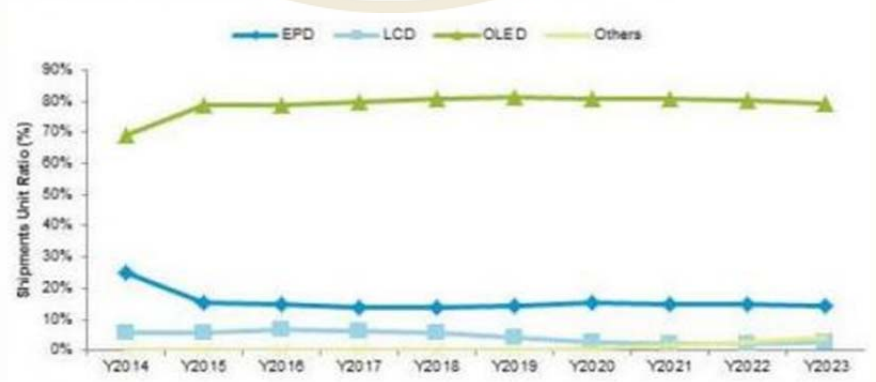


Figure 2.8 Flexible Display Market Share by Technology (Shipment Unit)

Source: IHS 20142014 | Transmittal Notices. (n.d.).

2016 was an important year in the battle between (AM)OLED and LCD, as the price of a 5-inch (AM)OLED panel fell below that of an equivalent LCD panel for the first time. One of LCD's major advantages over(AM)OLED had been that it was cheaper to produce, but with this advantage eroded, mid-tier and low end manufacturers are going to start showing an interest in the most cost effective display technology. This will place increasing pressure on the already limited supply chain.

As predicted two years ago, it has only taken 24 months for (AM) OLED production costs to fall below that of LCD, according to new data from IHS Technology. Production costs in the first quarter for a 5-inch Full HD smartphone display are $14.30 for an (AM) OLED panel and $14.60 for an LCD display. In the fourth quarter of 2015, these figures were $17.10 and $15.70, respectively.

The importance behind these numbers, is the fact that reports that had predicted this event, have gain credibility making them the ones the company should base their assumptions in.

2.6.1.5 Key Players: OLED/AMOLED

- Samsung Display
- LG Display
- Sharp
- JDI
- BOE
- Tianma
- GVO
- Truly
- CSOT

2.6.2 LCD

LCD is the main display that TV and cellphone use in flat formats for the past 20 years (see Graph 10 However, they are losing terrain in the flexible market due to the (AM)OLED capacity to be flexible in comparison with LCD displays. LCD's market share right now is about 90%of the market of displays, thus these technology should not be taken as an obsolete technology since companies will fight to keep LCD displays and continue to leveraging of their economies of scale.

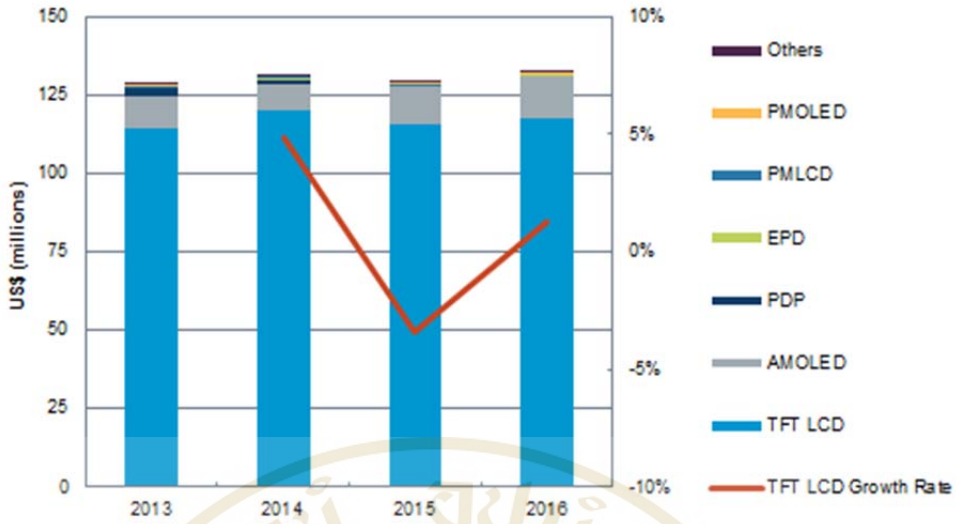


Figure 2.9 LCD leader in Flat (non-flexible) Display Market

Source: ihsmarkit. (n.d.)

Display history shows that changes in industry occurred gradually during time. The following timeline below shows how slow the display markets evolves. What we can conclude is that although (AM)OLED is the trending and new right now, because of its flexible quality, we may have to wait several years until it actually hits its peak of production making LCD obsolete. Meantime, LCD displays may have reached its peak of production and may gradually start to decrease its production volume.

Table 2.2 Historical Development of Display Technology

	1st Working Device	1st Demonstration	1st Production	Mass Production	Peak of Production
LCD	1962	1971	1983	1990	
PLASMA	1963	1964	1992	1997	2006
OLED	1987	1996	1998	2002	

Source: Mertens, R. (2017)

2.6.2.1 LCD is not over yet, new flexible LCD

Japan Display Inc (union between Hitachi, Sony & Toshiba) has announced the first release of flexible LCD screens, which bends like the (AM) OLED display from Samsung and LG. JDI flexible panels are not yet as good as the (AM)OLED Samsung display but is a big step towards LCD flexibility.

The technology enables flexible LCD panels by using a plastic substrate on both sides of the liquid crystal layer, rather than using a glass substrate. Not only is this much more flexible, but also makes the display much less prone to breaking when dropped. JDI plans to start manufacturing its Full Active Flex display in 2018.

The screen will support Full HD resolutions and can support a driving scheme as low as 15Hz in addition to the normal 60Hz driving scheme. It claims this will allow for lower power consumption in smartphones. They are supposed to be cheaper to produce than OLED displays.

Apple is apparently looking for next-gen flexible LCD screen technology from Japan Display to use in future iPhone models. According to the Wall Street Journal, Apple is 'considering' the new panels for future iPhone designs which could pave the way for bendable smartphones becoming mainstream (Mochizuki, 2017). However, JDI tech is brand new and we don't really know how will affect the industry. With the existing technology (AM) OLED is predicted to highly overcame LCD displays. Companies are investing in R&D on LCD displays because they had invested huge amounts of money in assembly lines and prefer a technology that use their existing technology.

2.6.2.2 Key Players: LCD

- Sharp
- JDI
- Dacon AS
- LG Display
- Samsung
- InnoLux

2.6.3 EPD

3.6.3.1 Electronic Paper Display

EDP is a daylight-readable, very low-power display technology that is used in e-readers, wearable display, smart cards, POP/ESL. EPD looks like 'ink on paper' due to the moveable pigments used in the pixels that reflect (or absorb) daylight, without the need for any backlights. Many e-readers are based on the electrophoretic display (EPD). EPDs have been produced using a glass substrates containing transistors, making them brittle.

In the present LG is producing flexible EPDs using FlexEnable's technology. LG Display announced that it has started mass production of the world's first plastic EP for use in E-Books. The 6" XGA (1024x768), e-ink. With the world's first plastic EPD, will help greatly popularize the E-Book market. According to LG announcer they are looking towards applying the concepts gain from this mass production experience in the development of plastic (AM)OLED and flexible display.

There are no signs that EPD will replace (AM)OLED in the coming years. EPD is also still less attractive to technologies such as LED or LCD, because it still unable to reproduce animations and it is difficult to read when there's no light. Despite this, as the figure 2.10 shows is still an attractive market due to its expected growth rate for the next years.

Figure 2.10 Global EPD Market Revenue and (Expected) Growth (2013-2022) (US$ Mn) (Y-o-Y %)

Source: Credenceresearch. (n.d.)

3.6.3.2 Key Players: EPD

- BeBop Sensors
- Interlink Electronics
- InVisage Technologies
- ISORG
- Parker Hannifin
- PST Sensors
- Sensitronics

- SPEC Sensors
- LLC

2.7 Components and Materials for Flexible Displays

In this section, we will focus on the materials used for one major component that is the substrate. Flexible substrates are needed both in the encapsulation and as the flexible platform on top of which sits the conductors, to form the conductive layer. Flexible substrates are involved in both the encapsulation layer and the conductive layer.

To support the above statement, the IHS Market revenue Forecast of AMOLED Equipment producers by process type shows how important the encapsulation layer and conductive layer (TFT) will be in 2107; and how in consequence the need for substrates will grow (Annis, n.d.)

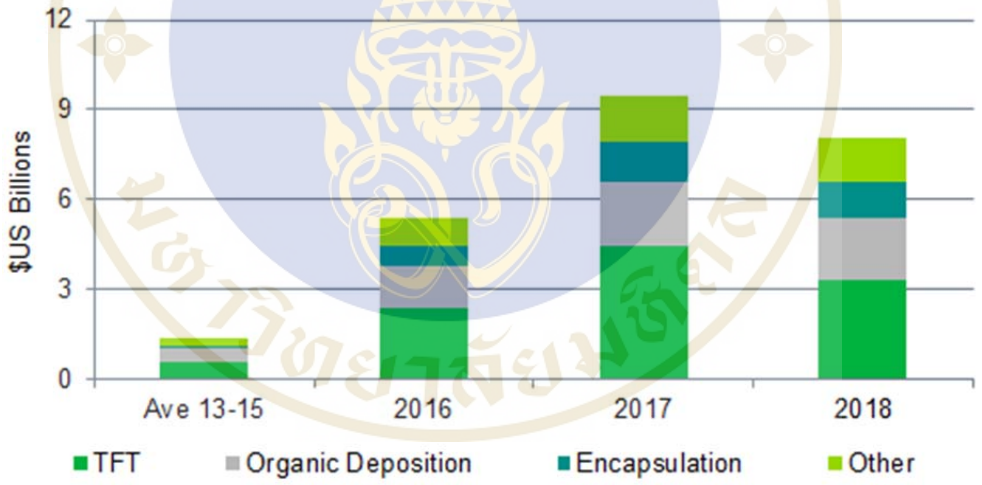


Figure 2.11 AMOLED Equipment Revenue by Process Type

Source: IHS 2017 (International Housekeepers' Summit). (n.d.).

The total AMOLED-specific production equipment purchases in 2017 will be worth $9.5 billion. Almost half of that amount will go to TFT backplane equipment ($4.4 billion in 2017), while the organic layer deposition market will reach 2.2 billion and the encapsulation tools market will reach $1.2 billion. IHS estimates that Canon Tokki is the leader in OLED deposition equipment, and has a market share of over 50%.

AMOLED displays require high-performance encapsulation to prevent sensitive organic light-emitting materials from environmental degradation. Encapsulation barriers are typically fabricated from metal, glass or stacks of thin films. However, a substantial share of the new AMOLED factories now under construction will target production of plastic, flexible displays, which rely on cost intensive, multi-layer thin film encapsulation (TFE).

According to experts, the flexible AMOLED makers have done an incredible job simplifying their TFE structures over the past several years. Even so, the productivity of depositing high-quality inorganic films and printing organic layers all in a closed environment remains a complicated challenge. The requirement of a large number of deposition chambers and auxiliary tools make TFE lines one of the largest segments of the AMOLED equipment market (IHS 2017 (International Housekeepers' Summit, n.d.)

Materials used to make flexible substrate: Materials have a key role to play in the advance towards flexible displays. Most experts in the industry will carry out a segmentation as follows:

- Glass
- Metal
- Polymer (plastic)
- Glass reinforced plastic

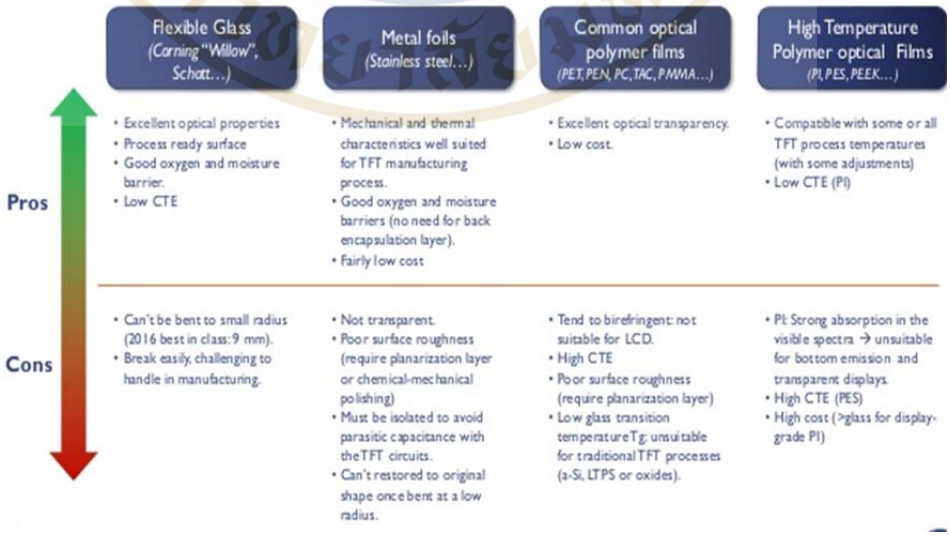


Figure 4.12 Major Types Of Flexible Substrates (Yole Développement institut - 2016)

One of the challenges the industry faces with respect to materials is moving away from rigid glass encapsulation without compromising the operation or reliability of the display's thin-film transistor (TFT) backplane when the device is flexed, folded, or bend.

2.7.1 Glass and Flexible Glass

2.7.1.1 Normal Glass

Today, LCD accounts for more than 90% of the displays sold, and they are made with glass. But the main problem associated with glass substrates is that they cannot meet the conformability, thinness and robustness requirements in many new flexible applications (Flexnables, n.d.). Therefore rise of plastic and flexible displays should be accompanied by a shift from glass substrates to plastic substrates such as polyimide. However, glass-based displays will remain an important technology, especially in the TV segment where scale-up and cost reduction are still the main challenges (Chang weng, n.d.)

2.7.1.2 Flexible Glass

The two biggest display producers, LG and Samsung in their latest report did not rank flexible glass as their preferred choice for the encapsulation and base substrate (David Savastano, n.d.). However this might change if current flexible glass developers achieve further improvements.

Corning and Schott to name a few, are coming up with flexible glass substrates with a thinness that was only possible with plastic substrates before. Schott would have been able to develop an ultra-thin and eco-friendly glass with outstanding mechanical properties.

The Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP has demonstrated the fabrication of large-area OLEDs using ultra-thin glass foils both as a substrate and a protection barrier, through a single roll-to-roll manufacturing step (Julien Happich, 2016).

2.7.2 Key Players: Flexible Glass

2.7.2.1 Corning: Corning® EAGLE XG® Slim Glass substrates enable panel manufacturers to innovate for thinner, lighter, and more environmentally conscious display panels. EAGLE XG Slim Glass delivers dimensional stability and exceptionally clean, smooth, flat surfaces – qualities essential to the successful manufacturing of LCD displays.

2.7.2.2 Asahi Glass: Asahi Glass produces Ultra-thin glass cover glass and substrates. Ultra-thin glass laminated substrate is a novel glass substrate which consists of AGC's ultra-thin glass (0.1 or 0.2mmt) attached on a sheet of career glass coated with their original bonding layer. Dragontrail is their their most popular cover glass. With impressive bending properties. (AGC Dragontrail, n.d.)

2.7.2.3 Schott: SCHOTT ultra-thin glass is available in different glass types with diverse chemical and physical properties in a thickness range of 25 - 210 µm.

2.7.2.4 NEG: NEG makes ultrathin glass plates to be used as substrates for flexible displays, functional glass materials, and so on. At the trade show, the version company also introduced a flexible OLED display made by using a 50-µm-thick of G-Leaf. Value proposition & positioning: “G-Leaf™ ultra-thin glass for use in some of the most talked-about next-generation technologies such as OLED and flexible displays. Ultra-thin glass is the ideal material for protecting humidity-sensitive OLED elements and maximizing their advantages. Meanwhile, in energy and other fields, we aim to sell G-Leaf™ as the solution to issues that film and other materials cannot resolve, and a means to achieve more advanced technologies and products. We are determined that G-Leaf™ will contribute to a future society that is environmentally and user friendly by expanding the scope of its uses to electronic paper, touch-panel displays, electronic billboards, and beyond.” (Mertens, 2017)

2.8 Key Take-Away and Insight of Part A

2.8.1 Overall Electronics market

Flexible Displays are the fastest-growing sector within the global consumer electronics market

We have analyzed different market in order to get a broad perspective to look at the Flexible Display market. We have seen that the Consumer Electronics Market is expected to grow with a CAGR of 5%, the Display market with 6.75%. The growth rate of these market are relatively low, since they are well established. More emerging markets such as the Flexible Electronics market and Flexible Display market show a higher growth the CAGR's of respectively 21.73%, and 35%. We can see that the market growth increases when the market get more specialized, and when the market involves newer technologies, since here is in the largest opportunity for growth. In addition, we can see that in 2020 flexible displays will comprise 13% of the total display market, which will grow to 15% by 2024. These numbers show that there is a tremendous growth expected in this market in the near future, which can lead to interesting sales potential. In Part B we will combine these results with the predictions for the Force Sensing, in order to forecast Nanomade's sales potential.

2.8.2 Applications

Flexible displays will mostly be used in mobile phones, followed by tablets and notebooks, automotive & aerospace, and the wearable electronic applications.

Furthermore, they will be used in microdisplays and displays for industrial and professional use, however, this market share is expected to be a lot lower.

We believe that Nanomade would be able to gain a relevant market share when focusing on the application of their ink in mobile phones and tablets.

2.8.3 Technologies

Three major technologies in the race to flexibility. (AM) OLED ahead. LCD lagging behind.

- Top three (AM)OLED display manufacturers: LG Display, Samsung Display, Sharp (Foxconn-Owned)
- Three identified leaders in flexible display technologies: LG Displays, Samsung Displays, JDI

We observed that (AM)OLED has had an enormous growth during the last years, since companies like Samsung, LG, Huawei, OPPO, Vivo, and Meizu had already adopted this tech, and Apple is expected to make the change this year. For the reason

that, lower costs has being the main advantage of LCD over (AM) OLED but in the last quarter of 2016, the last one became cheaper to produce.

We believe this technology is going to have an significant growth in the coming years, for both regular and flexible displays. The fact that (AM) OLED can be a flexible technology is also promising for manufacturers that have already start to make some bendable products.

As for LCD's displays, JDI announced the first release of flexible LCD screens, which bends like the OLED display and supposed to be cheaper to produce than OLED displays. We will have to wait to see if this new technology is release in the near future, which will consequently lower down (AM) OLED growing rate.

2.8.4 Materials and components

Confidence in the capacity of plastic-based substrates to overcome the challenge of flexibility both for encapsulation and base substrate.

The two biggest display producers, LG and Samsung in their latest report did not rank flexible glass as their preferred choice for the encapsulation and base substrate. The main problem associated with glass substrates is that they cannot meet the conformability, thinness and robustness requirements in many new flexible applications (Flexnable, n.d.). Therefore rise of plastic and flexible displays should be accompanied by a shift from glass substrates to plastic substrates such as polyimide.

CHAPTER III
RESEARCH METHODOLOGY

3.1 The Five Force Model

Figure 3.1 Five Force Model for Nanomade's direct industry

We study the industry to analyse the key players, their activities and the nature of their relationships within this industry in order to gain an overall picture of the environment in which Nanomade evolves. By uncovering the dynamics that guide the multi-force sensing market for flexible displays, we will provide insights into the strategies adopted by the competition, highlight their limitations, and we will be able to tell which factors in this industry should be leveraged by Nanomade to its own advantage.

CHAPTER IV
FINDINGS AND DATA ANALYSIS

4.1 Industry Rivals (Low - Moderate)

4.1.1 Scope of Study

An analysis of the industry's rivals shows us the current players and the intensity of the competition compared to the company's product and technology. From our study and research towards the industry, we realized that the driving factors that defined rivalry intensity are Strategic Focus, Diversity of Competition and Capacity increases.

Moreover, we compare the resources and competency of each players in order to reach deeper insight of them. The study covers the company background of the players including the field of the products, target industry, company size, production capacity, research and development facility, financial resources, intangible and tangible assets, core competency and their value proposition.

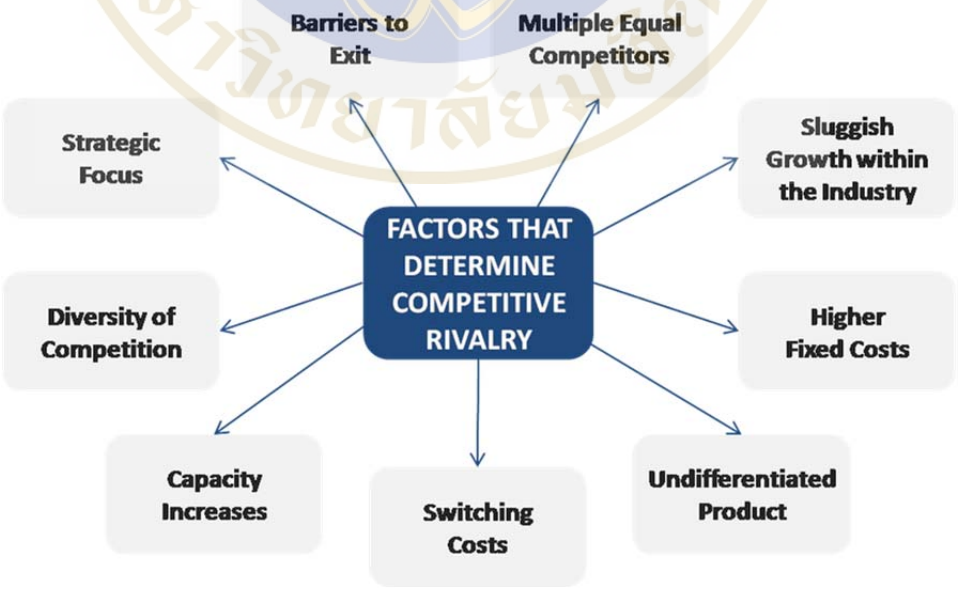


Figure 4.1 Features of Competitive Rivalry

The Industry rivalry is low-moderate, since the number of direct competitors to Nanomade who are able to deliver force-sensing on flexible display technology, are three which are Peratech, Nissha-C3Nano and Royole. For a detailed description of the product's, value proposition and resources of each company see Appendix C.

4.1.2 The strategic focus

The strategic focus of the current players in the market is mainly to co-develop with the supplier or the buyer in order to reach the market requirement of the display manufacturers. We found interesting strategic moves made by competitors in the industry which is the key insight we found.

The feature related on diversity of competition, is affected by the strategic moves we found from the study. The benefits gained from their move are for; resources (including production capacity), research and development laboratories, and human resources. Finally, working together with other players increases the reach into the market.

Three industry rivals:

- Peratech
- Nissha & C3 Nano
- Royole

4.1.3 Industry rivals analysis

4.1.3.1 Peratech

Peratech was founded in 1996, and invented the technology called QTC materials providing touch and force sensing solutions. They co-develop the product with other electronics producer to integrate their force sensing sensor such as SHARP, and other PC manufacturers. The company has the patent of QTC which is their distinctive product to take a role in patenting with the manufacturer. Moreover, SHARP is owned by Foxconn who is the Taiwanese electronics devices producers for Apple Blackberry and, so there is the possibility for Peratech to increase its production capacity.

Table 4.1 Peratech

	Peratech
Company Background	Peratech is a Force-sensing HMI/MMI Solutions Company, founded in 1996 and inventor/developer of proprietary QTC® (Quantum Tunnelling Composites) materials, providing Touch/Force-Sensing solutions. The founders are from Stanford University
Target Industry	Consumer Electronics, Automotive Electronics, Smart Home & Appliances, Industrial
Products	QTC Multiple Touch and Force called QTC Multi-force Matrix Sensors which Integrated under top surfaces(including flexible display)
Accumulated Revenue	No information
Already used the tech in	Smartphones, Electronic whiteboard, Cordless drills, NASA Robots
Resources	
HQ	York Shire, United Kingdom
Subordinates	USA,South Korea, Stockholm, Sweden
Employee	20people as on Apr2015
Production Capacity	Refers to part A, Technology in (AM)OLED, Foxconn(which own Sharp)has invested the OLED production capacity Sep.2016 means, Peratech could use their production capacity for the products.
Technology related	R&D in HQ, Test Labs both for function and cost efficiency,International Patents
Financial aspect	Founded for 1 Million Pound in 2015 / 1.25M.USD
Intangible	Possible approach to the production capacity from Joint Development Partnership,
Core competency	Custom sensor design , including Mechanical and electronic design and test with software by keeping existing buyers factories
Value Proposition	Custom Sensor Design and , Consultancy Service(Complete service such as designing, testing, plan purchasing and production)
The strategy and Marketing Target	Co-Develop with other electronics producer to integrate their sensor such as Sharp, and other PC manufacturers and Use their Patents. Which Foxxconn (the Taiwanese electronics devices producers)owns Sharp, so there is possibility to reach its production capacity.

4.1.3.2 Nissha-C3 Nano

Nissha is a Japanese player, and the leader of the printing industry. They own a capacitive Touch Sensor after a joint development with C3 Nano in 2015. C3 Nano owns the transparent conductive ink and film for the touch sensor and display.

With this strategic move, Nissha could expand their product line into the Sensor Category for resistive multi touch sensors with transparent conductive ink. The product is called “Fine Touch Z”, however, no sales revenue have been presented to the market yet.

Table 4.2 Nissha-C3 Nano

JOINT VENTURE	Nissha	C3 Nano
Company Background	Japanese Leading Printing company established in 1929. Currently has 52 consolidated subordinates globally. The main idea is to develop the technology of printing without using paper and they have been improving into different dimensions relevant to printing	Transparent conductive ink and film for the touch sensor and display provider who signed Joint Development Agreement with Nissha in 2015. The company was founded in 2010
Target Industry	Industrial materials, Devices, Life innovation, Information & communication, Medical, Automotive	Solar Cell, Electronics, Clean Energy, Manufacturing
Products	Capacitive Touch Sensor "Fine Touch" and Resistive Type Touch sensor "Fine Touch Classic" called "Fine touch Z" : resistive type multi touch sensor	C3 Nano Active Transparent Conductive Ink "Active Grid Ink", C3 nano Activegrid Film: ITO alternative,C3 Nano Activeguard HC; Coating to prevent scratch on flexible film
Accumulated Revenue	1.25 M.USD	No information
Already used the tech in	Digital Camera, Automotive	Touch sensors, OLED lighting, OLED displays, EMI shielding, smart windows, E-paper, LCDs and solar cells
Resources		
HQ	Kyoto,Japan	California, USA
Subordinates	52 all around the world	

Table 4.2 Nissha-C3 Nano (cont.)

JOINT VENTURE	Nissha	C3 Nano
Employee	5,087people, from Dec2016	40 people
Production Capacity	2012 Mass Capacitive Touch Panel production line in Japan. Factory located in Kaga and Himeji Prefecture	Acquired Aiden Co ltd. the Silver Nanowire manufacturer
Technology related	Research and Development Team	Machinery and technology development from acquiring and partnershipping with other companies ie.Aiden Inc., Nissha Printing, Hitachi chemicals
Financial aspect	Public Company	Accumulated funding at 37million USD since 2010. They have 15Million equity in 2017 (Main Raised fund from mainly Japanese and US companies)
Intangible	Great reputation and history. The strong experience in printing industry	Relationship and network with Big player in Japanese market (Nissha and hitachi Chemicals)
Core competency	Deliver the complete sensor offering, Ready to make the mass production due to the production capacity	High performance ITO replacement for flexible force sensor (Films & Ink)
Value Proposition	One stop Service(Providing devices, Services ,Systems,After sale service)	Solution oriented product offering, ITO replacement
The strategy and Marketing Target	Joint Development agreement with c3 nano in 2015 who is the Conductive ink and flexible encapsulation producer which shows their move in consumer electronics industry and inhouse development for the material solution Focused on capacitive touch panel in automobile and home appliances industry. Because consumer electronics' demand is fluctuated. Market industry target: Healthcare, medicine, agriculture, education, housing equipment, industrial equipment, and automobiles	Strong research and development move from partnership with leading company Nissha and Hitachi Chemicals The material provider to the big player. Can assume from partnership move that the first target can be in Japan

4.1.3.3 Royole

Royole was established in 2012. They now mass produce flexible sensors and flexible electronic devices and succeeded to present the world's' first thinnest flexible AMOLED display. They mostly co-develop their product with clients of AMOLED display, sensors and electronics devices. Their main focus is the mobile device market due to their partnership with China Mobile, China's largest telecommunication company.

Table 4.3 Royole

	Royole
Company Background	The company established in 2012 by Stanford Engineering graduates. 2014 introduces world's thinnest AMOLED flexible display
Target Industry	Wearable products, Mobile devices, Consumer electronics, Vehicles, Flights, Smart home appliances, Sportswear, Fashion,
Products	Flexible Sensor, Foldable 3D virtual mobile theater,
Accumulated Revenue	No information
Already used the tech in	Foldable 3D Virtual Theater($799 USD) Curved Dashboard
Resources	
HQ	California, USA
Subordinates	HK,China
Employee	700 people, from 12 countries
Production Capacity	2015 began mass production of flexible sensor and flexible electronic devices. Flexible display mass production campus in China(fully operate in mid 2017) with 1.8B.USD investment
Technology related	R&D, Sensor Design team in China(Shenzhen), Technology insight team in USA
Financial aspect	AUG2015, Funded 172M.USD, NOV2016, Funded $80 USD(Accumulate 252M.USD) In October 2016 market valuated at 3 Billion USD
Intangible	First mover in innovation field, Great innovative image, Awarded know-how
Core competency	Custom design and co-development with Display producers. Mass Production Capacity for sensor, and forward integration to mass produce the flexible display.
Value Proposition	First mover technology, Co development with other components provider
The strategy and Marketing Target	OEM manufacturer who co-develop with clients regarding AMOLED display and sensors. Including the first mover on Mass production for flexible sensors and electronics devices Focusing on Mobile devices market due to the partnership with China Mobile(largest telecommunication company in China)

4.2 Bargaining Power of Suppliers (Moderate)

4.2.1 Scope of study

Suppliers provide the raw materials needed to provide goods or services. This means that there is usually a need to maintain strong and steady relationships with suppliers. Depending on the industry dynamics, suppliers may be in the position to dictate terms, set prices and determine availability timelines. Powerful suppliers may be able to increase costs without affecting their own sales volume or reduce quantities that they sell.

4.2.2 When do suppliers have power?

Suppliers may enjoy more power if there are less of them. Costs of switching to an alternative option are high, or there are no alternatives. A supplier may also be the only provider of a certain raw material. This may be the case in instances where a supplier holds a patent or has proprietary knowledge. Because of a lack of alternates, they may be able to withhold quantities or increase prices without losing sales.

4.2.3 Supplier's bargain power in this industry will be defined through the following parameters:

- Concentration of the supply compared with buyers
- Switching cost of moving to another supplier
- Availability of alternate producers
- Availability of substitutes
- Importance of the supplier in the buyer's value chain
- Importance of the buyer in supplier's business
- Supplier's capacity to integrate forward

4.2.4 Consequences of having powerful suppliers:

- Reduce profit potential in the industry

- Increase competition within an industry by threatening to raise prices or reduce quality of goods or services. Therefore, reduces profitability where companies cannot recover cost increases in their own prices

When a company's supplier has significant power over the value chain, it can directly impact the way it serves its own customers. Depending on what power the supplier chooses to exert, a company may have to reflect this through product prices, product quality and available quantity. Too much disruption in any of these areas may even mean that a company is no longer able to stay in business. A company may need to end operations or shift to another industry to avoid being dictated by the whims of a supplier.

Table 4.4 Overview of the Bargaining Power of Suppliers

BARGAINING POWER OF SUPPLIERS	MODERATE		
	Encapsulation	**Substrates**	**Conductive track**
OVERALL BARGAINING POWER	HIGH	LOW	MODERATE
Concentration of the supply	**High**	**Low**	**Moderate**
Importance in value chain of force-sensing providers	**High**	**Low**	**High**
Importance of force-sensing providers in the business of suppliers	**Low** (Force-sensing providers don't purchase high volumes yet)	**Low** (Force-sensing providers don't purchase high volumes yet)	**Low** (Force-sensing providers don't purchase high volumes yet)
Availability of Flexible Alternate Products	**Low** (Thin Films vs. flexible glass)	**Moderate** (every alternate product comes with advantages and limitations also: Polymers, elastomers, glass, hybrids)	**Moderate** (ITO vs. ITO-replacement)
Players	Thin Films : Junsung, Meyer Burger, Encapsulix, Vitex, Veeco, Kateeva) Flexible Glass : Corning, NEG, Schott, Asahi Glass)	Could not identify main players (many undifferentiated product suppliers)	Known players: Canatu, C3Nano
Distance to industrial Readiness	**Moderate** (Due to cost of Thin Film processes and mechanical limitations of flexible glass)	**Low** (established production processes)	**Moderate** (non-ITO conductors production processes emerging rapidly)
Risk of Integration	**High** (with rivals and buyers)	**Low** (Commoditization, low innovation rate ; lead to low demand for integration)	**High** (eg: C3Nano)

4.3 Bargaining power of Suppliers per group of suppliers

4.3.1 Power of Flexible Encapsulation suppliers (High)

- Weight of encapsulation part in rivals' value chain: HIGH

Encapsulation is critical for the durability of the sensors.

- Alternates for flexible encapsulation : LOW

Manufacturers of the encapsulation layer for flexible sensors are mostly using plastic layers, especially the Thin-Film encapsulation (see "Materials" in Part A).

The offer for flexible encapsulation is still limited due the challenge in making glass flexible. Glass is historically the material used for encapsulation as it is the most efficient protection against the external environment. However, glass encapsulation does not yet meet the requirements of highly flexible sensors. Currently, the most promising alternative to glass for flexible encapsulation is the TFE method

4.3.1.1 Option 1: Thin Film Encapsulation (TFE)

TFE consists in the superposition of layers of plastic films that seal and endure deformation. The offer still seems to be very limited since the process of production and development is quite costly.

Players:

- Junsung (Jusung Engineering, n.d.)

High Quality Thin Film forming technology at low temperature. For Flexible OLEDs. Jusung Engineering Says it has signed a 18.03 billion won (US$15.2 million) contract with Chinese Kunshan Govisionox Optoelectronics Co., Ltd. to provide display manufacturing equipment. According to Iter News the equipment from Jusung is for OLED Encapsulation and the OLED Display line in Kushan will begin 4Q 2017 and will have a monthly capacity of 8,000 sheets. Reportedly, Jusung has previously supplied equipment also for LG Display and Innolux in Taiwan.

- Meyer Burger (Mertens, 2017)

Meyer Burger supplies TFE systems to flexible OLED manufacturers. The company announced in January 2017 that it was shipping its TFE system to an Asian customer for flexible OLEDs.

- Encapsulix (Pays d'Aix Développement, 2017)

Encapsulix SAS is a company based in Aix En Provence, France. It announced in January 2017 that it has been selected as the supplier of ALD-TFE deposition systems by a leading Asian AMOLED manufacturer. The first tool is presently under construction and scheduled for operation from the spring of 2017 onwards. The systems will be used to encapsulate flexible AMOLED displays with multifunctional nanolaminated coatings. The order was awarded to Encapsulix SAS after an extensive evaluation of available ALD equipment suppliers of barrier and encapsulation coatings.

- Kateeva (Kateeva, n.d.)

The YIELDjet FLEX tool was developed to enable Thin Film Encapsulation (TFE), which is the process that gives thinness and flexibility to the OLED device. It is the first product to emerge from Kateeva’ s YIELDjet platform, a breakthrough precision deposition technology platform that uses innovative inkjet printing to cost-effectively deposit coatings on complex applications in volume-manufacturing environments.

- Veeco

Selected by Samsung Display for its flexible encapsulation development. (Pays d'Aix Développement, 2017)

4.3.1.2 Option 2: Flexible Glass Encapsulation

Although, flexible glass encapsulation is still not ready, the same companies that are supplying flexible display manufacturers for encapsulation, are now developing flexible encapsulation for sensors as well.

Players:

- Corning (Corning, n.d.)

1. Their main client is Apple for whom they provide Apple iPhone 7 surface durable glass, which is called Vibrant Corning-Gorilla Glass. They offer the benefit of customization upon customer’s request.

2. The product with Flexible function which is under development is called “Corning Willow Glass Laminates”. The value proposition is the ultra thin and durable surface. Also easy to design to fit the devices because it is not necessary to have the specific tools to adjust it.

3. The iPhone 6 was released in Q3 2014, and the iPhone 7 in Q3 2016. Therefore, we can assume that most of the revenue in Q4 2016 will be from the iPhone 6 and 7. (Schott SAS, n.d. A)

In Q4 Apple sold 45.5Million units, with a revenue of 28 Billion. We assume that almost all units sold in Q4 2016 will be the iPhone 6 and 7, with Corning as the sole supplier for glass. Therefore, we can conclude that Corning has delivered around 45.5 Million units for glass displays to Apple.

- Asahi Glass

1. The industry leader producing glass.

2. Besides Flexible Glass, Asahi glass also produces a product called Fluon ETFE Film (Nippon Electric Glass, n.d.). This is a Flexible and durable film which could be used to replace PVC, PVF, PET

3. Currently the Fluon ETFE Film is used with Flexible Solar Panel and Roof material in football stadium in Germany (Schott SAS, n.d. B). Since it is flexible, it can be customized.

4. Possibility of high-price for new technology and innovation.

- SCHOTT

1. Ultra-thin glass material provider (Schott SAS, n.d. B).

2. SCHOTT ultra-thin glass is available in different glass types with diverse chemical and physical properties in a thickness range of 25 - 210 μm.

3. They are ready to supply with minimum volume (50-100 sheets both standard and custom cuts).

4. SCHOTT's business units cover in home appliance, pharma, electronics, optics, life sciences, automotive and aviation industries.

- NEG

Their G-Leaf product: G-Leaf™ ultra-thin glass, is truly innovative. Not only is it light, but it is also so smooth and pliable it can be rolled up. Still, G-Leaf™ has all of the qualities typical of glass; it has optical and gas-barrier properties, and is weather and heat resistant. G-Leaf™ takes only minimal materials to manufacture and can be transported in compact rolls, so it saves on resources and energy and reduces costs (Ghaffarzadeh, & Yamamoto, 2018). However, this product is not yet mass produced.

Distance to Industrialization: MODERATE

Several announcements from companies such Encapsulix or Junsung provide signs that mass-production could happen sometimes this year or early next year. Once again these are announcements. The processes associated with TFE systems for example are the highest the barrier to making flexible encapsulation really viable for now.

4.3.2 Power of Substrate suppliers (Low)

Concentration of suppliers: LOW

Availability of alternate products: HIGH

Flexible sensors are made of substrates such as polycarbonate (PC) and polyethylene terephthalate (PET) (Yeo, & Lim, 2016), which offer superior deformability and high optical transparency.

Nevertheless, another class of flexible substrates, like soft silicone elastomers, such as polydimethylsiloxane (PDMS) and silicone rubbers, can provide additional advantages such as stretchability and compliancy. In particular, PDMS and the trademarked silicone rubbers like EcoFlex® (Smooth-On, Macungie, PA, USA), DragonSkin® (Smooth-On, Macungie, PA, USA), and Silbione® (Bluestar Silicones, East Brunswick, NJ, USA) (Ghaffarzadeh, & Yamamoto, 2018; Yeo, & Lim, 2016; Khan & Lorenzelli, 2015). This group of flexible elastomers provides a high degree of deformability and conformability on different surfaces with varied textures and geometries, rendering them viable candidates for use as one of the fundamental components of stretchable and wearable sensing devices. Furthermore, these flexible silicone elastomers are generally chemically inert and biocompatible, making them excellent for use in implantable flexible sensors (Ghaffarzadeh & Yamamoto, 2018). Table 4.5 summarizes the polymeric substrates and soft elastomeric materials typically employed for the fabrication of the soft templates of flexible and stretchable physical sensing devices (Ponce, Posner, & Santos, 2012)

Table 4.5 Polymeric Substrates and Soft Elastomeric Materials Summary

A	Flexible templates	Young's modulus (MPa)	Tensile strain (%)	Poisson's ratio	Processing temperatures (°C)
Polymeric Substrates	Polyethylene terephthalate (PET)	2,000–4,100	<5	0.3–0.45	70
	Polycarbonate (PC)	2,600–3,000	<1	0.37	150
	Polyurethane (PU)	10–50	>100	0.48–0.49999	80
	Polyethylene naphthalate (PEN)	5,000–5,500	<3	0.3–0.37	120
	Polyimide (PI)	2,500–10,000	<5	0.34–0.48	270
Silicone Elastomers	Polydimethylsiloxane (PDMS)	~ 0.36–0.87	>200	0.49999	70–80
	EcoFlex	~ 0.02–0.25	>300	0.49999	25
	DragonSkin	1.11	>300	0.49999	25
	Silbione	~ 0.005	>250	0.49999	25

However, most importantly, every alternate product essentially offers its own advantages, but also has accompanying limitations. We therefore have to look at the acceptable feature trade-offs. For instance, thermoplastics are limited in their stretching characteristics and exhibit poor conformability on three-dimensional contours. In comparison, soft elastomeric substrates, which possess similar physical properties to biological skins, are not limited by these issues.

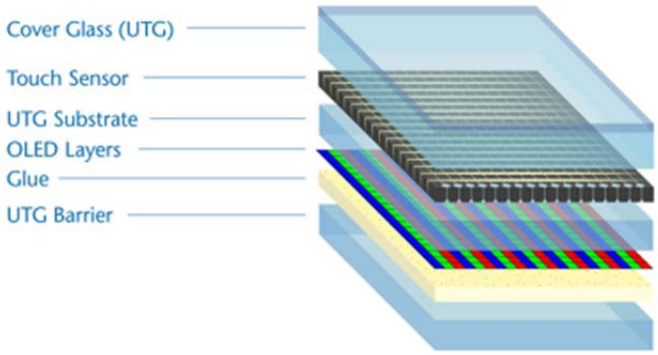


Figure 4.2 Flexible Glass Based Encapsulation Layers

Source: Schott SAS (n.d. A)

Companies developing glass-based encapsulation layers also claim that their ultra-thin glass can comply with the required features to become templates for flexible force sensors. SCHOTT, for instance, is an American company that provides ultra thin cover glass, but also mentions ultra-thin substrates for application on touch panels. There aren't many players proving such glass-based substrate solution so far; usually because full glass-based substrate are still very challenging to produce at an industrial scale. Hence, these suppliers are not yet considered reliable. But it would be worth keeping on eye on them to keep track of their progress. The pace of innovation can accelerate suddenly, and these substrate manufacturers could be not so far from an industrialization breakthrough.

Hybrid substrates are a combination of organic and inorganic materials (plastic and glass) that some manufacturers produce. Ares Materials for example claims that its Pylux substrate is the best of both worlds without the limitations of neither glass or plastic (Jang et al, 2015). However, there is no sign of industrialization yet, even though their website mentions undergoing partnerships with major electronics manufacturers to reach industrial scale validation.

Features required for flexible substrates are:

- High optical transparency
- deformability
- compliancy
- conductivity
- durability
- cost of fabrication
- ease of fabrication
- -chemical inertia
- additional feature for biosensors is biocompatibility

Since there are mainly different manufacturers, the concentration of the suppliers in this industry is low, especially compared to the buyer's competitive environment.

Moving from one substrate supplier to another doesn't involve high costs, as long as the switch to a new substrate producer doesn't involve changing the conductive material (for the compatibility of electrodes with substrate material) or a change in the concentration of the pressure-sensitive ink.

There are no substitutes to flexible substrates as substrates are necessary to the making of force sensors.

Importance of Substrate in buyer's value Chain: LOW

Force-sensors are, as for now, not a critical market for substrate producers in terms of volumes. Players in this industry are not yet purchasing high volumes of substrates, this gives force-sensing providers a quite low bargaining power over these type of suppliers.

We haven't seen any substrate manufacturer integrating forward.

4.3.3 Power of Conductive track suppliers (moderate)

High competitive pressure of these suppliers. (Wong, Posner, & Santos, 2016)

4.3.3.1 Importance of Conductive track in Buyer's value chain: MODERATE

Conductive tracks are very important in the value chain for force-sensing developers and manufacturers. Conductive tracks conduct currents from a power source to the pressure-sensitive ink to make it functionable. Once the pressure-sensitive ink is in contact with the conductors (or conductive track) the electric current can flow through the pressure-sensitive ink that can then sense the force. Without this conductive track, neither resistive, nor capacitive pressure-sensitive sensors can really work.

4.3.3.2 Availability of alternates LOW

The conductive tracks can either be made of ITO (a material with certain properties, similar to copper) carved onto the substrate; or now they can be made of conductive inks that are taking the role of ITO-like materials. The ITO-replacements are considered thinner and better conductors, that are now also transparent and better suited for flexible displays. These inks are not carved onto the substrate like ITO-related materials. They are printed onto the substrate.

As below you will see a list of conductive materials that could be considered as alternate products to the currently used ones:

Table 4.6 Conductive Materials

Conductive materials	Metallic nanomaterials (e.g., Ag, Au, Cu, Al, Mn, Zn)	Nanoparticles, nanowires, nanorods		2–400 nm (in diameter) and 200–1000 nm (in length)	0.015–20 $\Omega\,sq^{-1}$
	Carbon-based nanomaterials (e.g., CNTs, graphene)	Nanoparticles, nanowires, nanotubes, nanofibers		10–2000 nm (in diameter) and 500–5000 nm (in length)	$30–5\times10^{6}$ $\Omega\,sq^{-1}$
	Ionic or metallic liquids (e.g., eGaIn, Galinstan)	Liquid		Not applicable	2.63×10^{-9}–0.025 $\Omega\,cm^{-1}$
C	**Fabrication techniques**	**Resolution (μm)**	**Throughput ($m\,min^{-1}$)**	**Limitations**	
Additive processes	Gravure printing	50–500	8–100	Limited resolution due to alignment	
	Screen printing	30–700	0.6–100	Small selection of inks due to high viscosity requirements Requires hard masks to be replaced regularly	
	Inkjet printing	15–100	0.02–5	Not suitable for roll-to-roll production Coffee-ring effect Limited printing area	

Source: Wilson, M. (2017)

4.3.3.3 Importance of ITO-replacement business for conductive ink suppliers: HIGH

Overall, the conductive ink industry is still in search of the next big thing. Adverse competitive pressures in core volume markets has led most suppliers to seek new nascent opportunities. The prevalent strategy is now to have a product portfolio that is as broad as possible; seeding multiple nascent markets, garnering as much customer feedback as possible, and establishing value networks early on. The share of conductive ink production dedicated to ITO replacement on conductive tracks is on the rise (see Figure 4.3). Some of the players in the industry, like Nissha-C3Nano are already using these conductive inks for their sensors.

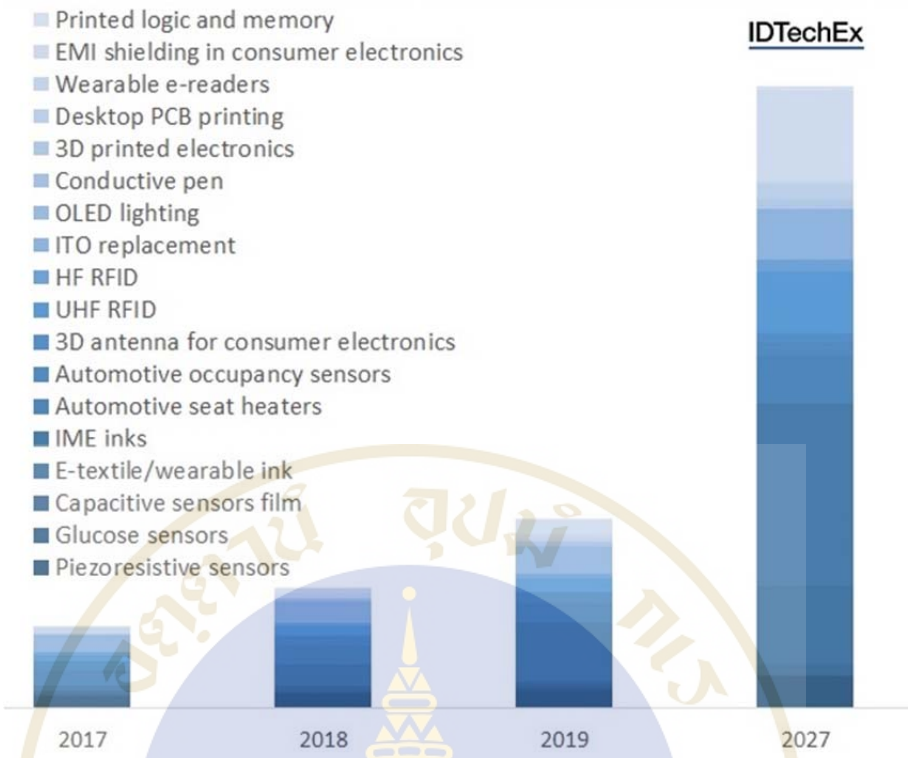


Figure 4.3 Share of ITO Replacement in the Conductive Market (in Million $)

Globally the demand for conductors ranges from photovoltaics to automotive (defoggers, seat occupancy sensors, seat heaters, etc), ITO replacement (hybrid, direct printing, etc) to conductive pens, digitizers and more.

4.3.3.4 Concentration of supply LOW

There is a high number of conductive material producers both in the case of ITO-related materials (such as copper or silver) and in the case of non-ITOs, which is to say conductive inks essentially.

4.3.3.5 Risk of forward integration HIGH

Forward integration through mergers or acquisitions haven't been observed. However, the case of C3Nano may imply that there is a potential trend towards more of a partnership instead of a supplier/buyer. C3Nano, an expert in conductive inks and films, joint-ventured with Nissha to co-develop complete force-sensing solutions to its buyers.

Another player, Canatu, also specializes in conductive inks and films and produces touch-sensors. However Canatu has not yet been able to find partners in the force-sensing industry.

Observing players in this industry developing and producing in-house conductive materials to secure cost and develop their own conductive track technology, reflects that current non-ITO suppliers are not yet up to the standards of what flexible multi-force sensing requires. That can hint to the fact that maybe good supply of non-ITO is still quite scarce, or prices are too high, as some of the players decides to make it themselves.

4.4 Bargaining Power of Buyers (Moderate)

When is power of buyers high? When buyers are able to gather together and amount for a large percentage of the producer's sales revenue or when there is a number of suppliers providing the same type of product.

The buyers' bargaining power is about the possibility to purchase or takeover the company in the industry. This is one of the issue which Nanomade should be aware of. If the buyers have the capacity to invest on the new technology that the company owns, they are able to be the one who takeover and become the owner themselves. When we studied the industry, the buyers are the devices makers and substrate manufacturers. They are only few players in the market with high financial power to bargain with the company, Nanomade.

4.4.1 Types of buyers:

Innovators: early purchasers. These people stay updated on the industry and what the current and upcoming trends and technologies a (Cleverism, 2018). They are confident and look forward to experiment with new things.

Early Adopters: These people set an example for others and are opinion leaders of a particular market segment. They will try a new product out if it offers them significant benefit. Being change agents, they will understand the product before they adopt it and this leads credibility to their references.

Early Majority: The early majority is relatively slower in trying out a new product offering.

Late Majority: This group will become consumers of a product much later in the product's life cycle.

When we think about Innovators and Early adopters there is a big difference between each other. First ones, are willing to make and investment and take a risk in the technology, meaning that we have the chance to receive an investment from them, create a partnership or even sell the technology as we have it right now.

Early adopters, on the other hand, would be the biggest companies, that want to have a ready to use product, but still are the first ones to use it in an industrial way.

4.4.2 Bargaining power of Buyers (Moderate)

Buyer Concentration: There are only few phone makers that have the possibility to apply force sense technology on their flexible phones at an industrial level. So if we are only aiming to phone makers then the concentration power would be HIGH. However, force sense can also be integrated by other display makers (Sharp, JDI, LG, etc.) making the possibilities wider and turning the concentration into MODERATE.

Percentage of Sales: Any of the buyers of the technology in this market represent a big player with high production rates and will take up a large amount of capacity of the force sense technology. Therefore, the percentage of sales power is HIGH.

Undifferentiated products: The offering of force sense can be imitated by multiple players, but patents can protect the know-how for the printing of force sense technology on flexible substrates, which can differentiate the product offering. Therefore the level of undifferentiated products is MODERATE.

Switching Cost: Due to the patents, here are only few competitors in this industry, which makes the switching costs HIGH.

Threat of Integration: This threat is HIGH, in the sense that companies have enormous economic power and can easily acquire the producer.

Information: the information power is LOW, buyers don't have insights in the production cost and can not ask for better prices based on this.

Price Sensitivity: Is LOW, because buyers have a lot of power and will not be affected by small or moderated changes in price if the benefits their are getting are high.

If we take all this facts into consideration we can conclude that barging power of buyers is MODERATE. This is why, we should look carefully and make a conscious decisions as for how should we sell or partner with.

4.4.3 Choosing the right buyer

We can select buyers who value the quality and reliability of the product and its delivery above the price. These will not push on costs and prices and instead work on ensuring that the product provided is top of the line. So we need to select buyers for whom the product plays a vital part in the assembly of their final offering, where the item provided makes up an important part of their own product portfolio, or select buyers whose customers will also be willing to pay a higher price. This means that the entire value chain will easily absorb cost increases.

4.4.4 Importance of flexible sensors in flexible electronics industry

In value, flexible sensors come second in terms of value within the the flexible electronics market, right behind the flexible OLED displays themselves (see Figure 4.4). IDTechEx found that the total market for printed, flexible and organic electronics will grow from $29.28 billion in 2017 to $73.43 billion in 2027. The majority of that is OLEDs (organic but not printed) and conductive ink used for a wide range of applications.

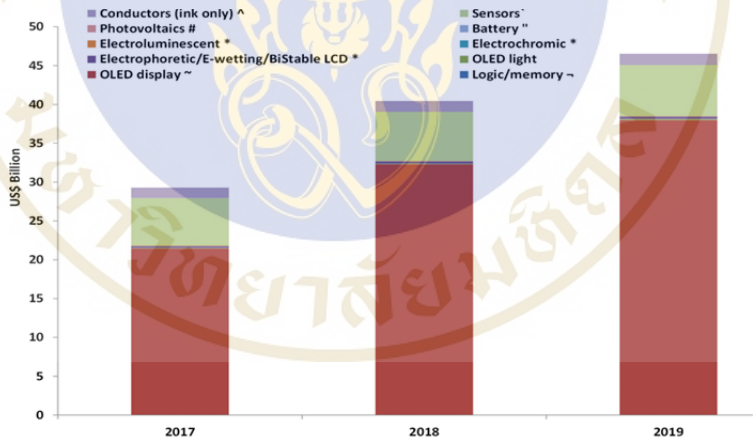


Figure 4.4 Market forecast Printed, Organic & Flexible Electronics by component type in US$ billions

Source: Das, Ghaffarzadeh, & He (2016)

4.5 Threat of New Entrants (Low)

What we have observed while studying this competitive environment is that overall there is only a handful of viable competitors in the force-sensing field for flexible displays. There are several reasons for this:

1. Initial Capital investment is not so high: We are not necessarily drawing the attention towards the initial capital needed to enter this industry. Although it is not low, a capital of 1 to 5 million USD of initial capital is an investment several high tech companies could take.

2. First mover and experience curve critical: As a matter of fact very few companies have decided to jump in the game few years back, when force-sensing was still considered a risky and far-reaching bet. These same companies that started investigating and developing a technology on their own have erected significant barriers to entry, that are translating into high cost for anyone who wants to develop force-sensing. Some of the learnings acquired through years in the business cannot be acquired with financial investments only.

3. Patents, proprietary information and technological knowledge erect high barriers to entry: The understanding of existing materials and knowledge of their quality, possession of any necessary and important patents, and proprietary information and technological knowledge.

4.6 Threat of Substitutes (Moderate – High)

4.6.1 Scope of study

Identifying substitutes involves searching for other products or services that can perform the same function (eg: 3D interaction) as the industry's product or service. To identify potential threats, the we need to be creative in our thought process and look beyond traditional competitors. A substitute is any technology that is developed to connect users with their electronic device beyond the 2-dimensional paradigm of touch; also called the 'X-Y' interaction. Substitutes in this industry are technologies heading towards what they believe to be a more intuitive user experience, but leveraging technologies

that are not relying on a ‘pressure-based’ interaction between user and screen. To define the level of threat of these substitutes we looked at several parameters:

1. Switching cost: If there are little to no switching costs for a consumer, then there is more of a chance that they may explore and move over to a more attractive substitute. In the absence of other factors such as brand loyalty or differentiation, the choice to move will not be a difficult one.

2. Substitute Price: If substitutes are priced more reasonably, then there may be a higher risk of consumers switching products. In addition, this can act as a barrier to how much a company can raise the prices for its own product. Any move to price higher than substitutes may lead to consumer migration and loss profits.

3. Substitute quality and performance: If a substitute product's functions at the same level or at a better level than a product then there is a chance that consumers will want to switch over.

4. Substitute Compatibility: This is a major element in our research as it is important to note that a higher compatibility can translate into this substitute becoming a complementor to deliver in combination with our technology an improved user experience.

5. Substitute availability: All of the above factors can only come into play if there are actually substitutes available in the market

4.6.2 Threat Level per Substitute

4.6.2.1 3D interaction based predictive technology

- Insight

Leveraging the power of Artificial Intelligence (AI) and big data to predict the user’s next move on a screen, this is a powerful solution to the “One tap. One Screen. One action” paradigm that Force is also trying to solve. By predicting behaviours on screen it is possible for the user to access different screens and options while touching the phone only once. Learning from billions of users journeys through data collection, some players can anticipate the user next move and develop what is called ‘deep linking’; the user taps on a link and goes straight into the relevant section of an app. The philosophy behind app links for instance is that users will surf their phone much like they surf the web. (Wilson, 2017)

Even offline, by learning their owners' habits, these new phones will be able to carry out tasks even when they're offline. During a first phase only high-end smartphones will use the technology, like the new models unveiled by China's Huawei at the Mobile World Congress. But the technology is quickly gaining ground. More than 300 million smartphones—or roughly a fifth of units sold worldwide—will have the function in 2017, according to Deloitte.

"It is one of the key areas we are investing in. After the smartphone, we will have the 'superphone' thanks to artificial intelligence," said Vincent Vantilcke, marketing director for Huawei in France.

Main threat: This interaction only requires Touch-based interaction and can provide depth of interaction through predictive intelligence instead of Force.

Limitations of the technology

1. The new technology is still being developed, where the profit comes from, is still unsure

2. Privacy concerns may throw up a roadblock to the technology (a new European Union data protection law which comes into effect in 2018 contains “very restrictive” rules to prevent algorithms from making decisions on their own)

3. Only Google possesses the sufficient power to commercialize elaborate versions of the system

- Players

Google Now On Tap: Basically much like Google can predict your search before you finish typing it, ‘Now On Tap’ will predict your next multitask before you multitask it. In doing so, it condenses anywhere you want to go on your phone next to the simplest of UI elements: a single button. One press sould bring up any one of dozens of services that you might need in the moment. One day, perhaps it might help you discover services you aren’t using but seem to need (thus solving the problem of app discovery, which has proven to be a severe bottleneck on the number of apps people use.

The point is, regardless of what Google does, it has quickly introduced what could become a powerful new paradigm in mobile computing; one that ties to its overriding goal of reducing user friction by answering question before

they've been asked. However, we do not have information on for how long it might take before we get to such levels of prediction.

4.6.2.2 3D interaction based on gesture

- Insight

Microsoft, Facebook, Apple and others are making public their intentions to track hand or body pose from image data. Mechanism: A user may provide inputs to the system by performing three-dimensional gestures. For example, a three-dimensional gesture may be the the user's fingerprint touching a front surface of the system and then pulling away from the front surface. When detecting such a three-dimensional user input, the system may determine a three-dimensional trajectory (eg: of the user's fingertip), and determine if the three-dimensional trajectory corresponds to one or more three-dimensional gestures.

Threat to Force-sensing technology: Less touch required. Force not necessary.

Limitations of the technology:

1. Patent stage
2. Only Facebook has publicly applied technology for displays
3. No information on the compatibility of this technology with flexible displays. Expected difficulties to make Camera components flexible. Adding a layer of complexity for midwares.

- Players

1. Facebook: Facebook's patent discovered on Patently Apple in February 2017 describes their 3D gesture system starting with the smartphone's camera being used to determine a distance and angle of an object. The system can incorporate one or more touch input devices, proximity sensors, or cameras may determine a location and movement of an object touching or at a distance away from the system's surface based on measurements of the object by the touch input devices, proximity sensors, or cameras (e.g., by using triangulation techniques). By continuously monitoring the touch input devices, proximity sensors, or cameras, the system may determine a three-dimensional trajectory of a moving object based on measurements of the object by the touch input devices, proximity sensors, or cameras.

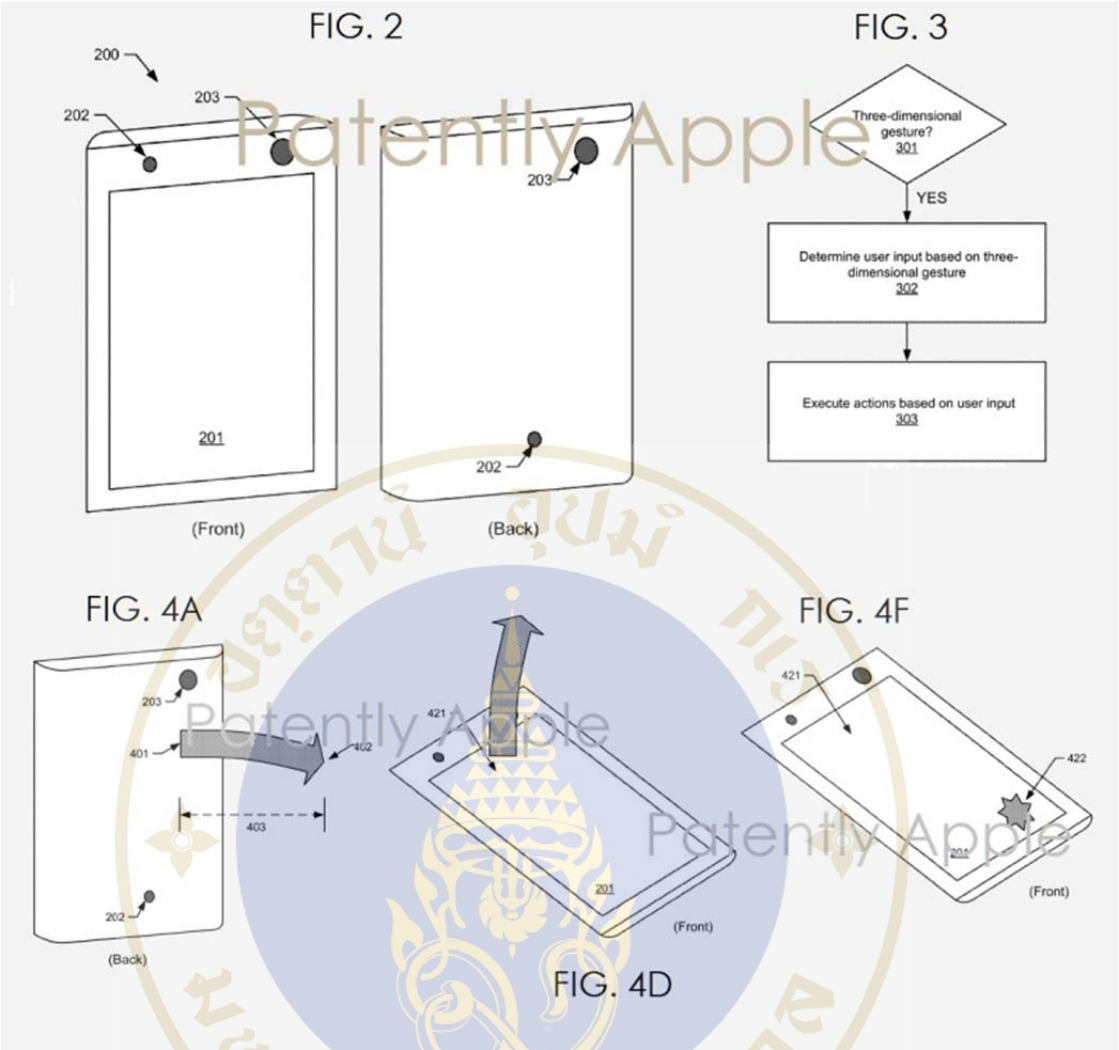


Figure 4.5 Facebook's patent for 3D gesture system

2. Microsoft In-air gesturing: Microsoft is also in the race to bring in-air gesturing to future consumer electronics, ahead of Apple. But up until now, Microsoft only granted a patent in 2017 for tracking movement on PCs. But on the patent Microsoft's invention covers tracking hand or body pose from image data is described, for example, to control a game system, natural user interface or for augmented reality.

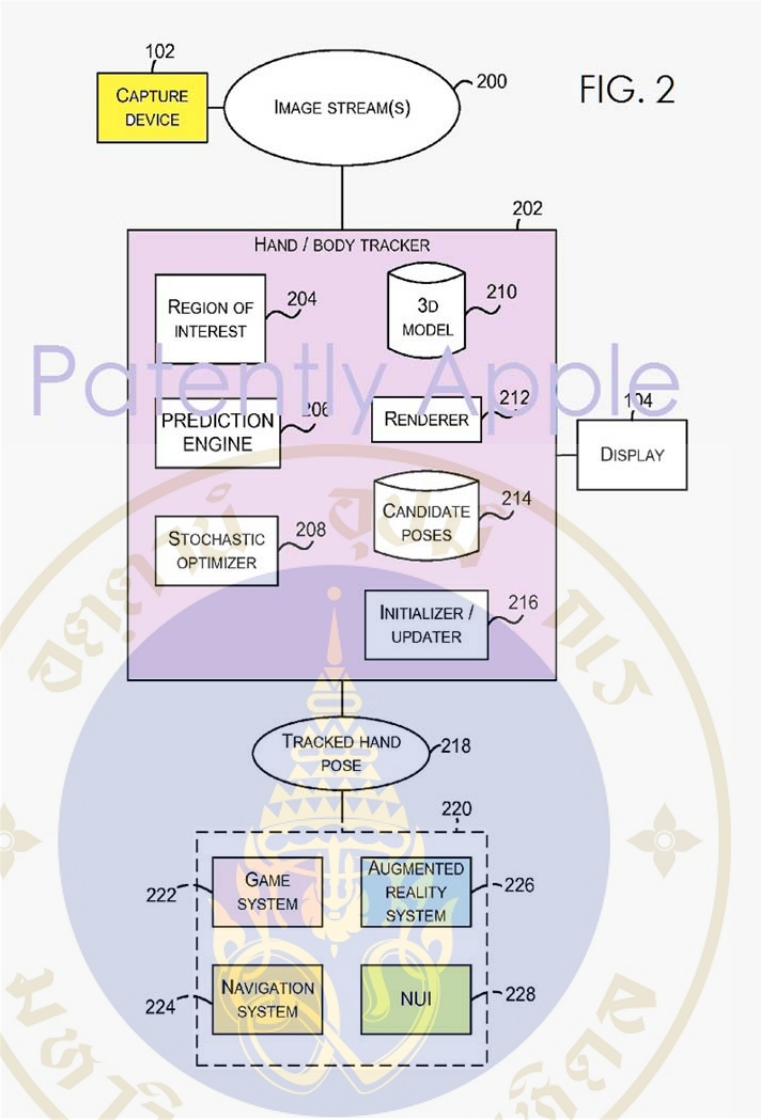


Figure 4.6 Microsoft Patent for tracking movement on PC's

3. Apple In-air gesturing and optical pattern projection: Apple's newly granted patent covers their invention related to optical systems and designs, and specifically to methods and systems for optical patterns projection. This 2017 Patent from January 24 2017 covers 3D projection for many types of possible future applications including in-air gaming user interface. (e3zine, 2017)

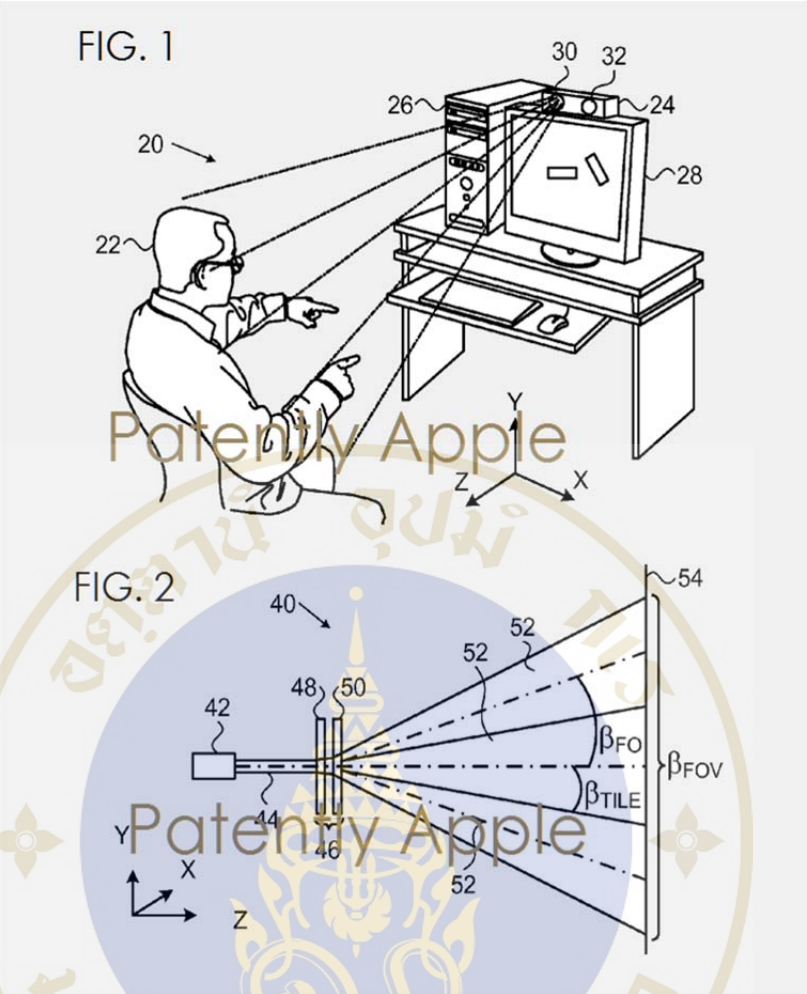


Figure 4.7 Apple In-air gesturing and optical pattern projection patent request

4.6.2.3 3D interaction based on Voice

- Insights

A deeper and more intuitive interaction between user and screen can be achieved through voice. How is this fulfilling the same function as our multi-force sensors. The objective is still to use ever more complex technologies and sophisticated User Interfaces to engage into a more immersive user experience.

The potential threat of voice-led interactions is a UI (screen) that doesn't require any touch. (e3zine, 2017)

Availability (market penetration) on consumer devices is already high and will accelerate as every product will virtually be designed to function with voice recognition from now on. This new function that is widely gaining acceptance among users of smart devices will be spreading and consumers will expect it to be

available without it impacting prices of their consumer devices which adds a degree of intensity to this already serious threat. By 2020, Gartner predicts that zero-touch UIs will be available on 2 billion devices and IoT endpoints, and speech recognition is expected to grow from USD 3.73 Billion in 2015 to USD 9.97 Billion by 2022. (Markets and Markets, n.d.)

Major companies such as Google, Apple, and Microsoft are leveraging their large customer base and neural networks to process, understand, and take decisive actions based on real-time voice inputs from the user.

"Interactions will move away from touchscreens and will increasingly make use of voice, ambient technology, biometrics, movement and gestures," said Ms Zimmermann. "In this situation, apps using contextual information will become a crucial factor in user acceptance, as a voice-driven system's usability increases dramatically according to how much it knows about the user's surrounding environment. This is where device vendors' assets or partnerships in VPAs, natural language processing (NLP) and deep machine learning experts will matter." It is expected that 20% of our Interactions with smartphones will be via VPA (Virtual Personal Assistant) by 2019. This will be led by gesture (mentioned above) and Voice. Gartner report predicts that by 2020 the majority of devices will be designed to function with minimal or zero touch.

- Players

1. Amazon Alexa: Amazon Alexa is soon expected to invade the world of smartphones. Users will need to boot up the Alexa app first before running it on their phones. It is not yet a built-in functionality like on the Google Phone. But Amazon could be expected to partner with Huawei to integrate Alexa into its smartphones.

The advantage of Alexa over its older competitors: more devices currently work with Alexa than they do with Google and Siri - and with fewer caveats that also require you to own specific hardware like an Apple TV or Google Home. That said, certain experts say that in the short term Alexa will complement, not replace, the voice powers your phone already has. (Wires, 2016)

2. Google Now: Google voice recognition system is virtually available on every Android Phone. It allows the user to carry out certain action on its phone without having to touch it. It was designed to help people with disability some years ago. But it started being widely adopted and every few months Google comes

with updates. One of its latest effort was to make the voice less robotic to improve the natural feel of the interaction with the phone.

3. Apple Siri: Apple was the first to integrate voice recognition onto his smartphones. Siri is available on every Mac product now. It is, however, considered less efficient than the upcoming versions of Google and Alexa

4. Microsoft Cortana: Cortana is Microsoft's owned version of a VPA. But Cortana is still lagging behind in performance in comparison to its rivals. (Mercredi, n.d.)

4.6.2.4 Screenless display market

- Insight

1. The total screenless display market is valued at $242.1 Million in 2014 and expected to reach $1,242.3 Million by 2020. With a CAGR of 31.44% between 2015 and 2020. (Fernandes, n.d.)

2. The global screenless display market size is expected to reach $ 5.59 billion by 2020, according to a new report by Grand View Research, Inc. These devices came into progress during the year 2013 with the arrival of products such as virtual reality headsets, holographic videos, mobile phones for the elderly, retinal displays, bionic contact lenses, etc.

Screenless displays are an emerging technology which would allow viewing images and videos without the need for screens. They offer an interactive projection technology developed to solve the issues related to device miniaturization of modern communication technologies. The lack of space in screen-based devices provides an opportunity for screenless display industry growth and development. High system cost may act as a growth restraint.

This market is expected to exhibit high growth in the next five years. The use of screenless displays in sectors such as medical, consumer, and commercial would be high. Sectors such as aerospace & defense, and automotive would also be an application area for screenless displays.

Screenless displays are still under research and development, while some products are commercialized. The fast growing gaming market would help the growth of head mounted screenless display products. The other factors such as space constraint and portability issues with screen-based displays would actually drive the

growth of screenless displays. However, the high cost of this technology could be a restraining factor for the growth of the market. (Fernandes, n.d.)

Visual image screenless display market is expected to dominate revenue over the forecast period, which can primarily be attributed to high demand for hologram technology. The limitation of conventional 3D displays is that the observer has no freedom of head movement or the freedom to

- Players

1. Avegant Corporation (U.S.),
2. Google, Inc. (U.S.),
3. Displair, Inc. (Russia),
4. Zebra Imaging, Inc. (U.S.),
5. Microsoft Corporation (U.S.),
6. Holoxica Ltd. (U.K.),
7. RealView Imaging Ltd. (Israel),
8. Leia Inc. (U.S.),
9. Microvision Inc. (U.S.)
10. Kapsys (France).

4.7 Key Insights

4.7.1 Pace of Innovation is key in this industry

How the different forces in the industry cope with the pace of innovation is paramount to the overall success of force-Sense in the flexible display market. To reach such a goal, suppliers, force-sensing providers and buyers need to be ready at the same time, otherwise the new technological wave will fail to take over the old one. Timing is key.

Some players are trying to keep up with the pace of change or to catch up, while others are set and ready technologically but not willing to release yet.

- Buyers of flexible force-sensors are busy making their technology ready to produce at industrial scale. They are still trying to determine how, when and with whom to release their technologies to the world. Many buyers may sometimes slow

down their pace of innovation in order to test the response of the market to innovation. Our industry will be looking for the buyers who are most enthusiastic and willing to move first, the so-called ‘early adopters’ and ‘early majority’.

- Suppliers of encapsulation and conductive tracks are slowly coming up with products that could fit the high quality and low cost production requirements of a flexible consumer electronics market that could go take off within 1 or 2 years. They are being asked to keep up with the pace of change while the market is still not really there. This creates tough strategic decision for them.
- Rivals have the technology limitation at their current product features that could not be mass produced or commercialized yet. The components to complete the finishing products are still under development in the laboratories. The distinguish technology they have will not be valued if they cannot provide the fully finished product to the market. This leads to an integration move we will discuss in key insight 2.
- Substitutes to force-sensing on Flexible Displays are complex and costly technologies to integrate into final products. But they can disrupt Force-sensing ecosystem anytime substitutes manage to overcome their complexity and cost issue.

The challenge in this industry is to reduce the asymmetries between suppliers, rivals, new-entrants, substitutes and buyers. Because together these 5 forces form the ecosystem of the force-sense technology, and it is very important in a rapidly changing environment to collaborate, in order to push the technology forward simultaneously. Therefore, the technology offered in this industry can only be as good as the whole ecosystem will be at preparing the next revolution in our devices.

4.7.2 Integration is the major trend

In order to carry the technology forward, and onto the market as fast as possible, force-sensing providers have decided they needed to change the nature of their relationships with the rest of the industry; more specifically, they chose to collaborate through several forms of integration.

The nature of these relationships between players reflects their preferred business strategy in the industry. These integration strategies are expected to sustain the pace of innovation and help force sensing providers to outstand. We observed that integrations took different directions: toward buyers and toward suppliers.

- Backward Integration (towards suppliers): The players seek for the new innovation and technology to develop new product with new competitive advantages that are required by the market. For example, NISSHA-C3Nano, they created a product called “Force Touch Z”. The pros of the case are to have a new innovative product, but in the other hand, to sell them to the end-users are still the critical bottleneck.
- Forward Integration (towards buyers): The players integrated with the buyers who are mainly the display makers such as AMOLED manufacturers. In this strategic move, the advantages are to secure the demands and to reach the sales channel of the buyers. Also, deliverables would be more customized and personalized. The cons are the timing and the readiness of the innovation would take time.

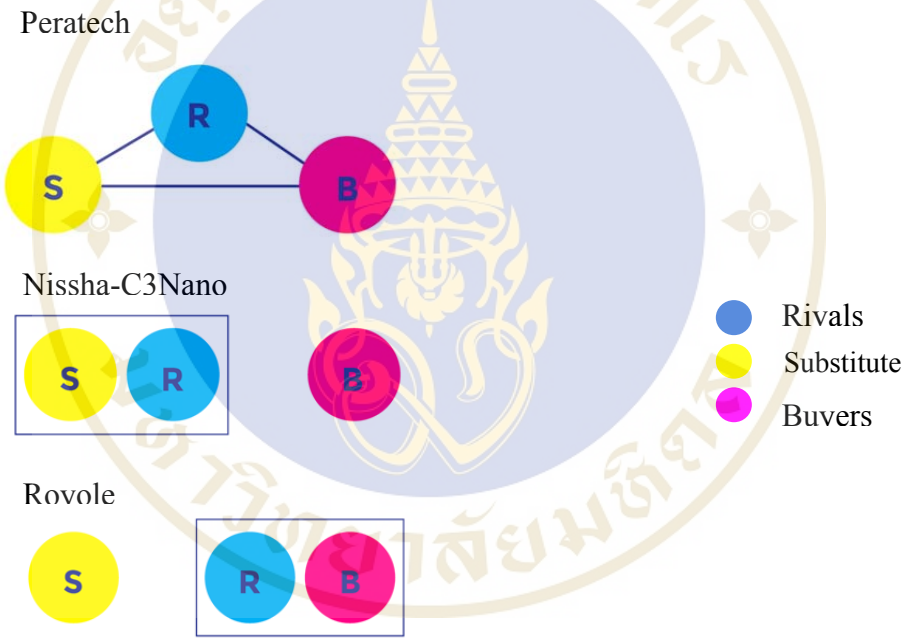


Figure 4.8 Industry Integration Strategies

CHAPTER V
RECOMMENDATIONS

5.1 Short-Term Recommendation

5.1.1 The Direct route to buyers:

Partner with Major flexible display manufacturers and develop custom solutions with them. Work together with an (AM)OLED display manufacturer; options: LG Display, Samsung, Visionex, BOE and Tianma.

Nanomade is looking for a volume industry to license or sell their product to. In order to obtain this goal, the key is to reach the display manufacturers. The ideal solution for Nanomade would be to work together with a display and phone maker, to be both in flexible display and all over the a flexible device.

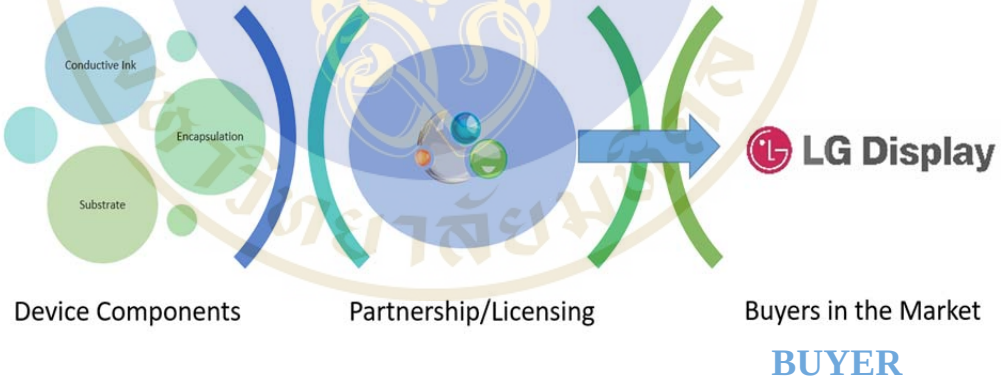


Figure 5.1 Reaching Forward

5.1.2 Why reaching forward?

- (AM) OLED technology will be the the most used in flexible displays 77% in 2021 (Business Wire, 2017)
- Nanomade's technology can go on top of the (AM)OLED display, thanks to its higher transparency. It's their main competitive advantage since it allows buyers

to remove a layer in their products so they can make them thinner, while in the meantime, reduce the production costs. Nanomade is, as far as known, the only one in the industry that can do this → this would create a LOW Buyer threat

- Opportunity to leverage the buyer's supply chain for encapsulation, base substrates and conductive tracks, since display manufacturers also need these components for their product. Can create synergies with Nanomade's supply chain.
- Secure demand for flexible sensors in flexible display market (case of Nissha-C3Nano that stopped force-sensors development for flexible force sensing display because their lack of relationship with buyers)
- Custom service: Fit to Buyer's needs (cost of production, production integration, applications, ink concentrations…)
- B2B2C Co-develop to better address concerns of the end-user.
- Not LCD: Even though we found that LCD can potentially become flexible, this technology is still too far behind to be interesting for Nanomade. JDI is working in Flexible LCD that would be ready to mass produce in 2018.
- Peratech is already co-developing with SHARP (owned by Foxconn) Peratech has similar offering to Nanomade which are Multiple Touch and force sensors (QTC Multi-force Matrix Sensors).
- Royole co-develops with a display maker, and can therefore offer Samsung a more finished product than Nanomade (possibly working together with Royole)

5.1.3 Possible Targets

- Samsung are the biggest flexible display player. However, due to their policy it's hard to approach them without a ready to use product. if we want to do so, we believe it is better to make an horizontal partnership to assure a better negotiation position.
- LG display is one of the biggest display manufacturers producer. Experts say the giant working along Apple, Google and Facebook to start developing OLED foldable smartphones. The fact that the GAFAs are willing to work with LG Display illustrates its position of innovator.

- Visionix is producing Flexible AMOLED and Chinese government is looking to diversify from Samsung.
- BOE is also a Chinese (AM)OLED display maker which is in negotiations to gain a contract as an Apple OLED supplier. This chinese company also offers Nanomade a gross share of the market and may not be as difficult to approach as other players.
- Tianma Micro-electronics is also a chinese AMOLED manufactures created in 2006, who in 2014 were able to rank first among global display makers as for shipment of small and medium size displays.

Based on the analysis of the possible targets, we recommend Nanomade to work together with LG Display. LG Display is a major player that nurtures the spirit of innovation. It currently leads the production ramp up of (AM)OLEDs and flexible (AM) OLEDs. Therefore, we recommend to licence the Nanomade technology to LG Display.

In addition, LG Mobile & Communication supplies a majority of top phone brands. After the connection is made with LG Display, Nanomade has a foot in the door to licence for LG Mobile & Communication afterwards as well, in order to use force sense technology in multiple devices. LG M&C shipped 55 Million Smartphone units in 2016 (LG SAS, n.d.) and LG Display is expected to reach 53% share on (AM) OLED displays by 2020 which would account for a market value of $23 Billion USD.

5.2 Long-Term Recommendations

Reaching out to Substitutes to co-create: Substitute technologies providing in-depth display interaction are rapidly gaining ground and it is just a matter of time before the most complex and costly technologies (eg: gesturing) become economically viable. In the meantime, voice and predictive technologies are already in our phones, improving everyday by collecting every data about every input users bring to their devices.

In the long run, these technologies can simply make Nanomade’s solution obsolete by moving user away from pressure-based interactions. That being said, both Nanomade and these other players are aiming to provide depth of interaction, which means both can work together toward that achievement. By turning substitutes into complementors, Nanomade is widening its scope of action, can anticipate the evolution of

its industry by co-developing with those who lead the way, and invert the trend towards less touch.

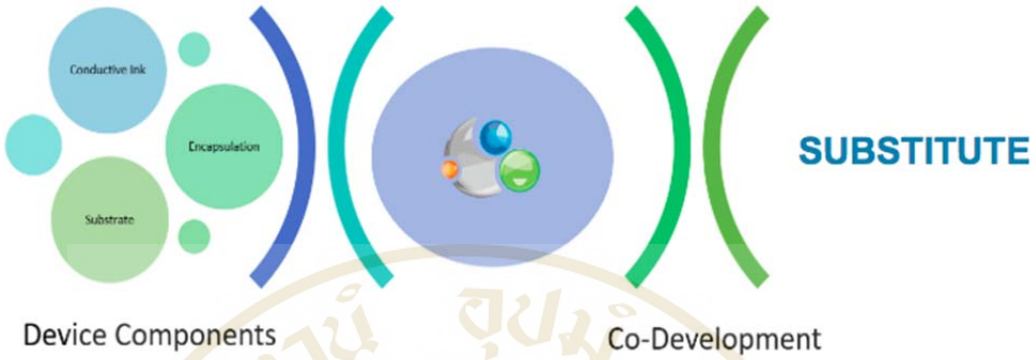


Figure 5.2 Co-develop with substitutes

5.2.1 Why Co-development with Substitutes ?

- GAFAs are involved. Main innovators in the market; Google, Apple, Facebook, Amazon + Microsoft
- Co-create improvement of 3D Interaction. Deliver an even more intuitive user experience
- Access larger market knowledge. Substitutes have large and direct contact to end-users to better connect with them
- Substitutes want to make flexible devices. Signed deal to develop flexible OLEDs with LG Displays
- Substitutes purchase from LG Displays. Signed deal to develop flexible OLEDs with LG Displays
- Avoid Touchless future. 20% of interaction with smartphones will be via voice in 2019 (Gartner Report)

Based on these insights we recommend Nanomade to target Google for their long-term strategy. With “Now” (voice) & “Now on Tap” (predictive) Google can become a complementor for Nanomade’s technology. Nanomade can leverage its short-term strategy which targets LG Display, in order to reach Google. How? Through the deal signed between the two giants to co-develop flexible OLEDs. Plus, Google Phones are

already equipped with LG displays. There are opportunities of co-development of software and technology for the use of force sense. Android has a 82% Market Share for operating softwares (2016), with a total of 1.4 Billion devices that run on Android. Currently there are 480 million devices that run on Android Marshmallow or higher, and therefore support Google Now on Tap. Future software updates will all support this application, and can thus create an impressive market share for Nanomade's technology.

REFERENCES

AGC Dragontrail. (n.d.). Retrieved from http://dragontrail.agc.com/en/.

Androidauthority. (n.d.). *AMOLED.* Retrieved from http://www.androidauthority.com/tag/amoled/.

Annis, C. (2017). *AMOLED Production Equipment Purchases to Reach Record High in 2017, IHS Markit Says*. Retrieved from https://technology.ihs.com/588697/amoled-production-equipment-purchases-to-reach-record-high-in-2017-ihs-markit-says.

AppleInsider. (2017). *As OLED iPhone rumors swirl, Apple supplier Sharp sinks $864M into display tech.* Retrieved from http://appleinsider.com/articles/17/01/09/as-oled-iphone-rumors-swirl-apple-supplier-sharp-sinks-864m-into-display-tech.

Brainia. (n.d.). *Essays on Advantages and Disadvantages of Electronic Devices.* Retrieved from https://www.brainia.com/topics/advantages-and-disadvantages-of-electronic-devices/0.

Business Wire. (2017). *Global Flexible Displays Market to Showcase a CAGR of 35% Through 2021: Technavio*. Retrieved from http://www.businesswire.com/news/home/20170306005649/en/Global-Flexible-Displays-Market-Showcase-CAGR-35.

Business Wire. (2017). *Global Flexible Displays Market to Showcase a CAGR of 35% Through 2021: Technavio*. Retrieved from http://www.businesswire.com/news/home/20170306005649/en/Global-Flexible-Displays-Market-Showcase-CAGR-35.

C3nano SAS. (n.d.). *Technology Overview.* Retrieved from http://c3nano.com/technology/.

Chang weng. (n.d.). *The Future of Displays Is Flexible*. Retrieved from http://www.appliedmaterials.com/nanochip/nanochip-fab-solutions/december-2015/the-future-of-displays.

Chansin, G., Ghaffarzadeh, K., & Zervos, H. (2016). *OLED Display Forecasts 2016-2026: The Rise of Plastic and Flexible Displays*. Retrieved from http://www.idtechex.com/research/reports/oled-display-forecasts-2016-2026-the-rise-of-plastic-and-flexible-displays-000477.asp

Chansin, G., Ghaffarzadeh, K., & Zervos, H. (2016). *OLED Display Forecasts 2016-2026: The Rise of Plastic and Flexible Displays*. Retrieved from http://www.idtechex.com/research/reports/oled-display-forecasts-2016-2026-the-rise-of-plastic-and-flexible-displays-000477.asp.

Cheng, Z. (2016). *A new $1.8bn market for force sensors in user interfaces as they move beyond touch*. Retrieved from http://www.thetechrevolutionist.com/2016/11/a-new-18bn-market-for-force-sensors-in.html.

Cleverism. (2018). *Seven Technologies that Will Change the World.* Retrieved from https://www.cleverism.com/seven-technologies-will-change-world/.

Corning. (n.d.). *Corning Willow | Flexible, Bendable Glass*. Retrieved from https://www.corning.com/worldwide/en/innovation/corning-emerging-innovations/corning-willow-glass.html

Credence Research. (n.d.). *E-Paper Display Market By Product (E-book Readers, Mobile Devices and PC, Poster and Signage, Smart Cards and Smart Packaging, Others), Technology (Electrophoretic, Electrowetting, Cholesteric, Others)- Growth, Share, Opportunities & Competitive Analysis, 2015 – 2022.* Retrieved from http://www.credenceresearch.com/report/e-paper-display-market.

Das, R., Ghaffarzadeh, K., & He, X. (2016). *Printed, Organic & Flexible Electronics Forecasts, Players & Opportunities 2017-2027*. Retrieved from http://www.idtechex.com/research/reports/printed-organic-and-flexible-electronics-forecasts-players-and-opportunities-2017-2027-000510.asp.

Das, R., Ghaffarzadeh, K., & He, X. (2016). *Printed, Organic & Flexible Electronics Forecasts, Players & Opportunities 2017-2027*. Retrieved from http://www.idtechex.com/research/reports/printed-organic-and-flexible-electronics-forecasts-players-and-opportunities-2017-2027-000510.asp.

Das, R., Ghaffarzadeh, K., & He, X. (2016). *Printed, Organic & Flexible Electronics Forecasts, Players & Opportunities 2017-2027.* Retrieved from http://www.idtechex.com/research/reports/printed-organic-and-flexible-electronics-forecasts-players-and-opportunities-2017-2027-000510.asp.

Data Markets Analysis. (2016). *Global Flexible Display Market Insights, Opportunity Analysis, Market Shares and Forecast, 2017 - 2023*. Retrieved from http://www.occamsresearch.com/flexible-display-market.

David Savastano. (n.d.). *Samsung and LG Move Toward ALD for OLED Barrier Films.* Retrieved from http://www.printedelectronicsnow.com/contents/view_blog/2016-10-12/samsung-and-lg-move-toward-ald-for-oled-barrier-films

e3zine. (2017). *Gartner: 20 % of Interactions With Smartphones via VPA by 2019.* Retrieved from https://e3zine.com/2017/01/26/gartner-says-by-2019-20-per-cent-of-user-interactions-with-smartphones-will-take-place-via-vpas/

Electric Skateboards | Hoverboards. (n.d.). *Electric Self-Balancing Scooters*. Retrieved from https://dailyhover.com/global-telecommunication-electronics-market-reached-around-us-847-6-billion-by-2016/.

Fernandes. A. (n.d.). *Screenless Display Market by Type (Visual Image, Retinal Display and Synaptic Interface) and Application (Holographic Projections, Head-mounted Display and Head-up Display) - Global Opportunity Analysis and Industry Forecast, 2015 - 2020.* Retrieved from https://www.alliedmarketresearch.com/screenless-display-market.

Fernandes.A. (n.d.). *Screenless Display Market by Type (Visual Image, Retinal Display and Synaptic Interface) and Application (Holographic Projections, Head-mounted Display and Head-up Display) - Global Opportunity Analysis and Industry Forecast, 2015 - 2020.* Retrieved from https://www.alliedmarketresearch.com/screenless-display-market.

Flexnable. (n.d.). Retrieved from http://www.flexenable.com/technology/flexible-olcd/

Ghaffarzadeh, K., & Yamamoto, Y. (2018). *Conductive Ink Markets 2018-2028: Forecasts, Technologies, Players*. Retrieved from http://www.idtechex.com/research/reports/conductive-ink-markets-2017-2027-forecasts-technologies-players-000521.asp.

Global fluorosurfactants market to reach $667.4 M by 2021. (2017). *Focus on Surfactants*, (5), 3. doi:10.1016/j.fos.2017.05.010.

Huang, T., & DIGITIMES Research. (2017). *Digitimes Research: China makers aggressively expanding AMOLED capacity*. Retrieved from http://www.digitimes.com/supply_chain_window/story.asp?datepublish=2017/2/3&pages=VL&seq=202.

IEEE Xplore - Conference Table of Contents. (n.d.). Retrieved from http://www.bing.com/cr?IG=B883630A83384CD99C0A1DF7DAEFD827&CID=3B03A1B6713161B13F27AA6F709E60B7&rd=1&h=.

IHS Markit. (n.d.). Retrieved from https://ihsmarkit.com/index.html.

Indian Health Service. (n.d.). *IHS 20142014 | Transmittal Notices.* Retrieved from https://www.ihs.gov/ihm/tn/2014/.

International Housekeepers' Summit. (n.d.). *IHS 2017* Retrieved from http://www.ihs2017.com/

Jang, K. I., Chung, H. U., Xu, S., Lee, C. H., Luan, H., Jeong, J., . . . Rogers, J. A. (2015). *Soft network composite materials with deterministic and bio-inspired designs.* Retrieved from https://iwe.pure.elsevier.com/en/publications/soft-network-composite-materials-with-deterministic-and-bio-inspi

Julien Happich. (2016). *Glass encapsulation here to stay on flexible OLEDs.* Retrieved from http://www.electronics-eetimes.com/news/glass-encapsulation-here-stay-flexible-oleds

JUSUNG Engineering. (n.d.). *PRODUCT*. Retrieved from http://www.jseng.com/eng/products/display.html?search_order=&search_type=&mode=v&code=G01&idx=533&fk_idx=&thisPageNum=CONx TFE.

K., Yeo, J. C., & Lim, C. T. (2016). *Emerging flexible and wearable physical sensing platforms for healthcare and biomedical applications*. Retrieved from http://www.nature.com/articles/micronano201643#ref20.

Kang, J. (n.d.). *Flexible Display Shipments to Increase Sharply in 2017, IHS Markit Says.* Retrieved from https://technology.ihs.com/586660/flexible-display-shipments-to-increase-sharply-in-2017-ihs-markit-says

Kateeva. (n.d.). Retrieved from http://kateeva.com/press-full/kateeva-introduces-the-yieldjet-flex-a-manufacturing-equipment-solution-to-mass-produce-innovative-oled-displays-tor-curved-and-flexible-consumer-electronics-products/.

Khan S, Lorenzelli L, Dahiya RS. (2015). Technologies for printing sensors and electronics over large flexible substrates: a review. *IEEE Sensors Journal 2015*; 15: 3164–3185.

LG SAS. (n.d.). *REPORTS: A range of LG Electronics' reports are available to provide current and potential investors with a better understanding of our business.* Retrieved from http://www.lg.com/global/investor-relations/reports.

Markets and Markets. (2017). *Display Market by Technology (LED-backlit LCD, OLED, QD-LED, E-Paper), Display Type (Flat, Flexible, Transparent), Application (Smartphone & Tablet, TV & Digital Signage, PC Monitor & Laptop), Vertical, and Geography - Global Forecast to 2022.* Retrieved from http://www.marketsandmarkets.com/Market-Reports/display-market-925.html.

Markets and Markets. (n.d.). F*lexible Display Market worth 15.14 Billion USD by 2022*. Retrieved from http://www.marketsandmarkets.com/PressReleases/flexible-display.asp.

Markets and Markets. (n.d.). *Speech and Voice Recognition Market worth 18.30 Billion USD by 2023*. Retrieved from http://www.marketsandmarkets.com/PressReleases/speech-voice-recognition.asp

Mercredi. (n.d.). *Windows Hello et Cortana : Microsoft dévoile aux OEM ses lignes directrices pour 2017*. Retrieved from http://www.zdnet.fr/actualites/windows-hello-et-cortana-microsoft-devoile-aux-oem-ses-lignes-directrices-pour-2017-39848028.htm.

Mertens, R. (2017). *CDT prices their IPO: 2.5 million shares at $12 ($30 million total).* Retrieved from http://www.oled-info.com/cdt/cambridge_display_technology_prices_ipo_of_2_5_million_shares_of_at_12_00.

Mertens, R. (2017). *DisplaySearch: The AMOLED market will reach US$23 billion in 2022*. Retrieved from http://www.oled-info.com/displaysearch-amoled-market-will-reach-us23-billion-2022.

Mertens, R. (2017). *IHS sees the flexible display market reaching $15.5 billion in 2022.* Retrieved from http://www.oled-info.com/ihs-sees-flexible-display-market-reaching-155-billion-2022.

Mertens, R. (2017). *Meyer Burger ships an inkjet PECVD OLED encapsulation system to an Asian customer*. Retrieved from http://www.oled-info.com/meyer-burger-ships-inkjetpecvd-oled-encapsulation-system-asian-customer.

Meyer Burger. (n.d.). *Products and Systems.* Retrieved from http://www.meyerburger.com/fr/en/meyer-burger/products-and-systems/product-detail/product/conx-tfe/.

Mochizuki, T. (2017). *Japan Display Joins Flexible-Screen Battle With Bendier LCD.* Retrieved from https://www.wsj.com/articles/japan-display-joins-flexible-screen-battle-with-bendier-lcd-1485333870.

Mordor Intellige. (2018). *Flexible Display Market - Segmented by Type (LED, OLED, LCD, EPD), Material (Glass, Plastic), Application (Smartphones and Tablets, Smart Wearable, Televisions and Digital Signage Systems, Personal Computers and Laptops, Monitors, Vehicle and Public Transport, Smart Home Appliances), and Region - Growth, Trends, and Forecast (2018 - 2023).* Retrieved from https://www.mordorintelligence.com/industry-reports/flexible-display-market.

Nippon Electric Glass. (n.d.). *G-Leaf™ ultra-thin glass overturns glass stereotypes.* Retrieved from http://www.neg.co.jp/glass_en/03.html.

Nissha and C3Nano. (2015). *Nissha and C3Nano Succeed in Joint Development of Next Generation Silver Nanowire Transparent Inks, Powered by C3Nano's Activegrid™ for Smarter, Flexible Touch-Sensor Displays*. Retrieved from http://c3nano.com/nissha-and-c3nano-succeed-in-joint-development-of-next-generation-silver-nanowire-transparent-inks-powered-by-c3nanos-activegridtm-for-smarter-flexible-touch-sensor-displays/.

Nissha product SAS (n.d.). *Resistive-type Touch Sensor Key features are lightweight, thin, optical clarity, durability and exact sensing*. Retrieved from http://www.nissha.com/english/products/dev/resi.html.

Nissha SAS. (n.d.). *Trace of Growth.* Retrieved from http://www.nissha.com/english/company/business/history.html.

Paratech. (2017). *3D Force-Sensing Technology Secures Corporate Vision 2016 Technology Innovator Awards for Peratech*. Retrieved from https://www.peratech.com/press-releases/2016/09/13/3d-force-sensing-technology-secures-corporate-vision-2016-technology-innovator-awards-for-peratech/.

Pays d'Aix Développement. (2017). *Encapsulix SAS selected as supplier of ALD-TFE deposition systems by leading Asian AMOLED manufacturer*. Retrieved from http://www.provence-pad.com/presse/encapsulix-sas-selected-as-supplier-of-ald-tfe-deposition-systems-by-leading-asian-amoled-manufacturer/.

Ponce Wong RD, Posner JD, Santos VJ. (2012). Flexible microfluidic normal force sensor skin for tactile feedback. *Sensors and Actuators A: Physical*; 179: 62–69.

PR Newswire. (2014). *Flexible Electronics Market by Components (Display, Battery, Sensor, Photovoltaic, Memory), Circuit Structure Application (Consumer Electronics, Healthcare, Automotive, Energy and Power), & by Geography - Analysis & Forecast to 2014 – 2020. h*ttps://www.prnewswire.com/news-releases/flexible-electronics-market-by-components-display-battery-sensor-photovoltaic-memory-circuit-structure-application-consumer-electronics-healthcare-automotive-energy-and-power--by-geography---analysis--forecast-to-2-271744691.html.

Provence-Pad. (n.d.). *Encapsulix SAS selected as supplier of ALD-TFE deposition systems by leading Asian AMOLED manufacturer*. Retrieved from http://www.provence-pad.com/presse/encapsulix-sas-selected-as-supplier-of-ald-tfe-deposition-systems-by-leading-asian-amoled-manufacturer

Royole Corporation. (2016). Royole Creates Strategic Partnership With China's Largest Mobile Company. Retrieved from http://www.prnewswire.com/news-releases/royole-creates-strategic-partnership-with-chinas-largest-mobile-company-300262025.html

Royole Corporation. (n.d.). *Royole.* Retrieved from http://www.royole.com/introduction

Royole Corporation. (2016). *Royole Corporation Builds Partnership with Li-Ning.* Retrieved from http://www.royole.com/royole-and-lining-sign-strategic-cooperation-en.

Royole Corporation. (n.d.). *Overview.* Retrieved from http://www.royole.com/investors

Royole Corporation. (n.d.). *Royole's Flexible Sensor*. Retrieved from http://www.royole.com/flexible-sensor.

Schott SAS. (n.d. A). *D 263®.* Retrieved from http://www.schott.com/advanced_optics/english/products/optical-materials/thin-glass/thin-glass-d-263-t-eco/index.html.

Schott SAS. (n.d. B). *Ultra-Thin Glass.* Retrieved from http://www.us.schott.com/advanced_optics/english/products/wafers-and-thin-glass/glass-wafer-and-substrates/ultra-thin-glass/index.html

Singh, A. (2015). *Global Electronics Industry - What's Ahead?* Retrieved from https://www.linkedin.com/pulse/global-electronics-industry-whats-ahead-anurag-singh.

Singh, A. (2015). *Global Electronics Industry - What's Ahead?* Retrieved from https://www.linkedin.com/pulse/global-electronics-industry-whats-ahead-anurag-singh.

Singh, A. (2015). *Global Electronics Industry - What's Ahead?* Retrieved from https://www.linkedin.com/pulse/global-electronics-industry-whats-ahead-anurag-singh.

Wilson, M. (2017). *Google's Minor UI Update Is Solving The Biggest Problem On Smartphones Right Now*. Retrieved from https://www.fastcodesign.com/3046887/googles-biggest-i-o-announcement-will-fix-a-major-problem-with-smartphone-apps.

Wires.W. (2016). *Voce Commands, Personal Assistants the Next Frontier for Device Interactions, Gartner Predicts*. Retrieved from https://www.wirelessweek.com/data-focus/2016/12/voice-commands-personal-assistants-next-frontier-device-interactions-gartner-predicts.

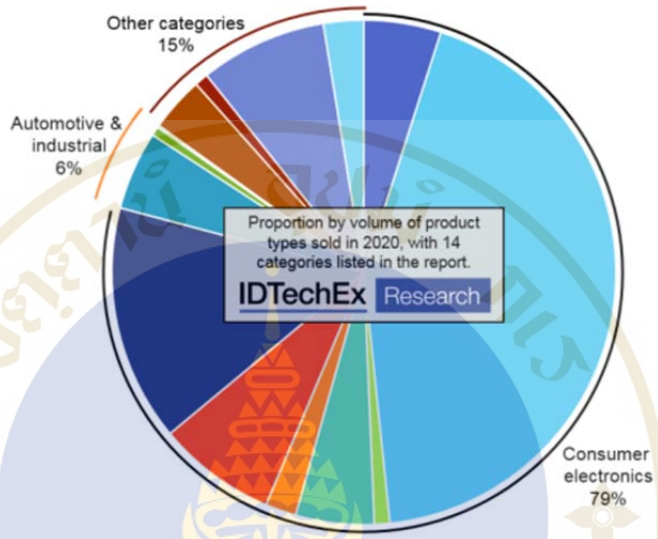
Wong, R. D., Posner, J. D., & Santos, V. J. (2016). Flexible microfluidic normal force sensor skin for tactile feedback. Retrieved from https://iths.pure.elsevier.com/en/publications/flexible-microfluidic-normal-force-sensor-skin-for-tactile-feedba.

Wu, D. (2017). *Foxconn considers $7bn US display facility with Apple.* Retrieved from http://asia.nikkei.com/Business/AC/Foxconn-considers-7bn-US-display-facility-with-Apple?page=2.

APPENDICES

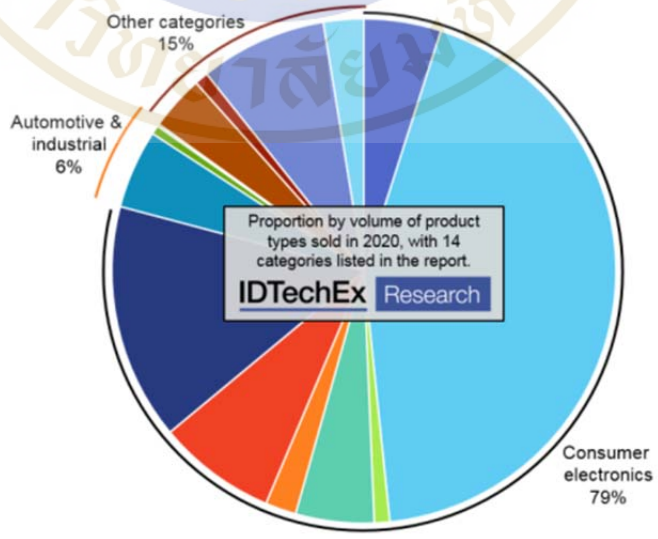
Appendix A: Proportion of Force Sense technology expected in the Consumer Electronics market

Proportion by volume of product types sold in 2020 with 14 categories

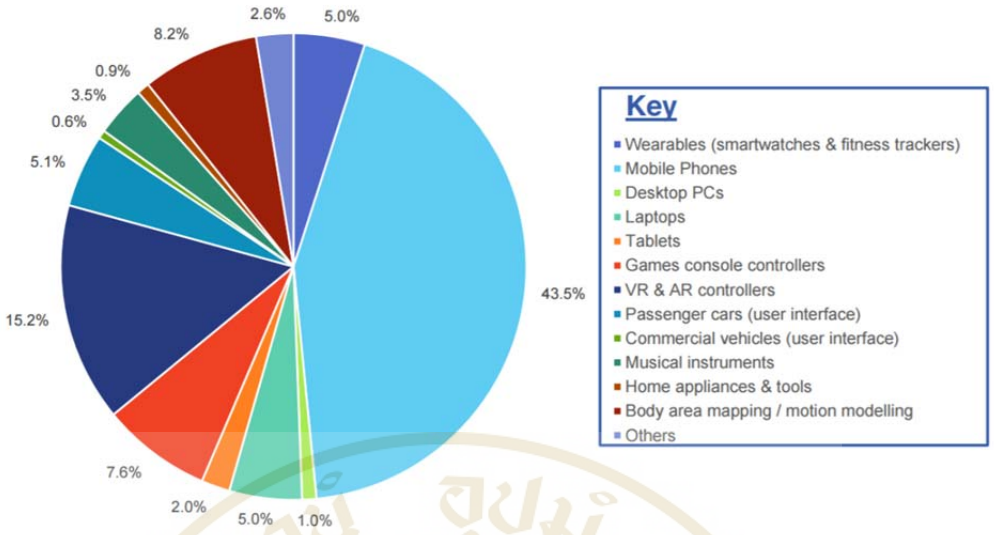


Source: Cheng, Z. (2016)

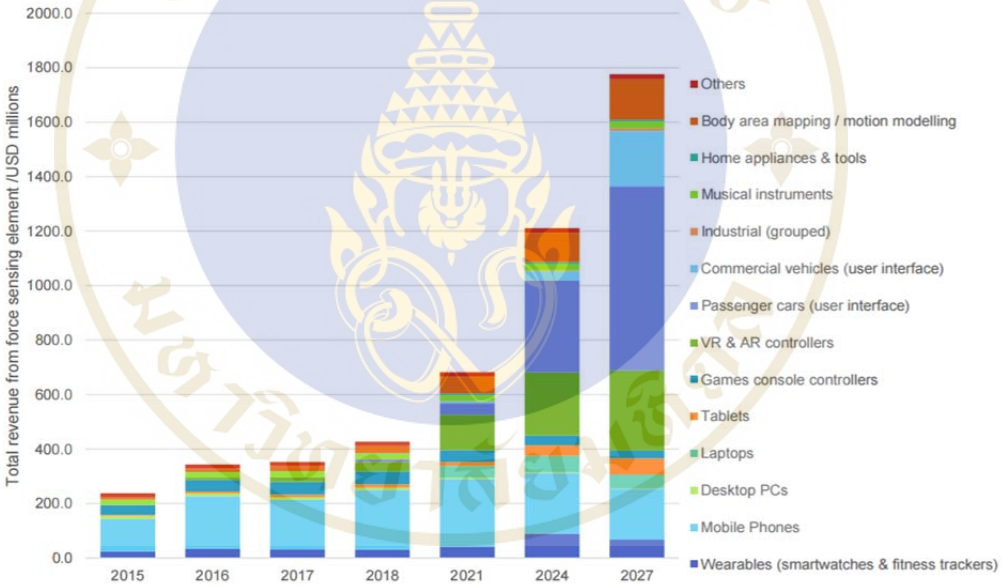
Force Sensors in User Interfaces forecast in 2020



Source: Cheng, Z. (2016)



Total Revenue form Force Sensing Element 2015-2027



Appendix B: Overview Forecasts (Flexible) Consumer Electronics, Displays & Force Sense

Forecasts of Force Sense in Consumer Electronics 2015-2024 based on various sources, missing data is predicted based on a linear regression model

VALUE in Billion USD$	2017	2018	2019	2020	2021	2022	2023	2024
Consumer Electronics	586.67	536.00	650.00	840.00	1,093.33	1,346.67	1,600.00	1,853.33
Displays	126.06	143.26	145.71	155.54	165.37	169.17	185.02	194.84
Flexible Electronics	8.37	9.99	11.61	13.23	16.50	16.47	18.09	19.71
Flexible Displays	2.29	2.85	3.40	3.96	4.52	5.07	5.63	6.18
Force Sense	0.36	0.41	0.50	0.60	0.69	0.86	1.03	1.20
Force Sense in Consumer Electronics*	0.28	0.32	0.40	0.47	0.55	0.68	0.81	0.95

Compound annual growth rate of Force Sense in Consumer Electronics 2015-2024 based on various sources

CAGR in %	2017	2018	2019	2020	2021	2022	2023	2024
Consumer Electronics	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	
Display	6.75%	6.75%	6.75%	6.75%	6.75%	6.75%		
Flexible Electronics	21.73%	21.73%	21.73%	21.73%	21.73%			
Flexible Displays	31.20%	31.20%	31.20%	35.00%	35.00%			
Force Sense	21.52%	21.52%	21.52%	21.52%	21.52%	21.52%	21.52%	

Forecasts of Force Sense in Consumer Electronics 2015-2024, calculated based on the expected CAGR with corresponding values from the same source (the numbers from the original source have the same colour)

VALUE in Billion USD$	2017	2018	2019	2020	2021	2022	2023	2024
Consumer Electronics	1,520.00	1,600.00	1,680.00	1,764.00	1,852.20	1,944.81	2,042.05	2,144.15
Displays	129.19	137.44	146.21	155.54	164.87	174.76	185.25	196.37
Flexible Electronics	6.34	8.10	10.36	13.23	16.10	19.60	23.86	29.05
Flexible Displays	2.97	4.58	7.04	10.83	16.66	22.49	30.36	40.99
Force Sense	0.36	0.41	0.50	0.60	0.69	0.86	1.03	1.20
Force Sense in Consumer Electronics*	0.28	0.32	0.40	0.47	0.55	0.68	0.81	0.95

*We assume the proportion of Force Sense in Consumer Electronics will stay 79% over the period of 5 years

Source: Cheng, Z. (2016)

Compound annual growth rate of Force Sense in Consumer Electronics 2015-2024, from one source

CAGR in %	2017	2018	2019	2020	2021	2022	2023
Consumer Electronics	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
Display	6.00%	6.00%	6.00%	6.00%			
Flexible Electronics	21.73%	21.73%	21.73%	21.73%	21.73%		
Flexible Displays	35.00%	35.00%	35.00%	35.00%	35.00%		
Force Sense	13.89%	22.76%	18.54%	15.64%	24.64%	19.77%	16.50%

Flexible Display Shipment 2017-2023 (in Million of Units)

Shipments (Million of Units)	2017	2018	2019	2020	2021	2022	2023
Flexible Displays	139	235	344	417	468	523	560

Source: Kang, J. (n.d.).

Appendix C: Industry Rivals Description" from Five-Forces Model in Part B

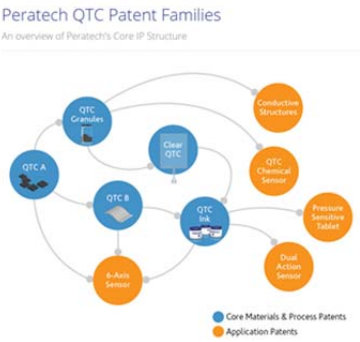
I. Paratech

Who are they?

The force sensor manufacturer which based on patented Quantum Tunnelling Composite (QTC®) technology. The sensors bring a new dimension to tactile, or force-touch controls. QTC materials change from being an almost perfect insulator to becoming increasingly conductive in proportion to the amount of force applied to them. The materials are very robust and resilient, so that changes in resistance due to even the slightest pressure are both predictable and repeatable over more than a million cycles.

The QTC touch experience is intuitive, consistent, precise, durable and reliable, whatever the environment, even when using gloved fingers or in the presence of moisture. (Paratech, 2017)

- Is a force sensing HMI/MMI solutions company founded in 1996. (HMI = Human Machine Interface, MMI=Man machine interface)
- The company invent and develop the proprietary called QTC (Quantum Tunnelling Composites)which is used as pressure sensors. When pressure applied, and move closer to electrons.
- Mature experience (21years) in Materials (QTC) and Software (HMI) development
- HQ in York Shire UK, team subordinates in USA, South Korea, Stockholm and Sweden
- Patented internationally



Value Proposition

- Custom sensor design, prototyping and volume production
- Mechanical and electronic design and development engineering for fully integrated solutions
- Embedded software development and software development platform providing the end-to-end solution, from 2D art, to prototype, to final product and test software
- Process development engineering, process transfer, and factory qualification to integrate force-sensing materials into existing factories by cost effectively adapting current manufacturing technologies
- Strategic material sourcing support early in the new product development phase to ensure sustainable, manufacturable, scalable, and cost-effective mass production
- Materials design and development to meet market application specifications in performance, stability, and reliability
- Low power, immune to EMI (electromagnetic interference, disruption of operation from others Electromagnetic Field/Radio frequency) and water events, work with gloved hands and passive stylus, and can be transparent as well as opaque.
- They do customization of the sensor either single or multiple. (Das, Ghaffarzadeh, & He, 2016)

Owned Resources/ Facility

- UK company headquarters
- Full mechanical and printed electronic design service
- Screenprinting artwork production

- In-house screenprinting of QTC® Material, Silver, Carbons and other conductive inks for prototyping sensor layouts
- Sensor layer cold lamination
- Material development
- Material and sensor testing, e.g. environmental, durability, lifecycle
- Laser profile cutting

Their products

- QTC Single Touch
- QTC Multiple Touch and Force called QTC Multi-force Matrix Sensors integrated under multiple top surfaces including plastics, metals, glass and flexible displays.
- Mechanical integration Support by designing the force and effect of the object with the software.
- Electronics and system design; see the capable, reliable and cost effective your force-sensing solution can be. Peratech's electronics design objective is to use as little space and system resources as possible, leveraging existing interconnect and controller processing. Peratech provides only the design support you need up to full electronics design and testing
- Supply Chain for cost effective, productivity, quality assurance, bargaining power by contract with suppliers and manufacturers.

Their positioning and target in the market

- Consumer electronics; Smartphones, tablets, personal computing, gaming and other consumer products are moving beyond 2D touch to 3D force touch. We have the mass production-ready solution for you today.
- Automotive Electronics;(IDEA) to create the seamless experience in the cockpit by developing the HMI (Human Machine Interface) solution, and to support the safety. Customers could customize the sensor's pressure for the application demands.
- Smart Home and Appliances; for full home-automation, to simplify the behavior and enhance seamless experience.

- Industrial; to be the solution of current HMI by enabling usage with Gloves. Providing durability.

II. Nissha

Who are they?

- Japanese Leading Printing company established in 1929. Currently has 52 consolidated subordinates globally. The main idea is to develop the technology of printing without using paper and they have been improving into different dimensions relevant to printing.
- Four main business areas:
  1) Industrial Materials
  2) Devices
  3) Life Innovation
  4) Information & Communication.
- 2007 launched the Capacitive touch panel product in for electronic devices
- 2012 Mass Production of Capacitive-type Touch Panel Using Photolithography Process. Its mass production was established in the Himeji Factory of Nitec Precision and Technologies, Inc..In the following year, the mass production line expanded to the Kaga Factory.
- 2016 expansion of the product technology and partnership toward Medical and Automotive sector (Acquired; Graphic Controls group is U.S.-based Global Medical Device and Consumable Products Manufacturer and European company, Schuster group, became the subsidiary). (Nissha SAS, n.d.)

Value Proposition

- Touch Sensors have gained attention for their "usability" and "fun operation".
- Applications are gradually spreading to a variety of other devices, such as digital cameras and car navigation systems.
- Diverse product offering
- Wide range of businesses by providing devices, services, and systems with sensing functions in addition to Touch Sensors .

- One stop service and after sales service for the customer

Their Facility/ Resources

- 52 subordinate all around the world which give the technology and know-how to the company. Also the benefits towards logistics, cost, manufacturing and R&D.
- Great reputation since 1949, after the war in printing industry. Including the strong network with PR company in Japan to reach the consumers.
- Further developed pressure-sensitive ink (a material in which the contact resistance value changes greatly with pressure) and optimized the production process to complete this high performance, high durability proprietary sensor. (Nissha SAS, n.d.)
- Joint Development agreement with c3 nano in 2015 who is the Conductive ink and flexible encapsulation producer

Their Products

- Nissha's force sensor is built into Force Sensor and Multi-Touch products, each with distinct characteristics
- Force Sensing, Multi Touch sensing place under the display

1. Capacitive Touch Sensor "Fine Touch" (Nissha SAS, n.d.)

- Features; Thin, Light, Break-proof, Same level of transparency and price with glass sensor, narrow frame(fine line)

2. Resistive Type Touch Sensor "Fine Touch Classic"

- Sense with Glove, Thin, Clean, high level of readability, input durability, can go with any products (Nissha SAS, n.d.)

3. Force Sensors

- Can work with both transparent and non transparent screen.

4. Multi Force Sensor (Nissha SAS, n.d.)

- Nissha further developed pressure-sensitive ink and optimized the production process to complete this high-performance, high-durability proprietary sensor.

- Recognize position, pressure, and area, it enables subtle input control and can reproduce even calligraphy-style brushstrokes
- Possible to input with pen while hand touch the screen

	Force Sensor	**Multi Force Sensor**
Pressure detection	1 point	Up to 10 points
Position detection	Not supported (External circuit required)	Supported
Product configuration	Sensor	Sensor module with control IC
Major use	Placed under the display and linked to an external touch panel, recognizes the inputting force to create a touch user interface.	Recognizes the inputting force on multiple points individually to create a new touch user interface. In handwriting applications, supports general writing instruments without the need for an active pen. Can reproduce brushstrokes according to the inputting force applied, and recognize the difference between pencil, eraser, and palm.

4.1 Fine Touch Z, Transparent force sensor

- FineTouch Z is a resistive-type multi-touch sensor employing transparent electrodes and a transparent pressure-sensitive ink layer to detect pressure (patent acquired).
- Identify both by finger or gloves

5. Wireless Sensor (Nissha SAS, n.d.)

- The device identifying the motion and send the information to the devices
- Safety, Productivity, Monitoring, Time management, Security, Convenient Meeting room, Logistics, Agriculture, Industry(Gas or Fire detector)

Their positioning and target in the market

- Japanese leading printing company who diversified the product variety to provide the market solution
- Healthcare, medicine, agriculture, education, housing equipment, industrial equipment, and automobiles.
- Main focus seems to be at Automobile and Consumer electronics ie.Digital Camera, Games, Mobile.

III. Royole

Who are they? (Royole SAS, n.d.)

- Royole was founded in Fremont, California, Hong Kong and Shenzhen China by Stanford engineering graduates in 2012,
- Core mission is to improve the way people interact with and perceive the world.
- Creates and manufactures flexible displays, flexible sensors, and smart devices.
- Providing IP licenses, services, and solutions for a variety of industries associated with displays and flexible electronics applications.
- 2014, Royole introduced the world's thinnest full-color AMOLED flexible display with a thickness of 0.01mm and a bending radius of 1mm.
- In 2015, Royole began mass production of proprietary flexible sensors and flexible electronic devices, and introduced the world's first foldable 3D virtual mobile theater.
- In 2016, Royole introduced the world's first curved car dashboard based on flexible electronics at the CES in Las Vegas.
- Royole also announced its 1.1-million-square-feet flexible display mass production campus in Shenzhen, China with a total investment of USD $1.7B to be fully operational by mid-2017.

Their Facility/ Resources

- Strong financial backups(investors) both from United States and China (Royole Corporation, n.d.)
- Flexible display mass production cambus in Chenzhen, China
- They have core teams covering the technologies both in developing and manufacturing.Ie.Shenzhen R&D team; Intensive experience in novel flexible sensing technologies; Deep understanding of flexible sensor design,Shenzhen PE team; Insights on flexible sensor industry & Professional manufacturing experience and US R&D team. Including Alumni from top research institutes

Their Products

Foldable Virtual Mobile Theatre (world's first)

- Using flexible screen /foldable devices with high quality image and sound
- Commercialized at 699-799USD 

Royole Flexible Sensor (Royole Corporation, n.d.)

- Custom design for flexible form factor, fully compatible with traditional applications materials
- Low resistivity enables flexibility in wire routing
- Excellent optical properties, low haze, high transparency
- Cost efficiency Process
- Cutting-edge process technology in combination with new sensing materials
- Smooth and eco-friendly fabrication procedure
- Refined and automated manufacturing
- Product Specifications
- Multi-touch capability
- Supported features ; stylus compatible, glove friendly, water resistive
- Support multiple interface connections, e.g. I2C, USB, SPI
- Work with driver IC from Synaptics, Goodix, FocalTech and other mainstream IC suppliers

- Driving voltage: 1.8V~3.3V
- Report rate: ≥80Hz
- Accuracy: center≤1.0mm, edge≤1.5mm
- Linearity: center≤1.0mm, edge≤1.5mm
- Sensitivity: 7mm (single layer) or 4mm (double layer)

Product Features

- Free form factor
- Refined borderless design
- Ultrathin
- Light weight
- Cost efficiency

Their positioning & Target in the market

- OEM manufacturer who co-develop with clients regarding AMOLED display and sensors.
- Innovative image and lead the technology by claiming the world's thinnest full-color AMOLED flexible display, world's first curved car dashboard based on flexible electronics which is Virtual Mobile Theatre,their main product.
- Quick mover to began mass production of flexible sensors and electronic devices, and introduced the world's first foldable 3D virtual mobile theater.
- Invested in 1.1-million-square-feet flexible display mass production campus which fully operational by mid-2017
- In May 2016, partnership with China Mobile the largest mobile telecommunication company in China. To reach their current customers and further product development. (Royole Corporation, n.d.)
- In Apr 2016, partnership with Chinese large sportwear manufacturer in order to develop new product of Flexible wearables. (Royole Corporation, n.d.)

IV. C3 Nano

Who are they? (Nissha and C3Nano, 2015)

- The performance leader in transparent conductive ink and film for the touch sensor and display who signed Joint Development Agreement with Nissha in 2015
- Founded in 2010 and raised fund from worldwide company mainly from Japan, United States. The last equity closure amount at 15Million USD. Accumulated funding at 37Million USD since 2010.
- 2015 acquired the Aiden Co. Ltd., Asia's Largest Manufacturer of Silver Nanowire
- Partner with Nissha because they want C3 Nano Active transparent ink
- Partner with Hitachi Chemical because they want transparent conductive transfer films using C3nano ink

Value proposition

- High optical performance, Low resistivity, Low cost
- Solution Processable: the material can be coated with exist process on flexible films and substrate.
- Versatile-printable and patternable : not required customer equipment
- Low cost: TCF layer cost using C3Nano technology is about one-fifth the cost when compared to sputtered ITO
- "C3Nano materials have already shown to be more durable, mechanically stronger and more robust than ITO" (C3nano SAS, n.d.).

Their Facility / Resources

- Strong reliability from the investors nationwide ie.GSR Venture, Guoli Minsheng (China), Phoenix Venture, Hitachi Chemical, Nissha Printing (Japan), Nagase America (USA)
- Machinery and technology development from acquiring and partnershipping with other companies ie.Aiden Inc., Nissha Printing, Hitachi chemicals

Their Products

1. Conductive Ink “Active grid Ink”

- achieves high transmission, low haze, and low b* over a wide range of sheet resistances, 10 – 350 Ω/
- Low-cost alternative to ITO, for applications like touch panel, OLED displays, OLED lighting, EMI shielding, E-paper, LCD and solar cells
- Activegrid ink is suitable for any standard industrial coating process
- Coating is performed in ambient conditions and is perfect for temperature-sensitive substrates like PET, PC and COP
- Activegrid ink is highly durable, stable at high temperature and high humidity, and resistant to chemical corrosion
- Coated film is highly flexible and ductile, making it applicable for flexible products

2. Activegrid Film

- C3nano Activegrid™ is a new material made by chemically fusing metallic nanowires into a singular nanoscale grid. Activegrid™ is incredibly flexible and is the highest performing ITO alternative; resistance, transmission, and haze values of Activegrid™ are far better than ITO on plastics.

Features:

- Conductive films with high conductivity as well as superb light transmission and color properties
- Highly stable, optically clear PET base films
- Product can be provided in wide roll widths, various film thicknesses or with protective films and hard coats. Other substrate materials such as PC, COP, PEN, COC and glass are available upon request.
- C3nano provides custom solutions for a variety of applications and unique user requirements. We are prepared to work with you to develop a film solution that meets your specific needs

3. Coating (Sounds like encapsulation but use to coat to anti scratch)

Features:

- Thin layer coating (100nm) with good scratch resistance and hardness > 3H.
- ActiveguardHC™ coating is flexible around a 1.0 mm mandrel, while retaining its ultra-hard properties.
- Provides protection during touch sensor processing, hence improving manufacturing yield.
- No impact on optical properties.
- ActiveguardHC™ hard-coat was designed as the hardest coating available on a flexible film, rated up to 9H, as measured on the Mohs hardness scale.

Their positioning & Target in the market

- Strong research and development move from partnership with leading company
- Nissha and Hitachi Chemicals
- The material provider to the big player. Can assume from partnership move that the first target can be in Japan