LexInnova

MEMS Display Technology

Patent Landscape Analysis

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Executive summary

Micro-Electro-Mechanical Systems (MEMS) can be defined as miniaturized mechanical and electro-mechanical elements manufactured by techniques of micro-fabrication. The development of MEMS can closely be associated with development of solid state electronics as their manufacturing processes have commonality. One of the very first commercial products of MEMS architecture was HP's Inkjet Printer launched in 1970s. Since then MEMS architecture has evolved and is now being widely used in various fields like wireless communications, sensors and bio-electronics.

Over the recent years, MEMS devices have found applications in next generation display technologies like Inter-ferometric Modulator Display (IMOD), Time Multiplexed Optical Shutter (TMOS) and Digital micromirror device (DMD). Some of the advantages of MEMS based display techniques are that they are extremely energy efficient and provide good visibility even in over-saturated ambient light. In today's electronics world, where battery life and energy efficiency are the most important factors, MEMS based display systems which consume less power for operation seem to be the best alternative.

IMOD display technology uses principles of relative refraction and reflection of light from Nano-structures and TMOS uses time multiplexed functioning of LEDs to create a range of colors in each pixel. The digital micromirror device, or DMD, is an optical semiconductor that is the core of the trademarked DLP projection technology used in HDTVs and DLP projectors. These technologies are deemed to be the prime movers of display technologies used in electronic products in the future.

Using LexInnova's proprietary patent analytics tool, LexScore^{TM}, we identify Qualcomm as the major player which has a good number of patents/patent applications but the average remainder lifetime is less. We also identify that Texas Instruments and Microvision, have a high average patent strength and high average life time. Patent holding pattern, coupled with high patent filing activity, indicates a significant patent licensing potential in MEMS-based display technology domain.

In subsequent sections of this report, we analyze the Intellectual Property landscape of MEMS-based display technologies. We discovered that the maximum IP generation activity has occurred in technologies related to Modulation and Picture Characteristics. Qualcomm has the highest number of filings with 4,179 patents/patent applications filed worldwide. As per our analysis, majority of Qualcomm's patents/patent applications pertain to the technology domain of IMOD Displays which they have acquired from Iridigm in 2004.

Using our proprietary Licensing Heat-map framework, we predict significant patent licensing activity in the '3D projection equipment' and 'interfaces' technology segment in the near future. Geographically, the maximum number of patents/patent applications have been filed in the United States. One of the reasons for this is that technology giants like Qualcomm are based out of USA. Other major geographies include Japan, China and South Korea.

Introduction

Display technologies are very important in today's digital world. They are now an integral part of everyday human life and the primary way we interact with digital and internet world. Since *John Logie Baird* publicly demonstrated televised moving silhouette images in 1925, the technology has grown on an enormous scale. In 90 years, it has evolved from big bulky cathode ray tubes to flat panel displays. We now have various technologies like OLED and LCD in the display domain which provide very vivid and high quality images. The focus of research and development over the past decade has been to make display technologies energy efficient while improving the picture quality. One such attempt is the use of Micro-Electro-Mechanical Systems (MEMS) architecture in display technologies. The major display technologies based on MEMS are Inter-ferometric Modulator Display (IMOD), Time Multiplexed Optical Shutter (TMOS) and Digital Micro Mirror Devices (DMD). In the subsequent sections of this report, we have analyzed the Intellectual property pertaining to these next generation display technologies.

Inter-ferometric Modulator Display (IMOD) uses the principle of light diffraction over Nano-surfaces which are manufactured using MEMS techniques. They project colors based on the principle of interference in reflected light. Unlike the earlier display systems, IMOD does not require backlight for picture projection. Instead, it uses natural ambient light in projecting images. The light modulator, made up of the Nano-surfaces, breaks up natural light, adjusts the resulting color wavelengths efficiently by the principle of mutual interference. The light modulator consists of two plates sandwiched with a small gap between them. A thin film on a glass substrate is placed over a suspended reflective membrane. When the electric charge is passed through this array the plates come together and all the light wavelengths except ultraviolet are absorbed thereby projecting only black color to the user. But when the charge is released dynamically, three different width gaps are formed between the plates corresponding to red, green and blue wavelengths. These width gaps can be combined to result in any desired color. These gaps can be adjusted thousands of times per second resulting in a dynamic display. Once the image is created, the display does not require any power to refresh or retain it. It only uses power when being switched on or off. This enables the display to use a significantly low amount of power, thus contributing to battery life. IMOD devices benefit mobile phones, MP3 players and e-readers because of the extended battery life and the ability to provide optimal viewing in over-saturated natural ambient light.

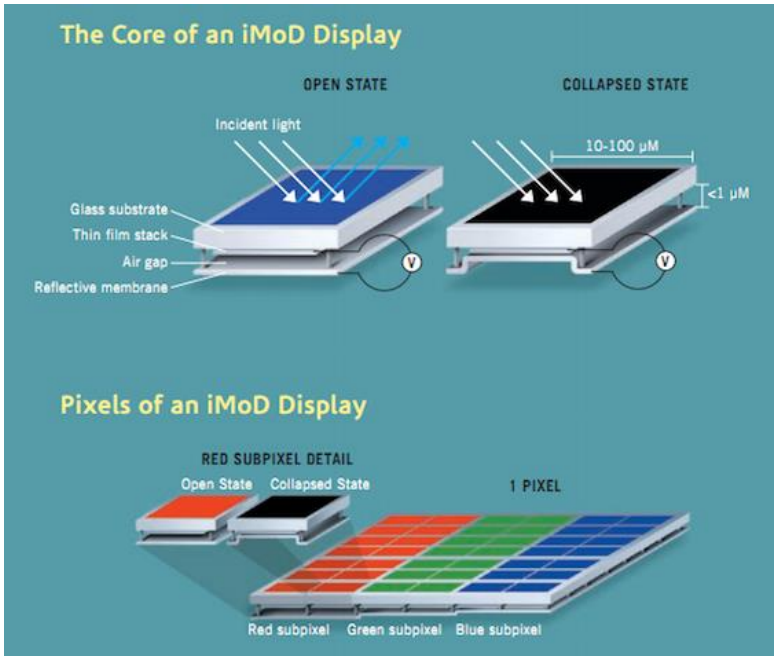

Figure 1: IMOD Technology Illustration[1]

Qualcomm acquired IMOD technology from Iridigm in 2004 for $170 million and re-branded it as "mirasol display".[2] Since then, Qualcomm has been one of the major players in the display technology. The first introduction of mirasol technology to an electronic gadget was done by Freestyle Audio in its next-generation MP3 player product line. The display of the gadget was a 0.9-inch IMOD color mirasol display.[3] This was followed by Qualcomm's smart watch Toq, which was released in December 2013. Sharp has been working on its new display, which deploys MEMS and is expected to implement it by 2017. In 2014, Apple has taken over Qualcomm's Mirasol (MEMS-IMOD) display lab in Taiwan as it aims to reduce its dependency on technology providers like Samsung Electronics and LG Displays.[4] Big corporations, understanding the importance of battery life in electronics have focused their attention to IMOD displays.

Time Multiplexed Optical Shutter (TMOS) is another display technology which employs MEMS architecture. TMOS is a unique technology due to the fact that it does not use the principle of superimposition of red, green and blue wavelengths to produce a colored vision. Instead, it multiplexes these frequency emissions in a timely manner for the brain to do the math and perceive the color. LEDs are placed in Nano-structures similar to that of IMOD displays which glow in a time-multiplexed manner. The number of filters, light goes through before emission is significantly reduced which in turn

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[1] Mirasol-: /. Retrieved from http://www.sotovik.ru/news/mirasol-rideri-novaja-politika.html

[2] Qualcomm to Acquire Display Technology Innovator Iridigm | Qualcomm. (2004). Retrieved from https://www.qualcomm.com/news/releases/2004/09/09/qualcomm-acquire-display-technology-innovator-iridigm

[3] Qualcomm pioneers industryâ€™s first IMOD color display | Digit.in. (n.d.). Retrieved from http://www.digit.in/general/qualcomm-pioneers-industry-s-first-imod-color-display-2352.html

[4] Apple has taken over Qualcomm's IMOD Mirasol display lab in Taiwan. Retrieved from http://appleinsider.com/articles/15/12/15/apple-has-taken-over-qualcomms-imod-mirasol-display-lab-in-taiwan

reduces the amount of power consumed, making TMOS one of the most energy efficient display technologies. Developed by UniPixel, TMOS displays have featured in Samsung products as an alternative to LCD and OLED technologies since 2009.[5] Rambus, realizing the potential of the technology acquired UniPixel's display and backlighting Intellectual property in 2010 for $2.25 Million.[6]

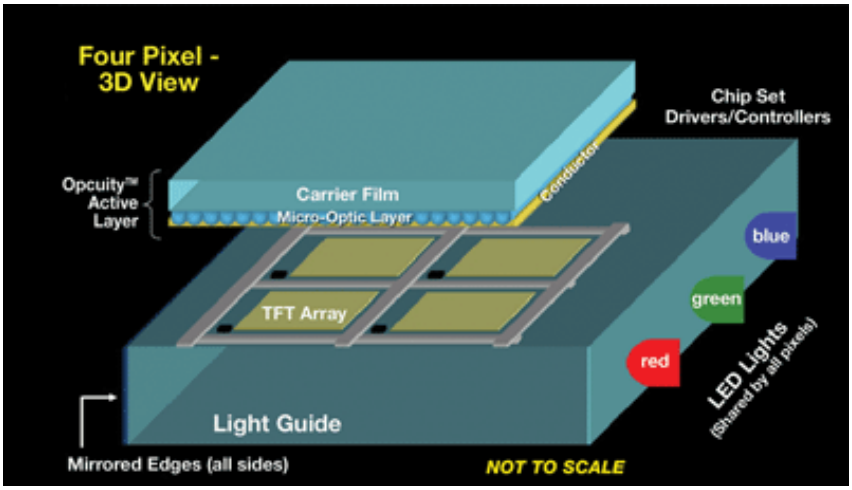

Figure 2: TMOS Technology Illustration[7]

Digital Micromirror Device (DMD) is an optical semiconductor chip (MOEMS) which has thousands of microscopic mirrors arranged in a rectangular fashion. Each of these mirrors correspond to a single pixel. These mirrors operate in bi-stable states depending on the tilt. In 'on' state these mirrors are tilted towards the illumination source and in 'off' state they are tilted away from the illumination source. DLP technology, developed by Texas Instruments (TI), is one of the most successful projector and display technologies. This technology is based on DMD chips and is being used all over the world for its high quality and resolution.

[5] Samsung hedges its bets with UniPixel's TMOS display technology. Retrieved from http://www.engadget.com/2009/02/04/samsung-hedges-its-bets-with-unipixels-tmos-display-technology/

[6] Rambus Acquires Uni-Pixel Display and Backlighting Intellectual Property. (n.d.). Retrieved from http://www.marketwired.com/press-release/rambus-acquires-uni-pixel-display-and-backlighting-intellectual-property-1267119.htm

[7] MEMS shutter heralds much-improved displays. (n.d.). Retrieved from http://www.electronicproducts.com/Optoelectronics/Displays/MEMS_shutter_heralds_much-improved_displays.aspx

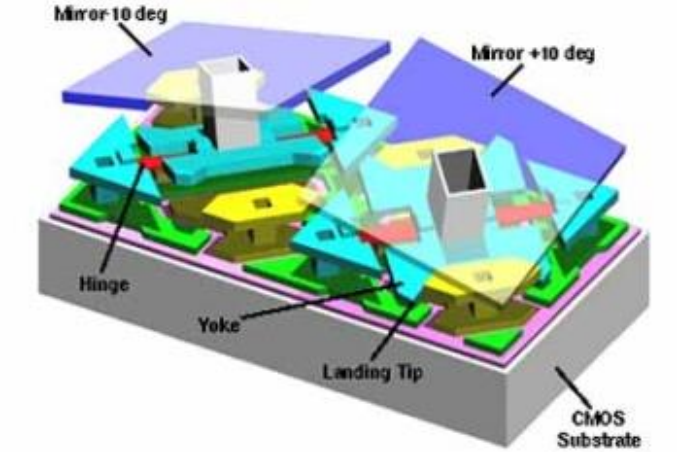

Figure 3: DMD Technology Illustration[8]

MEMS-based display market is expected to grow at a CAGR of 85.9% till 2019.[9] This will be mostly powered by IMOD and TMOS displays along with DMD technology. Understanding the growing importance of MEMS-architecture in displays, we have analyzed the intellectual property in this domain.

In such a financially lucrative and fast evolving market safeguarding a company's interest using Intellectual property is an important strategy for the market players. Assessing the IP landscape is therefore an important exercise for current market players as well as companies who are looking to enter this market. In the following paragraphs we have presented the MEMS display technology taxonomy, followed by a discussion on the major players in the market. The report concludes by highlighting future licensing areas in the technology domain.

[8] Optical Sciences Corporation - Aviation, Missile, NASA, Infrared, Engineering. (n.d.). Retrieved May 24, 2016, from http://www.opticalsciences.com/dmd.html

[9] Global MEMS microdisplay market to grow at a CAGR of 85.9% over the period 2014-2019. Retrieved from http://news.findit.com/news/1791672/global-mems-microdisplay-market-to-grow-at-a-cagr-of-8

Taxonomy

In the following sections, we have classified the intellectual property pertaining to MEMS-based display into various technology sub domains. We have also classified the patents/patent applications on the basis of performance-centered apparatus and arrangements.

Among applications of MEMS-based displays, Television has the highest number of patents/patent applications with 4,745 filings worldwide. Telephone and Touch Pad displays have also seen considerable amount of research with 901 and 1,282 patents/patent applications respectively. This is due to the fact that MEMS display is mostly being implemented in e-readers and mobile phones. Modulation and Picture characteristics technology domains also have a very high number of patent filings with 4,527 and 3,813 patents/patent applications respectively.

In the technology sector, apparatus for interference filtering has less number of filings with about 1099 patents/patent applications. Among applications, camera industry has only 514 patents/patent filings till date. This shows the camera industry hasn't widely adopted MEMS displays.

Level 1	Level 2	Level 3	Number of Patents/Patent Applications
Apparatus	Picture Display Control	Modulation	4,527
		Picture Charcteristics	3,813
		Filters	1,099
	Projecting/Viewing Apparatus	Mirrors	3,526
		3 Dimensional	2,643
		Laser	1,913
		Others	1,247
	Light Guides	Propagation	3,188
		Structure/Design	1,369
Control Systems	Signal Manipulation		4,597
	Transmission		4,744
Data Processing	Optical/Electrical		2,409
	Interfaces		1,413
	Image		963
	Others		752
Micro-Structural Technology	Flexible Structures		2,016
	Circuits		2,399
	Manufacturing		2,950
	Substrate		2,703
	Others		411
Applications	Telephones		901
	Television		4,745
	Headup Displays		982
	Touch Pad Dislays		1,282
	Cameras		514

Figure 4: Taxonomy

Publication trend

The number of patents/patent applications published in MEMS-based display technology has increased constantly every year between 1996 and 2006. 2033 patents/patent applications were published in the year 2006 alone.

The dip after 2015 is mainly because many of the applications filed haven't been published yet. It is safe to assume that the technology is still continuing on its positive growth trend and the number of publications of patents/patent applications in the year 2022 might cross the 3,000 mark.

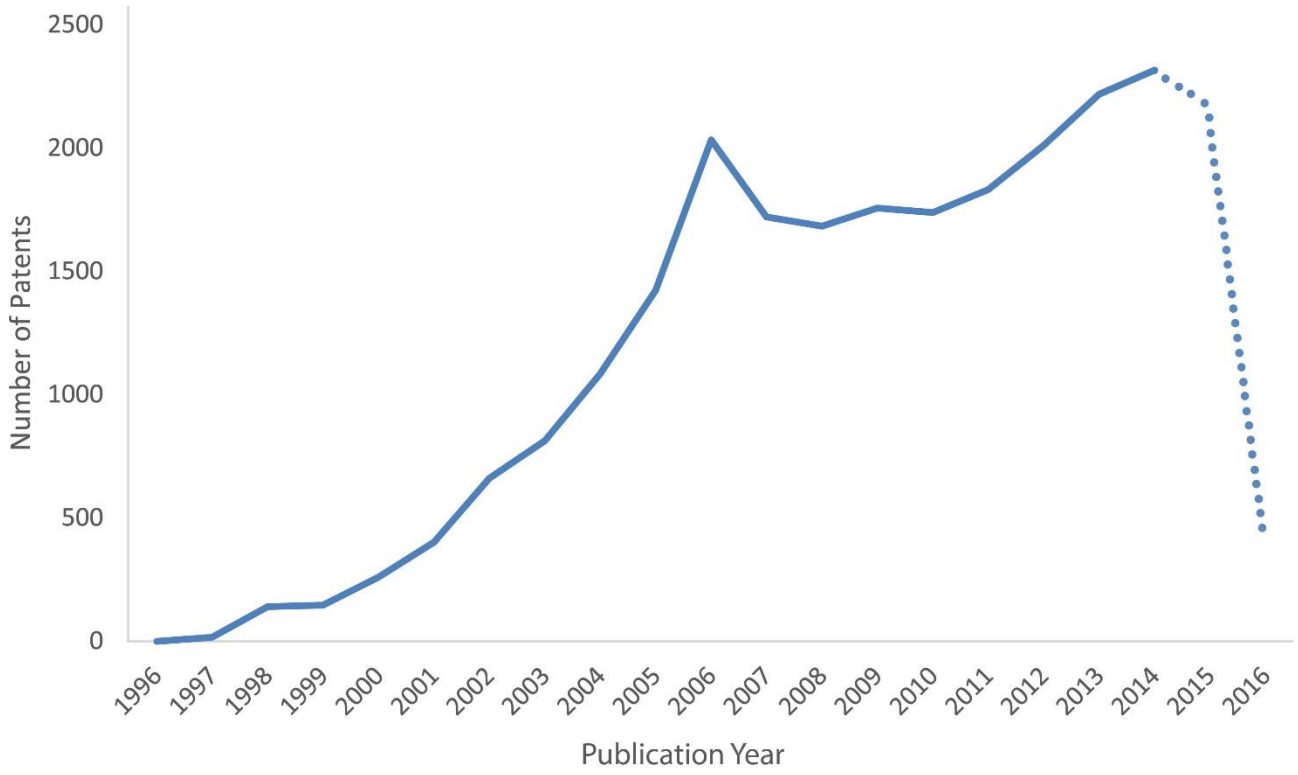

Figure 5: Publication Trend

Top Assignees

The following figure shows the top assignees in the field of MEMS-based display technologies. The bubble size represents the size of each assignee's portfolio. Qualcomm has the biggest patent portfolio with 4179 patents/patent applications. After acquiring Iridigm in 2004, Qualcomm has adapted MEMS based IMOD displays as the prime focus of their display technology research. After Qualcomm, IDC has the second highest number of patents with 756 filings. Texas Instruments also has a considerable number of patents majorly in the DMD technology sphere. Even Non practicing entities such as Intellectual Ventures and Silverbrook possess a significant number of patents in this technology domain.

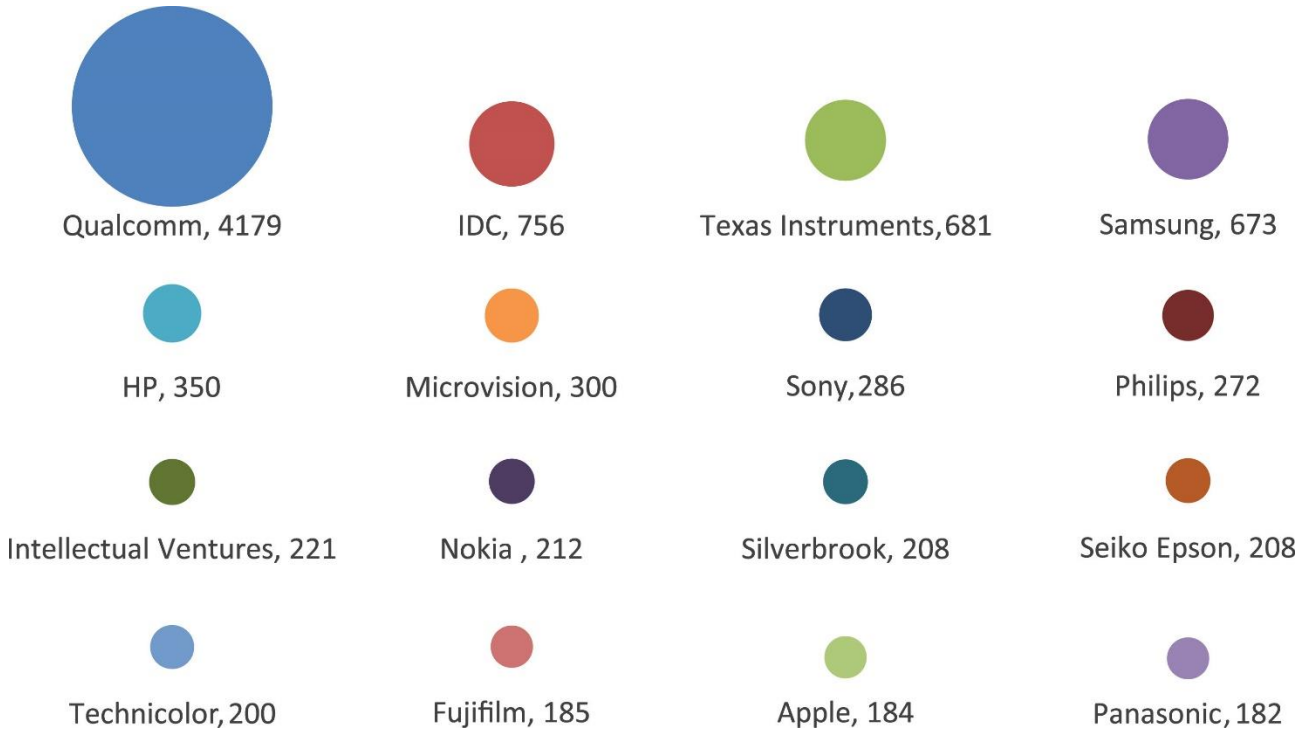

Figure 6: Top Assignees

Geographical Coverage

Geographically, the maximum number of patents/patent applications relating to MEMS-based display technology are filed in USA compared to any other jurisdictions. 9,406 patents/patent applications have been filed with the US Patent office since 1996. This is mostly because some of the major companies like Qualcomm and UniPixel are based in USA. After USA, Japan has the highest number of filings with 3308 patents/patent applications. China and South Korea also have also a high number of patent filings with 2400 and 1995 patents/patent applications respectively. This can be attributed to the fact that electronic giants like Samsung and Sony, which have now observed the advantages of MEMS-based display systems, are based in Asia.

Qualcomm and Texas Instruments lead the patent filings in US. Qualcomm is also leading in China and is being closely followed by Microsoft and Samsung.

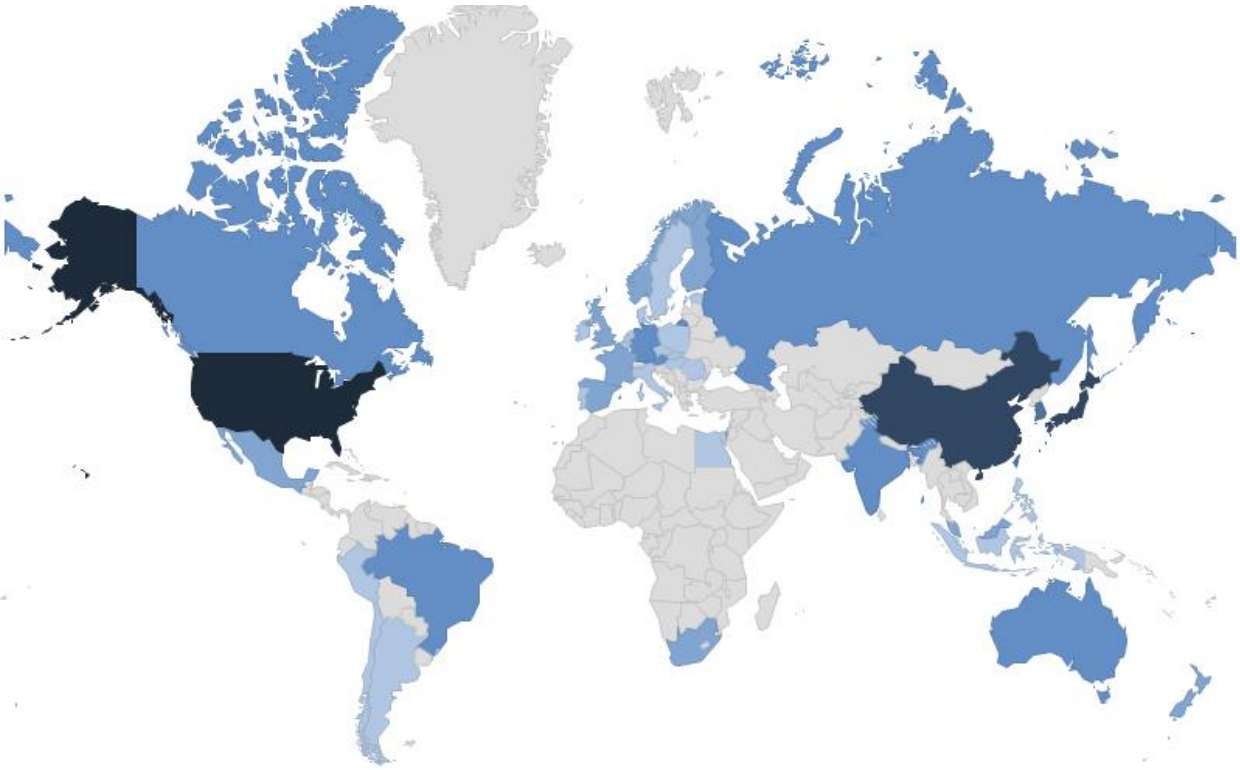

Figure 7: Geographical Coverage

Patent Strength

The patents in our report are ranked automatically by our tool that relies on an algorithm developed by *Mark A. Lemley, Kimberly A. Moore, John R. Allison, and R. Derek Trunkey* in their research paper, "Valuable Patents". Historical research has proven that 97% of the litigation-worthy patents in a portfolio are found in the top bracket of patents ranked by using this algorithm.

The figure below shows the classification of high strength patents/patent applications in MEMS displays into multiple domains. Application of MEMS display in Television have the most number of high strength patents. There are 1024 high strength patents under television amounting to 21.58% fo the total patents in this application sector. Cameras have the lowest number of high strength patents, with only 117 patents/patent applications. Telephones have a significant number of high strength patents amounting to 26.19% of the total number. Data Processing in interfaces has the least number of high strength patents with only 14.36% of the total filings.

Level 1	Level 2	Level 3	Number of Patents/Patent Applications
Apparatus	Picture Display Control	Modulation	841
		Picture Charcteristics	707
		Filters	273
	Projecting/Viewing Apparatus	Mirrors	749
		3 Dimensional	582
		Laser	410
		Others	277
	Light Guides	Propagation	622
		Structure/Design	239
Control Systems	Signal Manipulation		933
	Transmission		878
Data Processing	Optical/Electrical		433
	Interfaces		203
	Image		157
	Others		181
Micro-Structural Technology	Flexible Structures		404
	Circuits		485
	Manufacturing		521
	Substrate		552
	Others		87
Applications	Telephones		236
	Television		1024
	Headup Displays		206
	Touch Pad Dislays		224
	Cameras		117

Figure 8: High Strength Patent Taxonomy

Based on our analysis of patent portfolios, the following figure represents the number of high strength patents/patent applications filed by the top companies between1996-2016 globally. Qualcomm is the leader with 1063 high strength patents/patent applications. Microsoft and Texas Instruments also have a large number of high strength patents/patent applications in their portfolio.

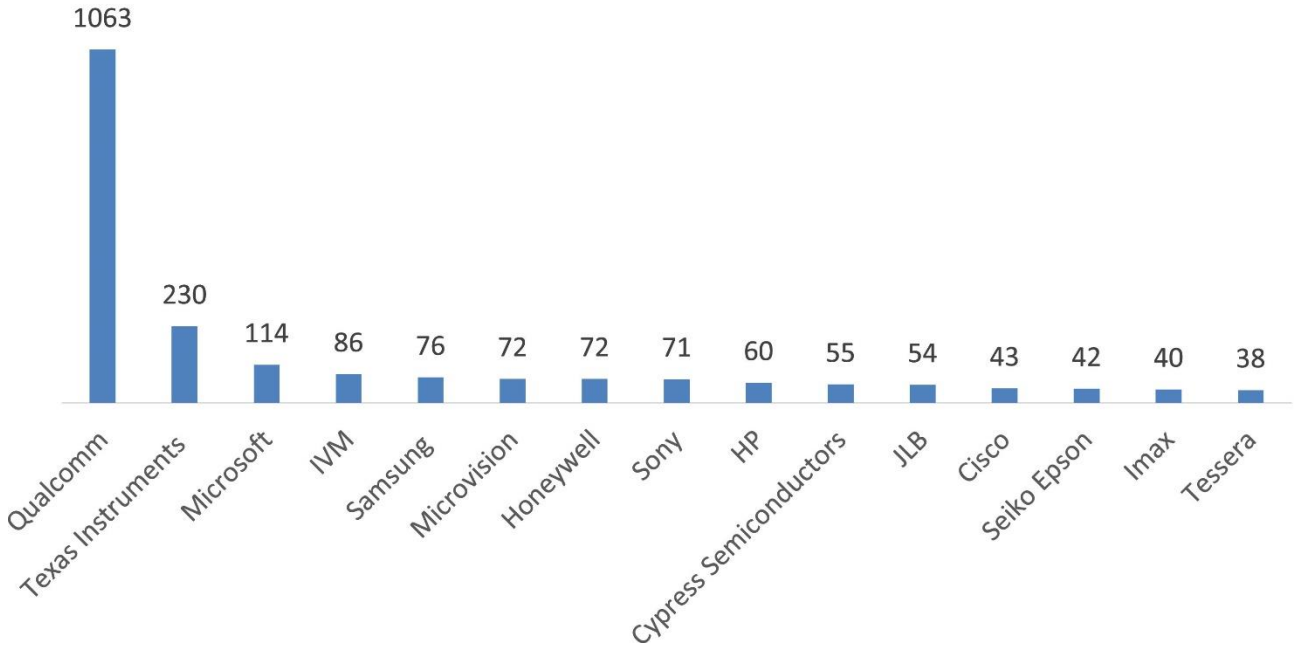

Figure 9: Top Assignees in High Strength Patents

LexScore™

We use LexInnova's proprietary LexScore™ framework to identify MEMS-based Display's intellectual property portfolio strengths and weaknesses. The figure below depicts the competitive standing of the top 15 assignees in this domain. The assignees are compared on the basis of patent strength, average lifetime and the number of patents in their portfolio.

We use our proprietary algorithm (based on bibliographic information and claim characteristics of an invention) to calculate the quality of inventions. The diameter of the circles represent the relative number of filings of patents/patent applications of each company. Qualcomm seems to have a balanced portfolio with good average patent strength and a high average lifetime. Texas Instruments, in spite of having a comparitively smaller portfolio has a high average patent strength. Apple, being one of the new entrants into the technology sphere has the highest average lifetime.

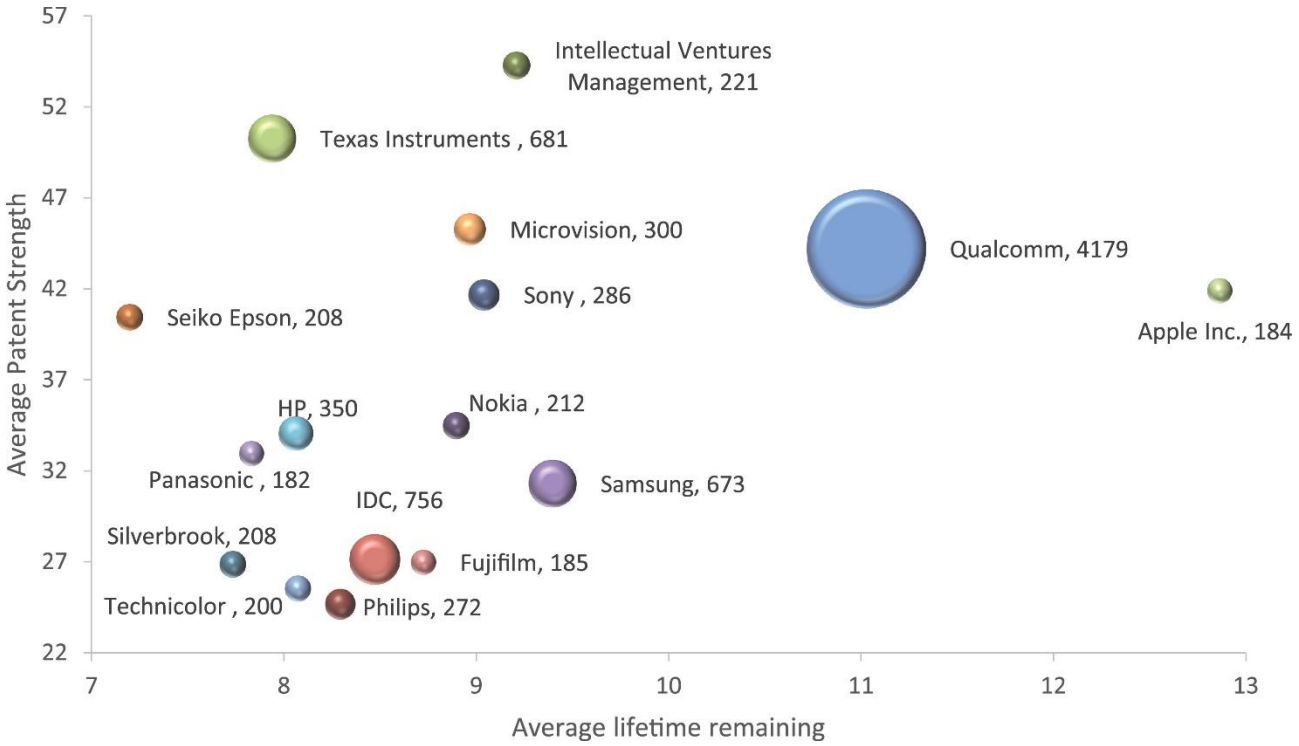

Figure 10: LexScore™

Licensing Heat Map

We use LexInnova's Licensing Heat Map framework to identify sub-domains in the field of MEMS-Based Display where licensing activity is expected to be high. The size of the sections (representing different technology domains) in the Heat Map indicates the number of patents/patent applications filed in that domain. The size in other words represents the relative importance of each sub-domain, while the color represents the likelihood of future licensing activity in that domain. We study the patent holding patterns to color code the technology sub-domain for future licensing activity.

In this heat map, Red (and shades thereof) signifies a high chance of licensing activity in a certain subdomain, whereas Green (and shades thereof) represents a low chance of licensing activity in the subdomain. We follow 80-20 rule to decide the colors, where Yellow is assigned to the domains that lie on the average median, i.e. 20% assignees having 80% of the patents/patent applications. The color drifts towards shades of Red if 20% assignees possess less than 80% of the patents/patent applications, while it drifts towards shades of green in the opposite case.

According to our analysis, Propagation, Substrate, and interfaces are the sub domains which have the highest possibility of licensing activity. Signal Manipulation, Modulation and Television are the sub domains which represent a relatively low chance of licensing.

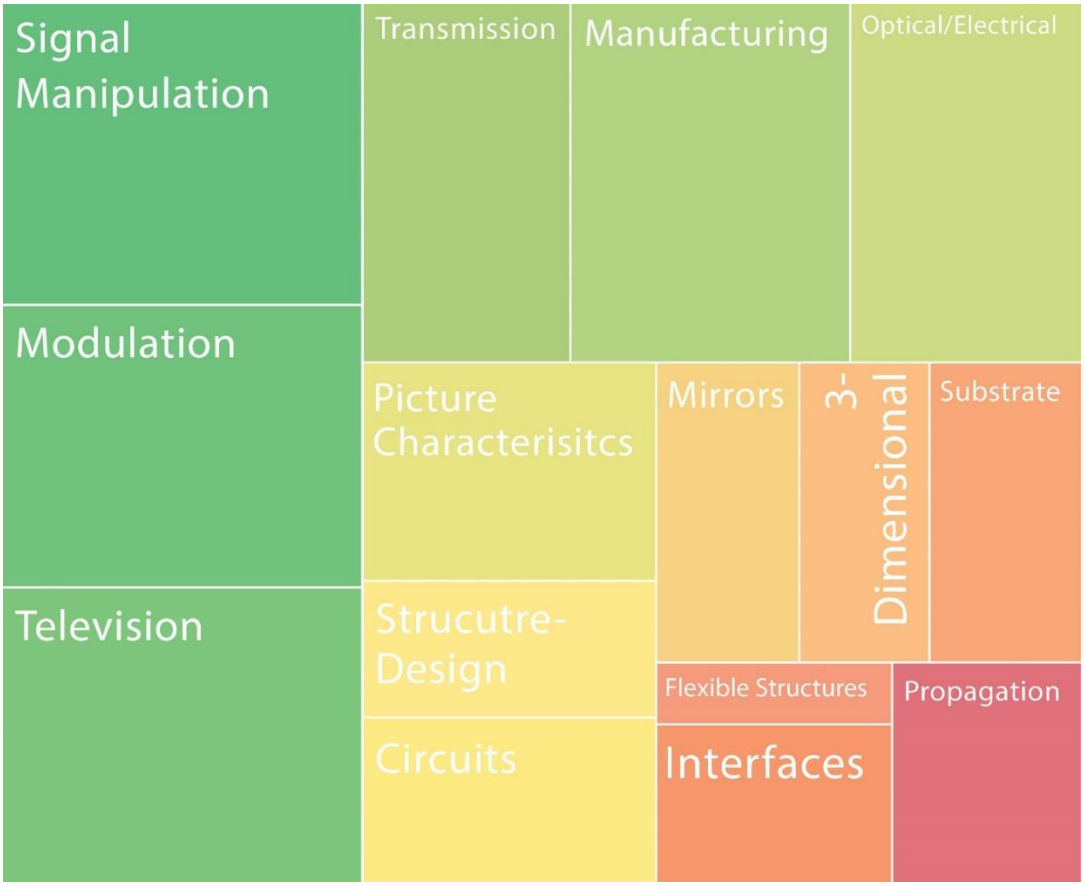

Figure 11: Licensing Heat Map

Products

Qualcomm Toq

Qualcomm Toq was released in December 2013. It features a 1.55" Mirasol display. This was a reference - demonstration of its impressive mirasol display and smart watch than a valued customer product. It has been critically acclaimed for energy efficiency and its quick refresh rate. This product put mirasol in the market as a compelling display technology. [10]

Figure 12: Qualcomm's Toq[11]

Texas Instruments' DLP 4K UHD Chip

TI recently announced its 0.67 inch Ultra HD Chip based on their acclaimed DLP Technology. DLP technology, which employs DMD chips, has provided high quality and resolution display systems over the years. 4k UHD chip employs a faster DMD chip with micro mirrors which can switch 9000 times a second. Also, due to the faster switching rates the chip can deliver 8 million pixels to a screen of 4 million. This results in two distinct and unique pixels per frame delivering 4k resolution.[12]

Figure 13: TI's DLP 4K UHD Chip[13]

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[10] TechWonda. Retrieved from http://techwonda.com/qualcomm-toq-smartwatch-speech-recognition/

[11] Qualcomm Toq Propose Improved Battery life Along With Bright light. (2013). Retrieved fromhttp://techclones.com/2013/10/02/qualcomm-toq-propose-improved-battery-life-along-bright-light-2/

[12] News Releases.. Retrieved from http://newscenter.ti.com/2016-01-06-TI-unveils-DLP-0-67-inch-4K-ultra-high-definition-UHD-chip-enabling-more-affordable-large-screen-projection-displays-for-home-business-and-education

[13] TI DLP Cinema® products.. Retrieved from http://www.ti.com/lsds/ti/dlp-technology/products/dlp-cinema/dlp-cinema-overview.page

Sharp MEMS

Sharp has introduced a MEMS display in partnership with Qualcomm subsidiary Pixtronix, which is reported to be commercialized in 2017. The display can be switched between a high brightness mode for showing pictures and text under sunlight and grey-scale monochrome mode for low power consumption. The display has been dubbed MEMS-IGZO, since it is a fusion of MEMS and IGZO display technologies. The display employs an IGZO backplane to drive the MEMS that is a significant application of IGZO oxide semiconductor[14].

Figure 14: Sharp MEMS Display[15]

Kyobo E-reader

Kyobo E-Reader was released in 2011 featuring a Mirasol display. Employing Mirasol Display, the battery life has been extended to weeks. It's powered by a 1GHz Qualcomm Snapdragon processor and a 5.7-inch color touchscreen display that runs at a resolution of 1024×768. [16]

Figure 15: Kyobo E-Reader[17]

[14] Sharp readying MEMS display for 2017 launch. . Retrieved fromhttps://www.semiconportal.com/en/archive/news/main-news/140917-sharp-mems-dsiplay.html

[15] Sharp's rich colored, LCD-challenging MEMS display coming in 2015. Retrieved fromhttp://www.pcworld.com/article/2692034/sharps-lcdchallenging-mems-display-coming-in-2015.html

[16] Kyobo 6-inch eReader goes on sale with Mirasol color e-paper display | Chips | Geek.com. (n.d.). Retrieved fromhttp://www.geek.com/chips/kyobo-6-inch-ereader-goes-on-sale-with-mirasol-color-e-paper-display-1443359/

[17] Qualcomm's Mirasol Display Tech Ships In Kyobo E-reader. Retrieved fromhttp://hothardware.com/news/qualcomms-mirasol-display-tech-ships-in-kyobo-ereader

Appendix: Taxonomy Definitions

S.No	Taxonomy Head	Definition
1	Modulation	Modulation is a category under picture display control. We have included all the patents which use modulation techniques among others for picture display control. Major Classes included in this head are G02B02600000 and G02B00635000.
2	Picture Characteristics	Picture Characteristics is one of the further classifications of picture display control. We have included all the patents which reveal apparatus to control picture characteristics. Major classes included in this head are G02B02602000 andG02F00113350.
3	Filters	Filters is a subhead under picture display control. We have included all the patents which reveal filter like apparatus for picture display control. Major classes included in this are G02F00121000 and G01J00326000.
4	Mirrors/Lenses	It is a subhead under projecting/viewing Arrangements. Patent which reveal mirrors/lens like apparatus for projecting/viewing applications have been included in this head. G02B02718000 and G03B02128000 are the major IPC classes in this head.
5	3 Dimensional	It is a subhead under projecting/viewing arrangements. Patent which reveal apparatus for 3 dimensional projecting/viewing applications have been included in this head. G02B02722000 and G02B00532000 are the major IPC classes in this head.
6	Laser	It is a subhead under projecting/viewing arrangements. Patent which reveal apparatus which use laser for projecting/viewing applications have been included in this head. G02B02748000 and H01S00300000 are the major IPC classes under this head
7	Propagation	Propagation is a subhead under light guides. Propagation includes patents which reveal techniques of propagation in light guides have been included in this head. Major IPC classes are G02B02608000 and G02B02709000.

8	Structure/Design	Propagation is a subhead under light guides. Patents which reveal techniques of structure/design of light guides have been included in this head. Major IPC classes are G02B00600000 and G02B00642000.
9	Signal Manipulation	Signal manipulation is a subhead under control systems. Patents which reveal techniques of controlling and monitoring signal manipulation have been included under this head. Major IPC classes are G09G00334000 and G09G00500000
10	Transmission	Transmission is a subhead under control systems. Patents which discuss about controlling and monitoring transmission of output signal have been included under this head. IPC classes like G09G00320000 and G09G00336000 have been included under this head.
11	Optical/Electrical	It is a subhead under digital processing. This head includes patents which reveal digital processing of optical or electrical entities. Major classes are G06F00304200 and G06F00116000.
12	Interfaces	It is a subhead under digital processing. This head includes patents which reveal digital processing application in interfaces. G06F00301000 and G06F00303300 are the major IPC classes included.
13	Image	It is a subhead under digital processing. This head includes patents which reveal digital processing of images. Major classes are G06T00100000 and G06T01900000.
14	Flexible Structures	It is a subhead under micro-structural technology. Patent including flexible parts made by micro-structural engineering have been included in this head. Major IPC classes are B81B00300000 and G09F00937000.
15	Circuits	It is a subhead under micro-structural technology. Patent including circuits made up by micro-structural engineering elements have been included in this head. B81B00702000 and G02B00612000 are the major IPC classes.

16	Manufacturing/Design	Patents including techniques for manufacturing/design of micro-structural elements have been included in this head. Classes like H01L02100000 and G03F00720000 have been included in this head.
17	Substrate	Patents analyzing substrate technology have been included in this head. Major IPC classes are B81C00100000 and H01L03300000.
18	Telephones	Telephones is a subhead under applications. Patents which include applications of MEMS-based display systems in telephones have been included in this head. Major IPC classes are H04M00172500 and H04M00100000.
19	Television	It is a subhead under applications. Patents which include applications of MEMS-based display systems in televisions have been included in this head. Major IPC classes are H04N00574000 and H04N00931000.
20	Head-up Displays	It is a subhead under applications. Patents which include applications of MEMS-based display systems in head-up displays have been included in this head. Major IPC classes are G02B02701000 and B60R01102000.
21	Touch Pad Screens	It is a sub-head under applications. Patents which include applications of MEMS-based display systems in specifically in touch pad screens have been included in this head. G06F00304100 and G02B02702000 are the major IPC classes.
22	Cameras	It is a subhead under applications. Patents which include applications of MEMS-based display systems in camera displays have been included in this head. H04N00522500 is the major IPC class in this head.

Table 1: Taxonomy Definitions

IS 607655

FS 614196

ABOUT US:

LEXINNOVA TECHNOLOGIES LLC DRAWS ON A COMBINATION OF TECHNICAL AND LITIGATION EXPERTISE TO SOLVE THE CHALLENGES THAT ARISE AT THE INTERSECTION OF TECHNOLOGY AND THE LAW.

OUR CREDENTIALS:

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