From Technologies to Market

MicroLED Displays Intellectual Property Landscape

SAMPLE

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Report

Picture: Vuereal

TABLE OF CONTENTS

- About the Authors 8
- Acronyms 9
- Objectives And Key Features Of The Report 10
- Scope Of the Report 12
- Methodology and Terminology 13
  - Terminologies For Patent analysis
  - Methodology
  - Patent Corpus
  - Additional Researches
  - Definitions: Key Patents
  - Strength and Blocking Potential Of Patent Portfolio
- Executive Summary 28
  - The Three Page Summary
  - Time Evolution Of Patent Publications
  - What happened in 2017?
  - Leading Patent Applicants
  - Time Evolution Of Patent Applications
  - Time Evolution Of Patent Applications Per Company
  - Time Evolution Of Patent Applications Per company Types
  - Breakdown by Company Types
  - Most Active Companies by Type
  - Breakdown By Company Headquarter
  - Positioning of Established Panel Makers
  - MicroLED Display Manufacturing Challenges
  - Remaining Roadblocks
  - Overview of Patent Families Per Technology Node
  - Portfolio Technology Segmentation Per Company (top 25)
- Introduction to microLED Displays 48
  - LEDs In displays
  - MicroLED Definition and History
  - MicroLED Displays Technology Evolution
  - Significant Industry Events
  - What is a MicroLED display?
  - MicroLED Display Assembly
  - MicroLED Chip Manufacturing
  - Display Structure and Backplane
  - Comparisons With LCD and OLED
  - MicroLED SWOT Analysis
  - MicroLED Display Manufacturing Challenges
  - Remaining Roadblocks
  - Major Manufacturing Technology Bricks
  - Status
  - MicroLED Application Roadmap
  - Supply Chain

TABLE OF CONTENTS

- MicroLED IP Landscape: Overview 69
  - Time Evolution of Patent Applications
  - Time Evolution Of Patent Publications
  - Leading Patent Applicants
  - Remaining Applicants
  - Number of patents and current legal status
  - Time Evolution Of Patent Applications
  - Average Age of Patent Portfolio
  - Time Evolution Of Patent Applications
  - Breakdown by Company Types
  - Start Up Companies
  - Time Evolution Of Patent Applications Per company Types
  - OEM And Consumer Electronics Companies
  - Display Makers
  - Positioning of Established Panel Makers
  - LED Makers
  - Research Institutions
  - Others
  - Breakdown By Company Headquarter
  - Technology Segmentation
  - Overview of Patent Families Per Technology Node
- Company Analysis 98
  - Introduction
  - Time Evolution Of Patent Applications
  - Time Evolution Of Patent Applications Per Company
  - Portfolio Technology Segmentation Per Company
  - Detailed Breakdown
  - Apple- Luxvue (US)
  - X-Celeprint (UK)
  - Oculus/InfiniLED/mLED (US)
  - Oculus/InfiniLED/mLED (US)
  - Industrial Technology Research Institute (TW)
  - China Star OptoElectronics Technology – (CN)
  - Mikro-Mesa (TW)
  - Sharp/Elux (JP-TW)
  - Goertek (CN)
  - SONY (JP)
  - Sony (JP)
  - AU Optronics (TW)
  - BOE Display Technology (CN)
  - Samsung (Korea)
  - Playnitride (TW)
  - Intel (US)
  - Collaboration Network

TABLE OF CONTENTS

- Pixel & Display Architectures, Driving 127
  - Introduction
  - Ranking by Number Of Patent Family
  - Patent Portfolio Strength Index
  - Average Strength Index vs Number of Family
  - Ranking By Strength Index of The Patent Portfolio
  - Singular Patent: MIT
  - Patent Portfolio Strength Index
  - Apple-Luxvue
  - Other Players
  - Sony
  - Nano & Advanced Materials Institute
  - ITRI
  - IP Blocking Potential
  - Conclusions
- Transfer & Interconnect 146
  - Introduction
  - Pick And Place Processes
  - Fluidic Self Assembly
  - Summary
  - Ranking By Number of Patent Families
  - Patent Portfolio Strength Index
  - Average Strength Index vs Number of Family
  - Ranking By Strength Index of The Patent Portfolio
  - X-Celeprint (UK)– University of Illinois (US)
  - Apple Luxvue (US)
  - LuxVue Transfer Process Sequence
  - Sony (JP)
  - Sharp/ELUX (JP) CM
  - PSI Corp. (KR)
  - Mikro Mesa (TW)
  - Goertek (CN)
  - BOE Technology (CN)
  - CSOT (CN)
  - LG Electronics (KR)
  - GLO AB (SW)
  - Vuereal (CA)
  - Playnitride (TW)
  - AU Optronics (TW)
  - Industrial Technology Research Institute
  - Intel
  - Summary
  - IP Blocking Potential
  - Other Microchip Transfer Patents: Timeline
  - Other Microchip Transfer Patents: Key players

TABLE OF CONTENTS

- Monolithic Structures
- Monolithic Integration of LTPS TFT
- Monolithic Integration of Metal Oxide TFT
- Monolithic Integration of GaN TFT
- Hybridized Structures
- MicroLED Array Hybridization on CMOS

- Chip Structure And Manufacturing 201
  - Overview
  - MicroLED efficiency
  - Ranking By Number of Patent Families
  - Patent Portfolio Strength Index
  - Average Strength Index vs Number of Family
  - Ranking By Strength Index of The Patent Portfolio
  - 3D Integration
  - Sony
  - Apple Luxvue
  - Current confinement Trenches
  - Reduction of Sidewall Defects
  - Mikro Mesa
  - X-Celeprint
  - Facebook/Oculus
  - Others
  - IP Blocking Potential
  - Conclusions

- Light Extraction and Management 225
  - Introduction
  - Viewing Angle and Power consumption
  - Ranking By Number of Patent Families
  - Illustration: InfiniLED
  - Patent Portfolio Strength Index
  - Average Strength Index vs Number of Family
  - Ranking By Strength Index of The Patent Portfolio
  - Apple/Luxvue
  - Industrial Technology Research Institute
  - IP Blocking Potential

- Color Generation, Conversion and Management 244
  - Introduction
  - Wavelength Converter Deposition
  - Ranking by Number Of Patent families
  - CSOT
  - Seoul Semiconductor
  - mLED
  - Patent Portfolio Strength Index

TABLE OF CONTENTS

- Patent Portfolio Strength Index
- Average Strength Index vs Number of Family
- Ranking By Strength Index of The Patent Portfolio
- Apple/Luxvue
- Hiphoton/Aledia
- Others: Osram, Verlase.
- IP Blocking Potential
- Conclusion

- **Epitaxy** 262
  - Overview
  - Wavelength homogeneity and Consistency
  - Ranking by Number Of Patent families
  - Intel
  - Sun Yat-Sen University
  - NanoWires
  - Patent Portfolio Strength Index
  - Average Strength Index vs Number of Family
  - Ranking By Strength Index of The Patent Portfolio
  - IP Blocking Potential
- **Defect Management & Repair** 277
  - Introduction
  - Bad Pixels
  - Defect Management Strategies
  - Ranking By Number Of Patent Families
  - X-Celeprint
  - Patent Portfolio Strength Index
  - Average Strength Index vs Number of Family
  - Ranking By Strength Index of The Patent Portfolio
  - Example of Repair Strategies
  - Apple/Luxvue
  - Facebook/Oculus
  - Other repair strategies
  - Mikro Mesa
  - Sharp/eLUX
  - Goertek
  - IP Blocking Potential
- **Testing** 299
  - Introduction
  - Ranking By Number Of Patent Families
  - Testing
  - Mikro Mesa
  - Vuereal
  - Patent Portfolio Strength Index

TABLE OF CONTENTS

- Integration of Sensor or Other Functions 307
  - Introduction
  - Ranking By Number Of Patent Families
  - X-Celeprint
  - Apple Luxvue
  - Others
  - Patent Portfolio Strength Index
  - Kansas State University (KSU)
  - IP Blocking Potential

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OBJECTIVES AND KEY FEATURES OF THE REPORT

This report provides a detailed analysis of the microLED display intellectual property landscape: Identify key patents, understand the key technology nodes, identify the key players.

- Time evolution of patents filings and countries of patent filing.
- Which technology nodes are generating the most activity (chip design, transfer, defect management etc.)
- Detailed overview of key patents for each technology nodes
- Which organizations are filing patents in microLED displays?
  - Types of companies (display makers, consumer electronic OEMs, startups, research institutions..)
  - Geographic areas by headquarters
  - Which technology node(s) are they focusing on?
  - Which companies are missing? Why ?
- Detailed analysis of key companies portfolio (Apple, Samsung, LG, BOE, Mikro Mesa, Playnitride, ITRI…)
  - Scope of their portfolio by technology node.
  - Strength, relevance.
- Identify IP collaborations networks between players
- Overview of important "peripheral" patents: technologies non specific to microLED displays but important for the field. For examples:
  - Micro/nano LED wires / columnar LEDs.
  - Mass micro-chip transfer

OBJECTIVES AND KEY FEATURES OF THE REPORT

- **The report also provides an extensive Excel database with all patents analyzed in the report.**

- **This database allows multi-criteria searches:**

  Patent information

  - Patent publication number
  - Hyperlinks to the original documents
  - Priority date
  - Title
  - Abstract
  - Patent Assignees
  - Segmentation
  - Legal status for each member of the patent family

- **This report does not provide** any insight analyses or counsel regarding legal aspects or the validity of any individual patent: KnowMade and Yole Developpement are research firms that provide market and technical analysis and opinions. The research, technical analysis and/or work contained herein is not a legal opinion and should not be construed as such.

SCOPE OF THE REPORT

This report provides a detailed review of the µLED display intellectual property landscape as of December 2017

The report does <u>not</u> cover non-display applications of µLED: AC-LEDs, LiFi, Optogenetics, Lithography, lighting…

METHODOLOGY

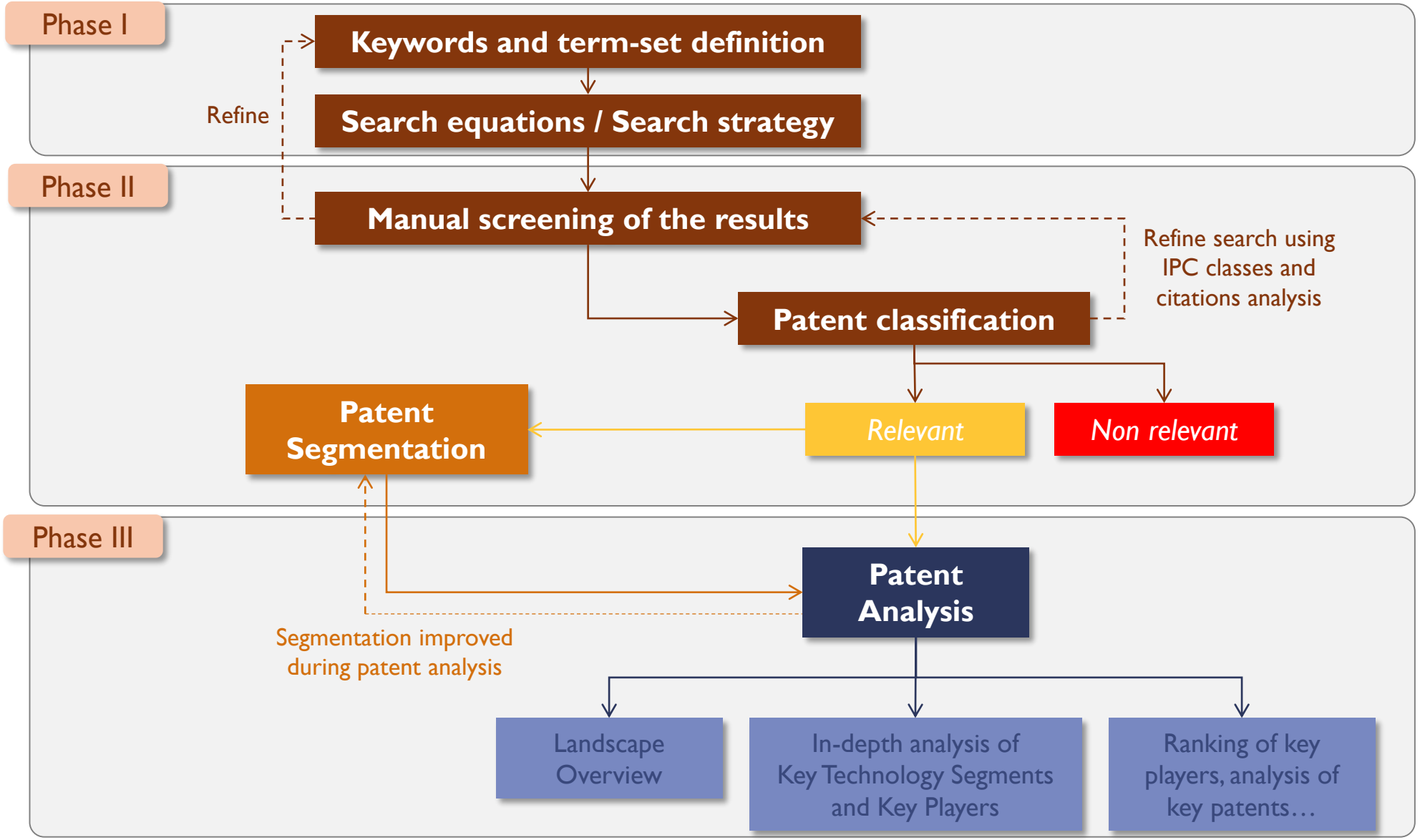
- The data are extracted from the FamPat worldwide database (Questel-ORBIT) which provides 100+ million patent documents from 95 offices.
- The search for patents was completed in November 2017, hence patents published after this date are not available in this report.
- The patents are grouped by patent family. A patent family is a set of patents filed in multiple countries to protect a single invention by a common inventor(s). A first application is made in one country – the priority country – and is then extended to other countries.
- The selection of the patents is performed both automatically and manually (next page)

Number of selected patents related to MicroLED displays:

XXXX patents and patent applications grouped in XXXX patent families

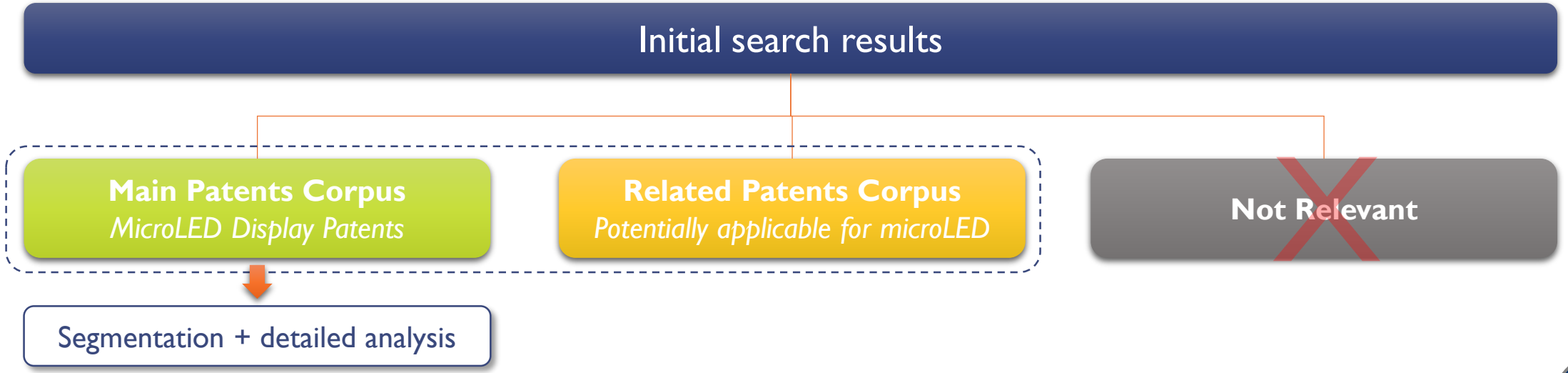
- The statistical analysis is performed with Orbit IP Business Intelligence web based patent analysis software from Questel.
- The patents are manually categorized in technical segments by manual analysis of each patent title, abstract, descriptions, illustrations and claims, in conjunction with expert review of the subject-matter of inventions.
- For legal status of European (EP) and PCT (WO) patent applications, EPO Register Plus is used. For legal status of US patents, USPTO PAIR has been used. For legal status of other patents, information is obtained from their respective national registers.

METHODOLOGY



PATENT CORPUS

- Large quantities of patents describe technologies that could be used for microLED displays but were not developed specifically for this application. Unless specified, in order to keep the focus on microLED-specific technologies and innovations, those are not included in the main corpus analyzed in this report. However, some of the most relevant are included in the "Related Patents" corpus and discussed separately when pertinent.
- An increasing number of patents include microLEDs among a list of display technologies that can be used in a device that is the object of the invention. For example, patents describing a head mounted device for augmented reality using a microdisplay that could be either OLED, LCD, LCOS or microLED. The invention described in those patents doesn't solve a microLED related issue. Those are therefore excluded from both corpuses (main and related) and not discussed in this report.
- The objective behind this segmentation is to ensure that the main corpus analyzed:
  - 1) Accurately represents the increase of activity specifically aimed at solving issues related to the development and manufacturing of microLED displays.
  - 2) Clearly identifies which companies have a strong focus on microLED and which specific problems they are attempting to address.

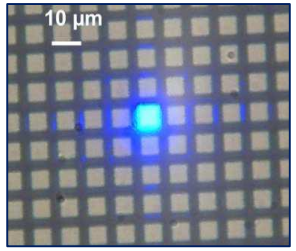


PATENT CORPUS

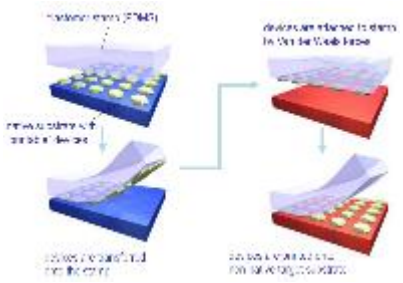
- The main corpus of patents analyzed in this report comprises XXXX patents grouped in XXXX families that focus on inventions explicitly related to the use of microLED in display applications.
- Our selection of "related patents" comprises 55 families and includes patent that don't explicitly mention microLED displays but are considered pertinent to the field. Those are not included in the analysis (graphs and tables) but are discussed individually on a per needed basis. More details and examples are given in the following pages.

"Main Patents" Corpus
XXXX Patents / XXXX Families

Patents explicitly related to microsized LEDs (< 50x50 µm²) for display applications: manufacturing, assembly, testing, defect management, microled display architecture and driving, color conversion and management etc.



Source: CEA-LETI

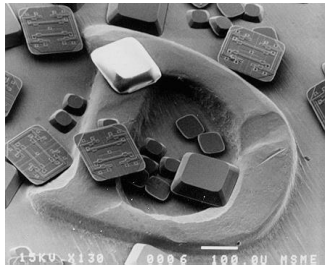


Source: X-Celeprint

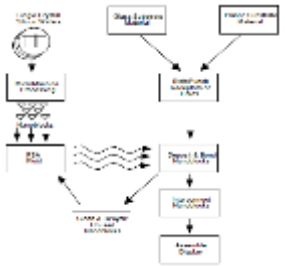
Source: Sony

"Related Patents" Corpus
XXXX Patents / XX Families

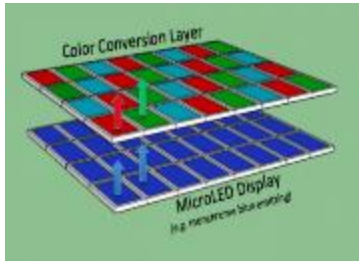
Patents describing technologies non specific but potentially highly pertinent to microLED display manufacturing: microchip massively parallel transfer and assembly, high resolution color conversion schemes, "mini-LED" (<100 x 100 µm²) etc.



Source: Alien Technology



Source: Alien Technology

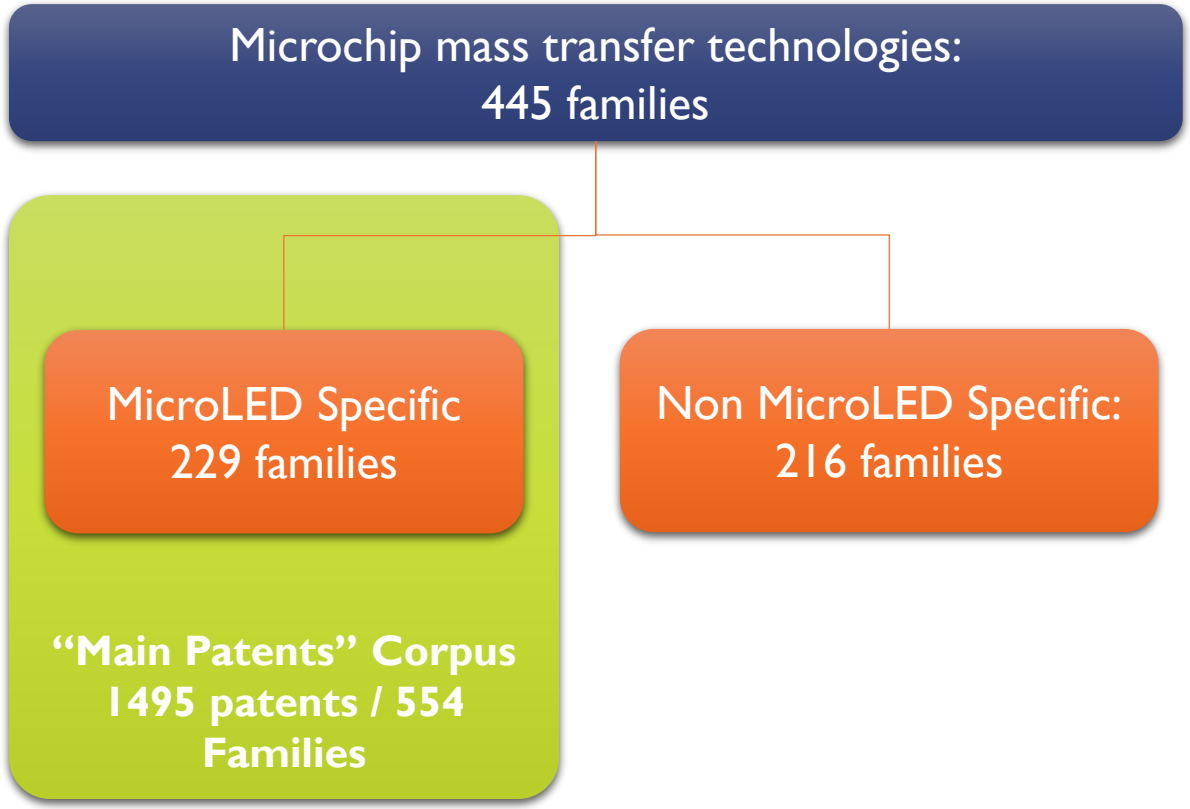


Source: Verlase

ADDITIONAL RESEARCHES

We have organized the patents in 2 corpuses ("Relevant" and "Related") and conducted additional searches on 2 groups of technologies: microchip mass transfer and nanowires.

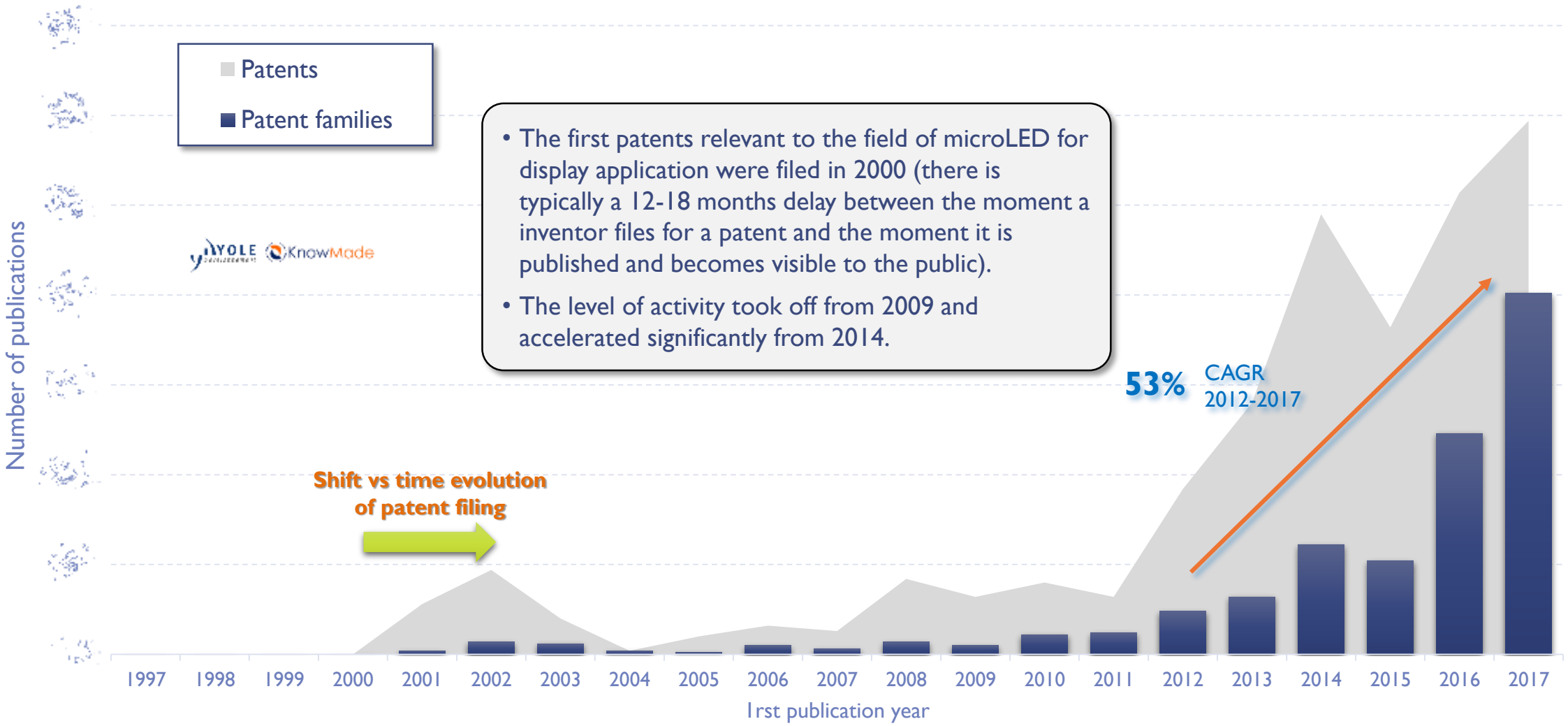
- Due to the importance of mass transfer technologies for microLED displays a dedicated search for this topic was also conducted. It resulted in a corpus of XXX patent families organized in 2 groups:
  - XXX families discussing mass transfer specifically for microLED (included in the "Main Patent" corpus)
  - XXX families non specific to microLED
- Similarly, we conducted a search on nano/micro wire LEDs.



TIME EVOLUTION OF PATENT PUBLICATIONS

Time evolution of patent publications

XXXX patents (XXX patent families*), including XXX granted patents and XXX pending patent applications

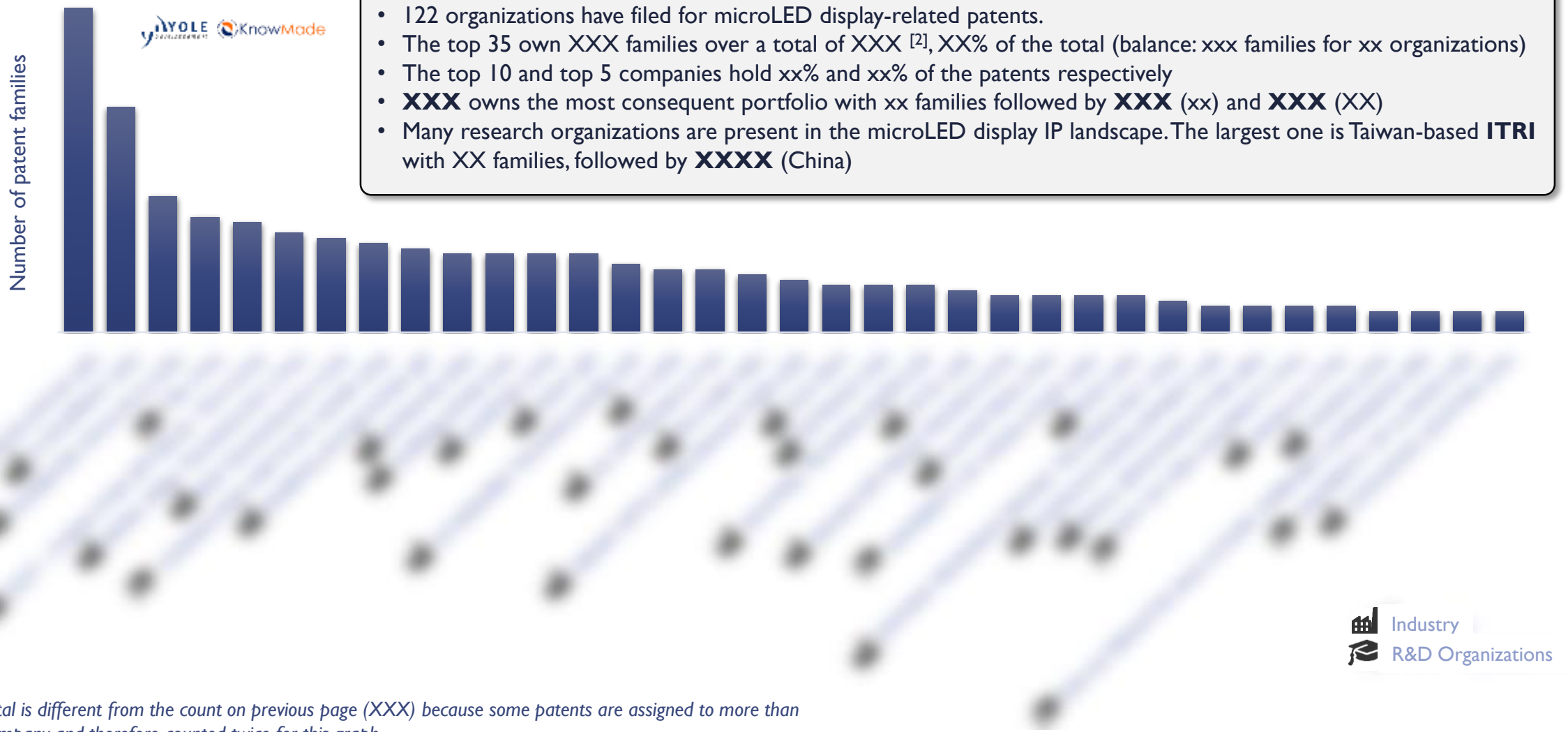


* *A patent family is a set of patents filed in multiple countries by a common inventor(s) to protect a single invention.*

LEADING PATENT APPLICANTS

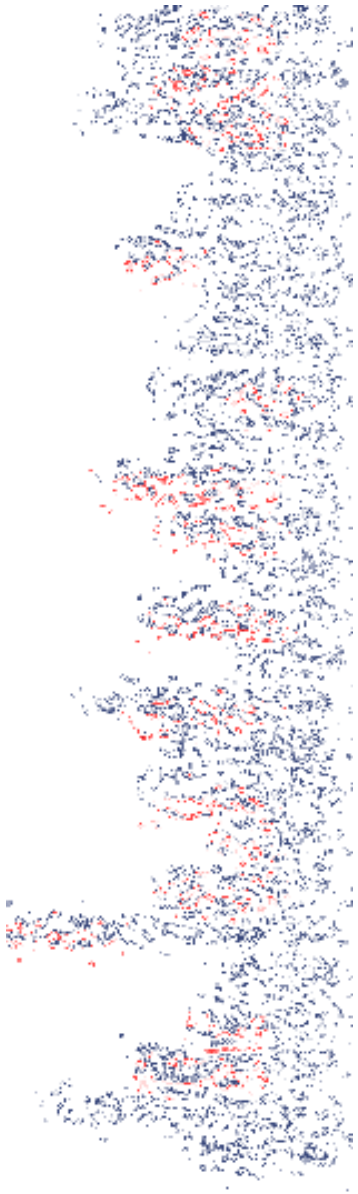
Ranking of patent assignees according to the number of their patent families

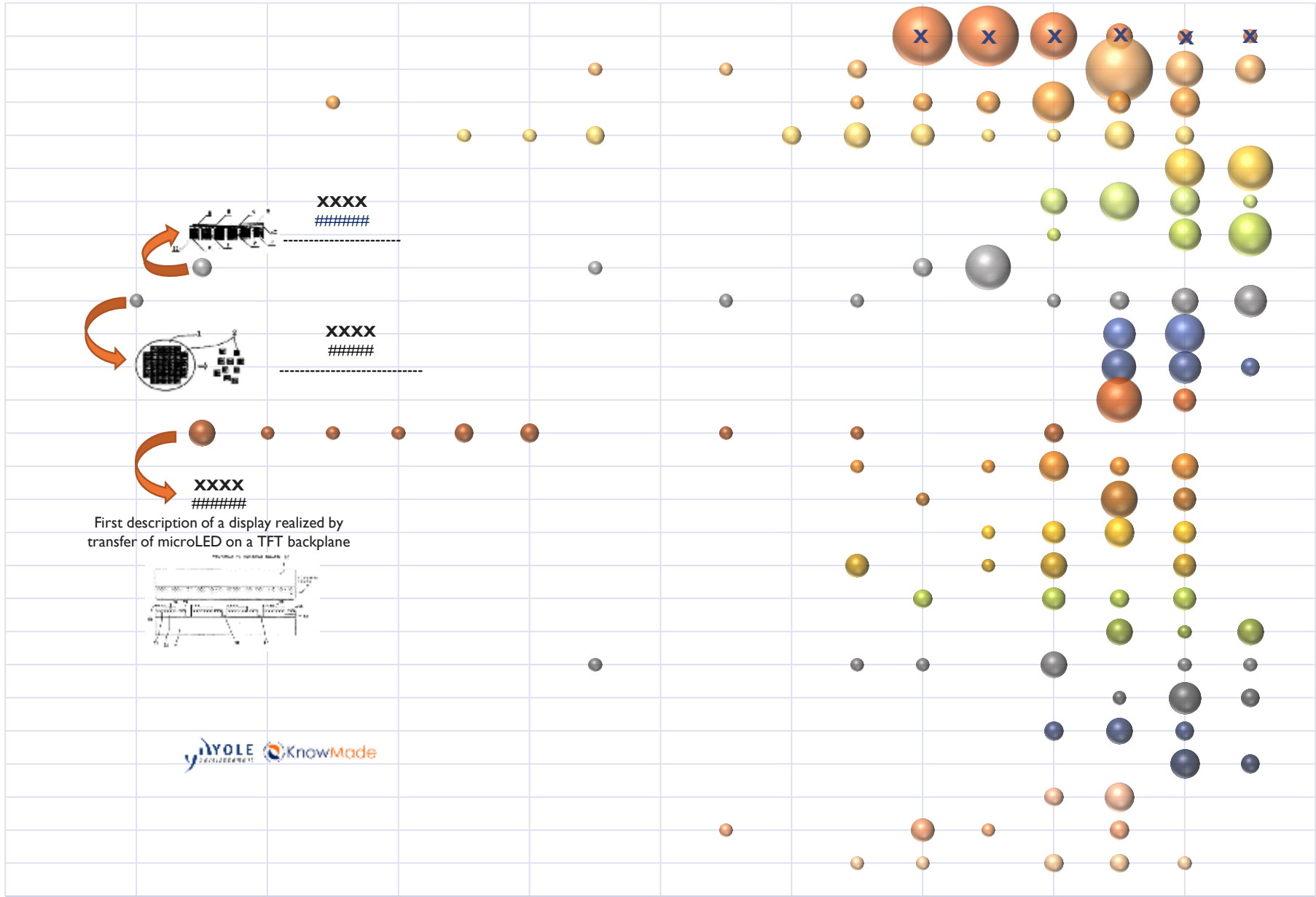
- 122 organizations have filed for microLED display-related patents.
- The top 35 own XXX families over a total of XXX [2], XX% of the total (balance: xxx families for xx organizations)
- The top 10 and top 5 companies hold xx% and xx% of the patents respectively
- **XXX** owns the most consequent portfolio with xx families followed by **XXX** (xx) and **XXX** (XX)
- Many research organizations are present in the microLED display IP landscape. The largest one is Taiwan-based **ITRI** with XX families, followed by **XXXX** (China)



[2]: total is different from the count on previous page (XXX) because some patents are assigned to more than one company and therefore counted twice for this graph.

TIME EVOLUTION OF PATENT APPLICATIONS





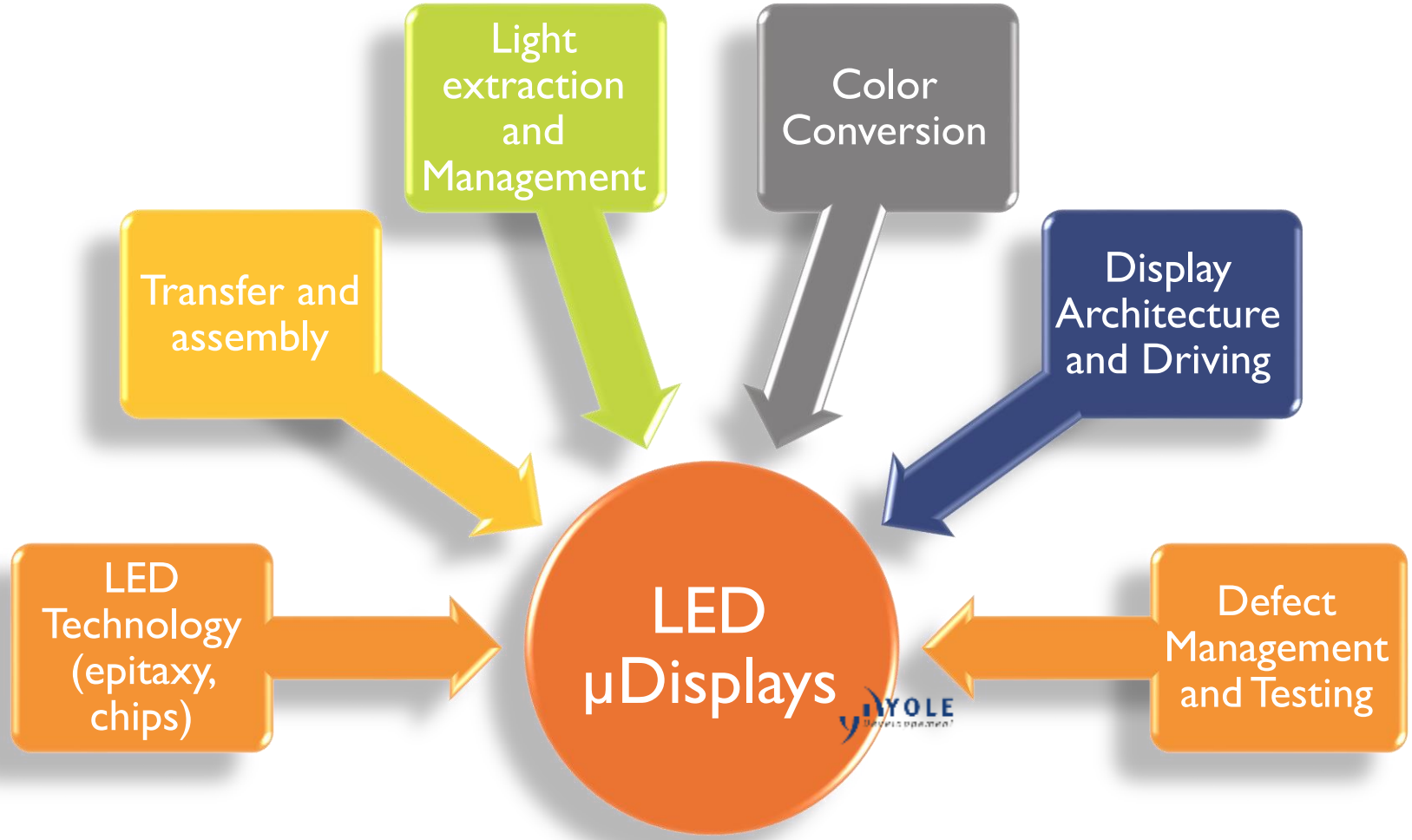
Note: Due to the delay between the filing of patents and the publications by patent offices, usually 12-18 months, we estimate that most of the 2017 filings and up to half of the 2016 filing are not visible as of December 2017.

POSITIONING OF ESTABLISHED PANEL MAKERS

	Korea	Taiwan	China	Japan
Background	Dominates OLED technology and manufacturing (LG in TV, Samsung in smartphones)	Strong position in LCD challenged by the rise of Chinese makers that could trigger overcapacity and price wars. Some OLED technology but no manufacturing capacity	Growing fast. Soon-to-be leader on LCD price, capacity and shipping volumes.	Former LCD display leader. Now fallen behind on capacity and market share. No OLED capacity but some technology (Sony, JOLED, Sharp)
Current Strategy	Phasing out <G8 LCD fabs Massively expanding OLED capacity (up to $24b combined over the next 3-5 years).	No major investment plans. Trying to maintain margins through product mix optimization, yield improvements and high utilization rates. Foxconn might invest in LCD through Sharp (acquired in 2016). Position regarding OLED unclear.	Massive investments in next generation LCD (G10.5). + Massive investment on flexible OLED for smartphone. But technology and manufacturing expertise is ~3-5 years behind Korea	No major investment plan beside Sharp/Foxconn possible new LCD fabs in China and the US. OLED possibly a card to play with JOLED: could be the first solution-printed technology ready for market. But access to capital will be challenging
Interest for microLED	**Defensive**	**Offensive:** Chance to level playing field for next generation display	**Offensive:** Chance to level playing field for next generation display	**Offensive:** Trying to regain former glory with disruptive technology

MICROLED DISPLAY MANUFACTURING CHALLENGES

While very promising in terms of performance, there are still multiple performance and manufacturing challenges that need to be addressed to enable cost effective, high volume manufacturing of high performance µLED Displays. The technology segmentation used to analyze the corpus of patents selected for this report follows the major nodes identified in this breakdown



Multiple challenges need to be tackled to enable the µLED display opportunity

TECHNOLOGY SEGMENTATION

"Main Patents" Corpus
1495 patents / 554 Families

Front End

Epitaxy
Substrates, epitaxy process or equipment specifically aimed at improving the performance, yield, homogeneity of microLED and/or enabling the realization of LED emitters with different wavelength (e.g.: R, G, B) on the same wafer.

Chip design and manufacturing
Structure or manufacturing processes to improve efficiency or other performance of the LED emitter. E.g.: etching techniques to reduce sidewall defects, current confinement layers, aperture to reduce non-radiative surface recombination and improve efficiency of microLEDs, addition of sacrificial layers to reduce kerf losses etc.

Transfer and interconnect
Techniques for microLED chip separation (release layers and mechanisms etc.), die stabilization, transfer from a donor substrate to a backplane and methods to realize the bonding and electrical connections of the chips with the backplane or the PCB.

Monolithic Structures
MicroLED microdisplay structures where full arrays of microLED are assembled directly (hybridization or direct growth) with the backplane (typically Si-CMOS)

Back End

Light extraction and management
Process, structures or components for light extraction, beam shaping, optical cross talk management. Can involve display structure (e.g.: pixel patterns, reflective layers in pixel cavity, black matrix etc.) or external optics as long as they are part of the display structure (e.g.: microlens array built or bonded directly onto the display stack)

Pixel / display architecture, driving
Describes pixel and/or of full display architecture: pixel/subpixel arrangements, pixel cavity, pixel interconnection schemes, electrode configurations, pixel driving etc.). Patents in this category often discuss the architecture but not the method to assemble and manufacture the display (e.g: transfer process, assembly etc.)

Defect Management
Discuss techniques specifically aimed at mitigating or reducing display defects, improving repairability or the repair technique itself. For example: pixel redundancy, electrode arrangement to easily disconnect defective pixels, laser repair strategies etc.

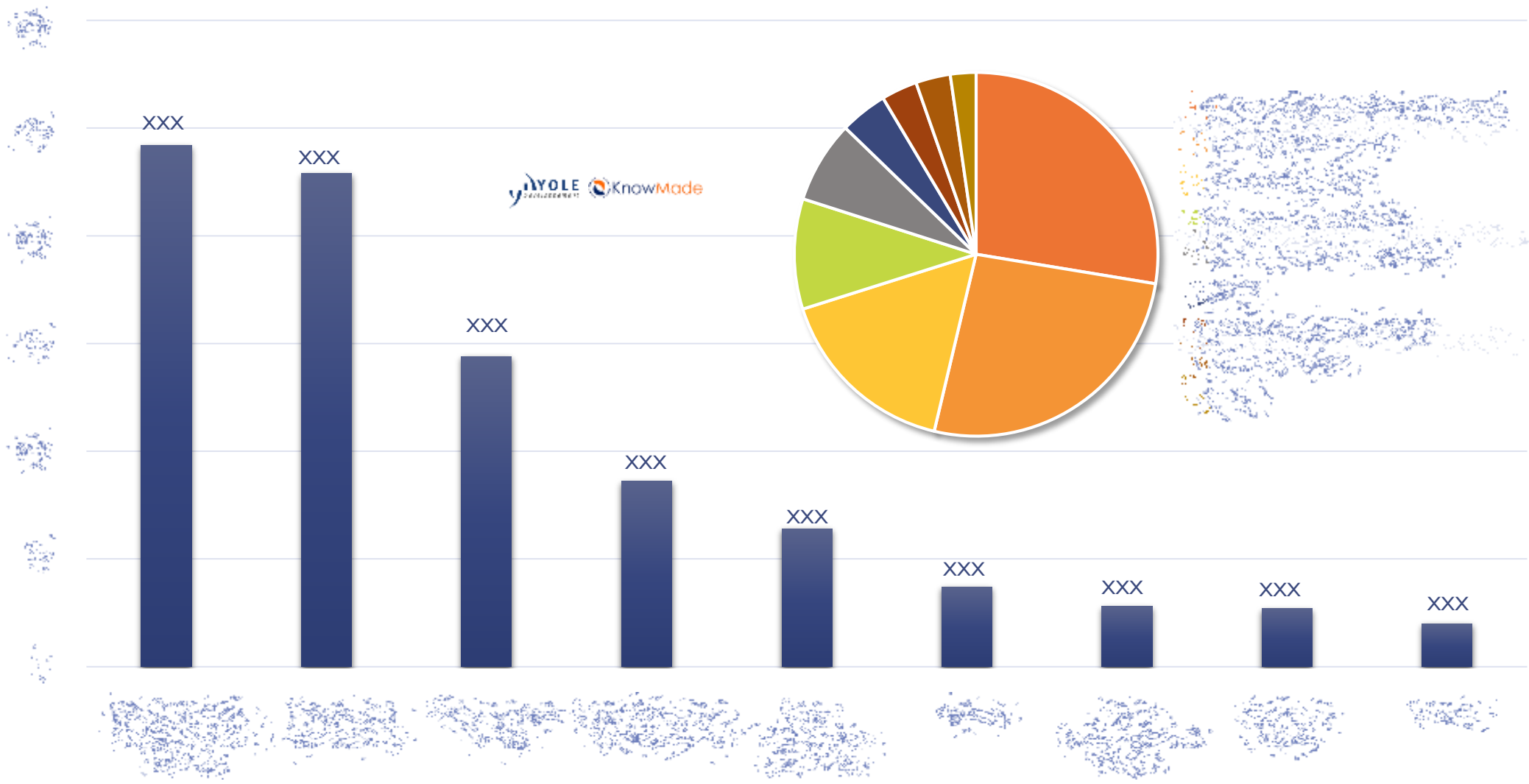
Color Generation, Conversion, Management
Techniques for color conversion via phosphor, quantum dots or other downconverters. Also color filtering and techniques allowing to create R,G,B pixels from the same substrate (the latter also classified in the "Epitaxy" category.

Testing
Techniques or tools aimed at testing individual pixels before or after assembly or testing a full display. Electrical or optical, contact or contactless.

Sensors In Display
Describes the integration of sensing or other functions into the microLED frontplane (sensors, pixel drivers positioned in between LED emitters). Example: touch, gesture recognition, IR imaging (fingerprint, iris, facial recognition)

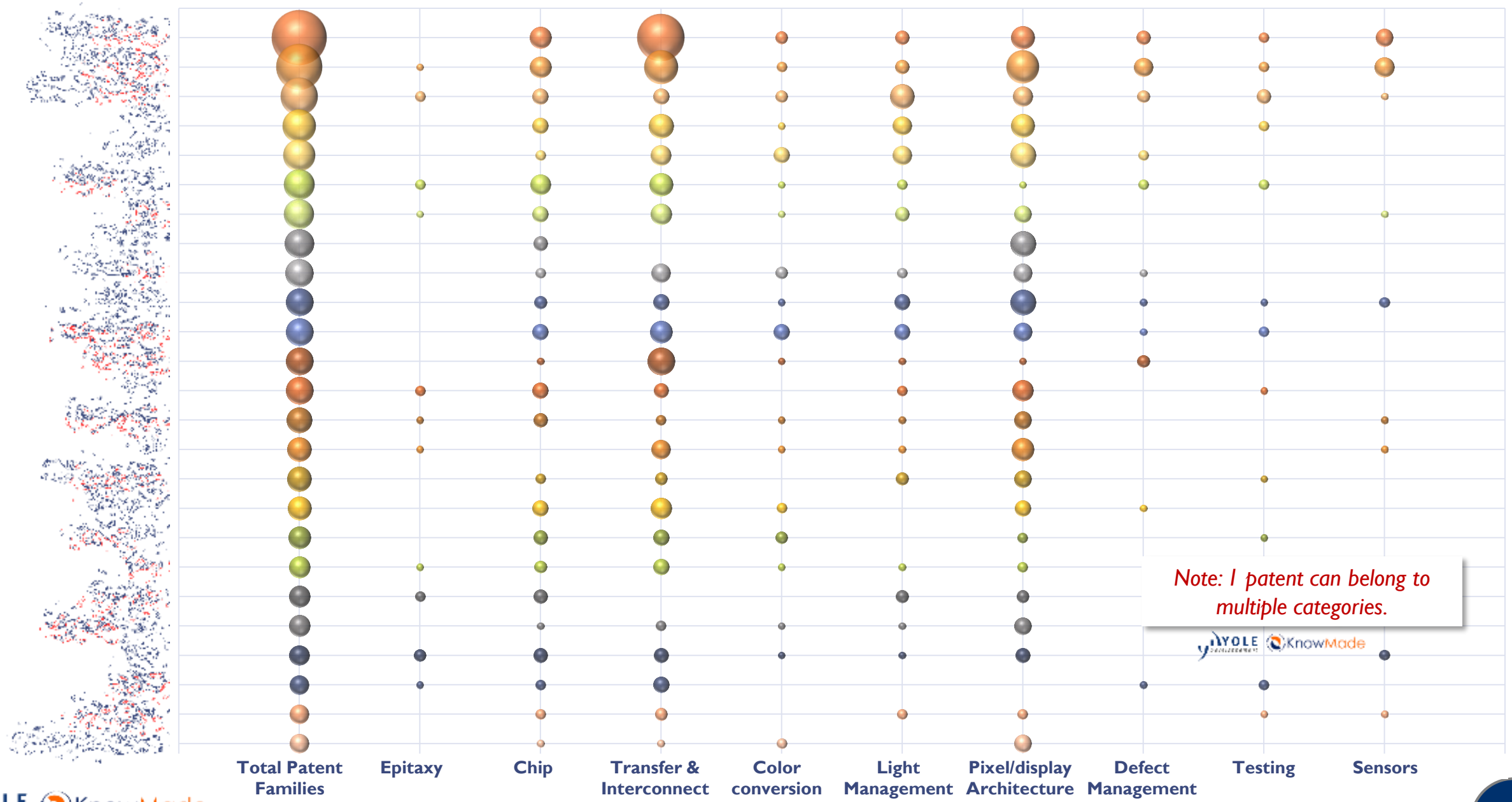
OVERVIEW OF PATENT FAMILIES PER TECHNOLOGY NODE

Inventions pertinent to XXXX and XXXX dominate the microLED displays patent landscape.



Note: a patent can belong to multiple categories. For example, a specific chip structure can be aimed at enabling its transfer (e.g: sacrificial layers), improving light extraction (mirrors) etc. Similarly, a transfer and assembly technology can be designed to enable pixel repair and defect management etc.

PORTFOLIO TECHNOLOGY SEGMENTATION PER COMPANY (TOP 25)



BREAKDOWN BY COMPANY TYPES

- We have segmented the patent corpus by various types of companies. The different categories are presented below.
- Some companies could arguably belong to different or multiple categories. For example, we chose to include Sony in the "Display Makers" group although it had stopped producing its own panels and also sells various consumer electronic goods beyond just TV or monitors.

Small companies, usually established within the last 10 years with a focus on developing microLED display technologies.

Display Makers

Companies producing display panels (LCD, OLED) or large LED video displays AND/OR producing TV/Monitors

OEM & Consumer Electronic

Companies selling consumer electronic good where the display is a key component but not the only feature (e.g.: smartphone, laptops, tablets…)

LED Makers

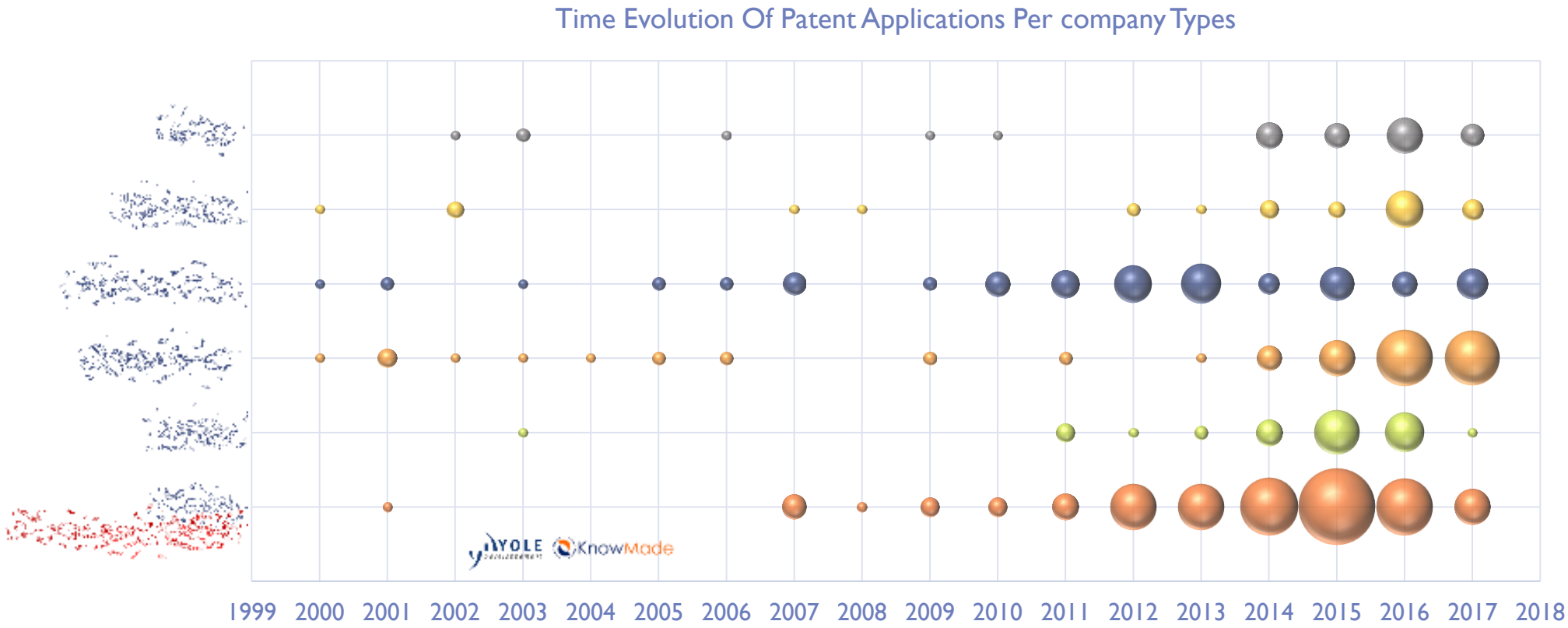
Companies producing LED chips and/or packages LEDs.

R&D Organizations

University labs, public research centers etc.

Include various component makers (drivers, PCB, semiconductors) as well as individuals who have filed patents under their own name and have no other assignees.

TIME EVOLUTION OF PATENT APPLICATIONS PER COMPANY TYPES



Note: Due to the delay between the filing of patents and the publications by patent offices, usually 12-18 months, we estimate that most of the 2017 filings and up to half of the 2016 filing are not visible as of December 2017.

- XXXX companies are leading the pack, and are currently assigned XX% of the published microLED display patents. If ----------this number would rise to 40%.
- ----------. This analysis is confirmed by looking at the time evolution of patent filings of the different types of companies and----------

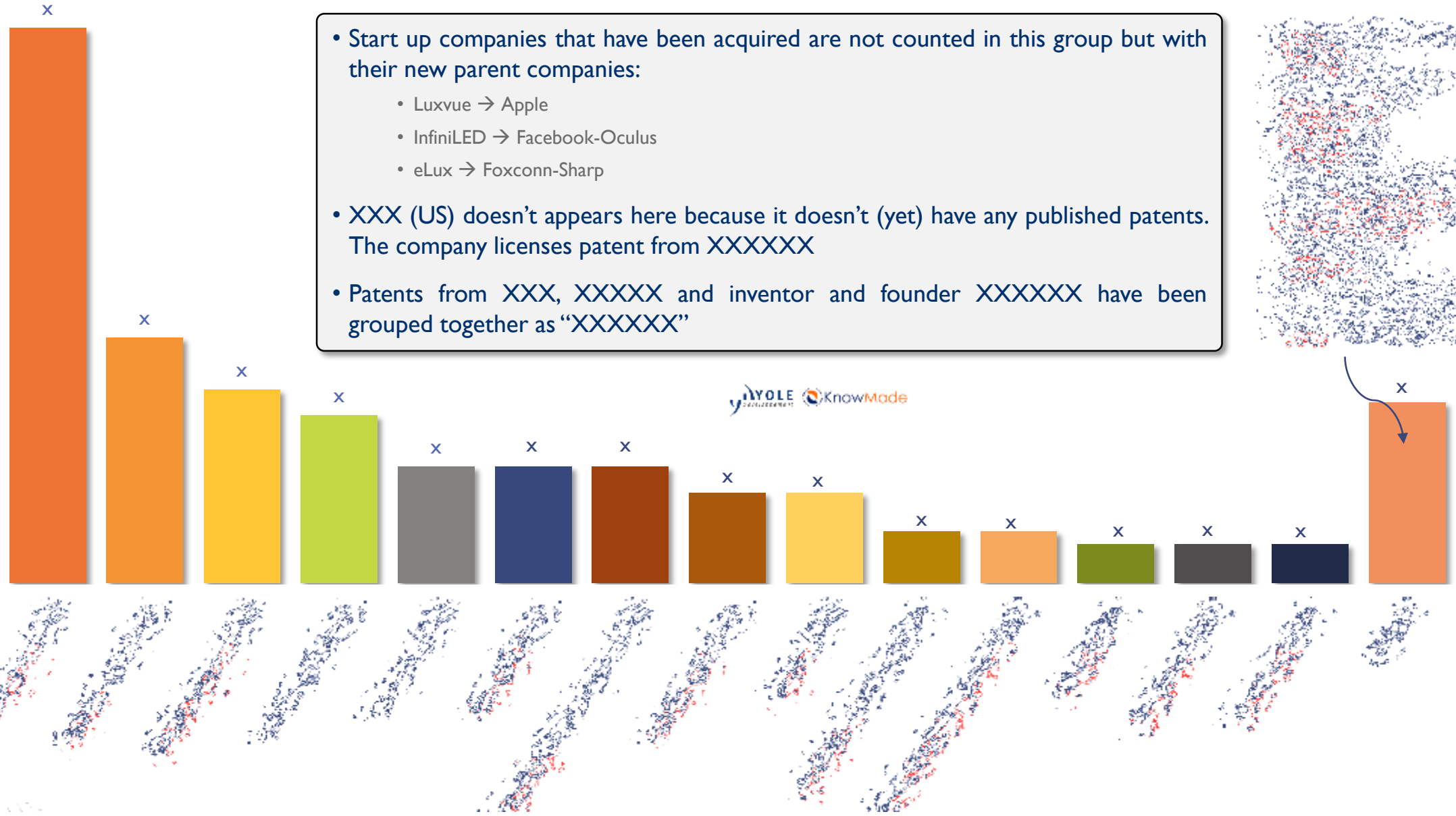
MOST ACTIVE COMPANIES BY TYPE

(x) = number of patent families

Start Up	OEM/CE	Display Makers	R&D Organizations	LED Makers	Others
xx	xx	xx	xx	xx	xx
xx	xx	xx	xx	xx	xx
xx	xx	xx	xx	xx	xx
xx	xx	xx	xx	xx	xx
xx	xx	xx	xx		
xx	xx	xx	xx		
xx		xx	xx		
xx		xx	xx		
xx			xx		

START UP COMPANIES

- Start up companies that have been acquired are not counted in this group but with their new parent companies:
  - Luxvue → Apple
  - InfiniLED → Facebook-Oculus
  - eLux → Foxconn-Sharp
- XXX (US) doesn't appears here because it doesn't (yet) have any published patents. The company licenses patent from XXXXXX
- Patents from XXX, XXXXX and inventor and founder XXXXXX have been grouped together as "XXXXXX"

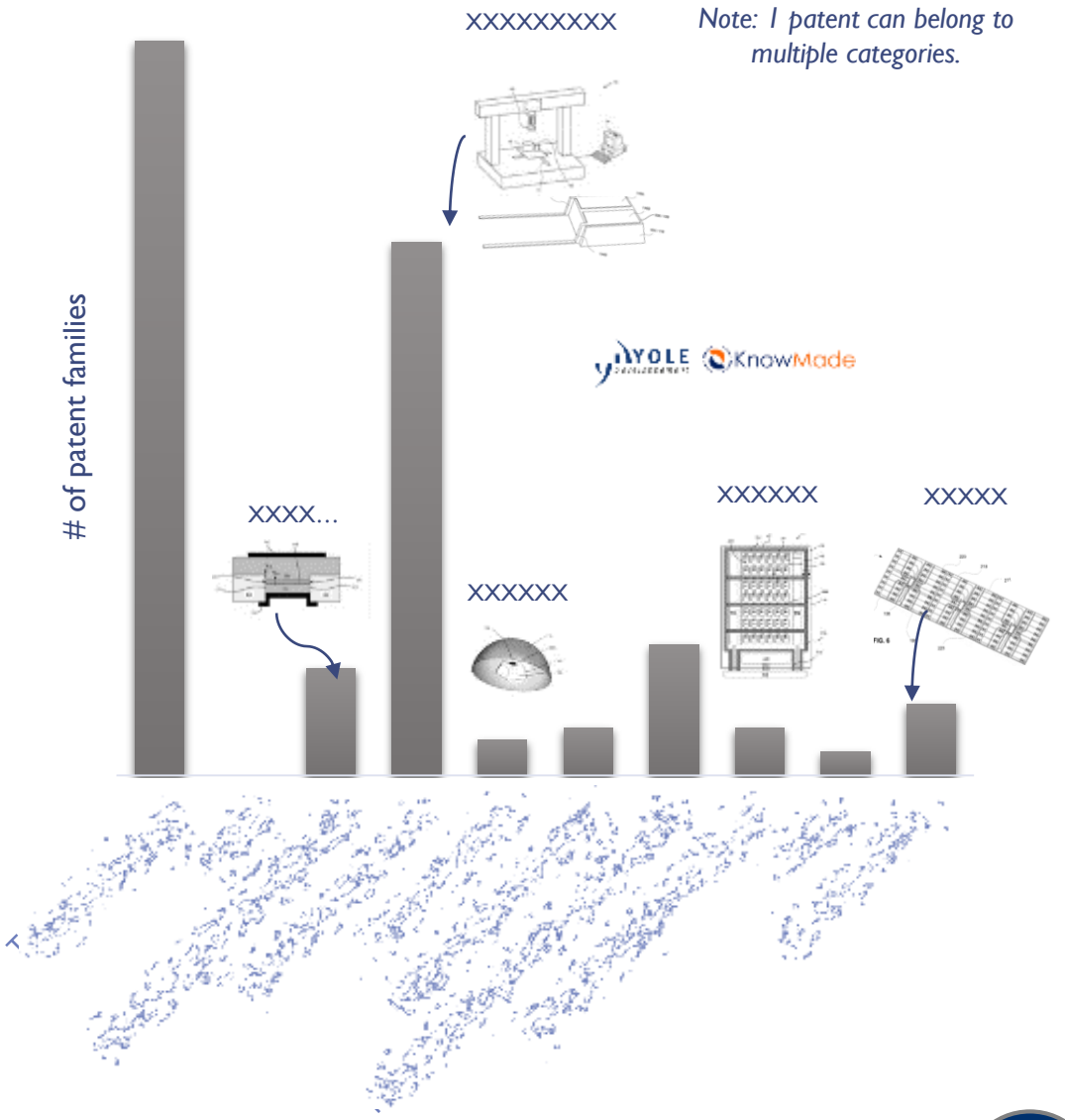


APPLE- LUXVUE (US)

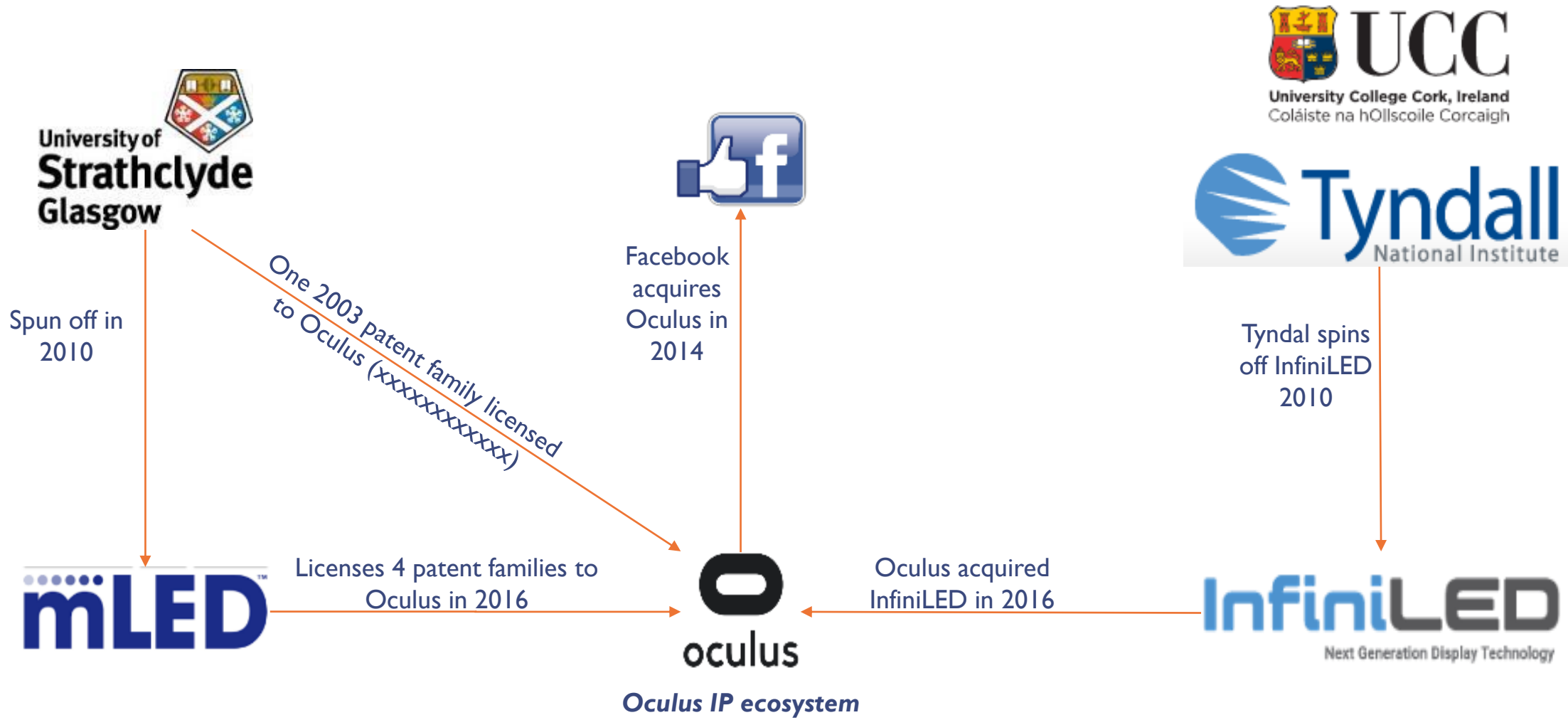
Luxvue was established in 2009 to leverage on technologies on electrostatic MEMS microtransfer technologies from FujiFilm Dimatix to develop microLED display

- Luxvue was established in 2009 and raised at least $43M from various investors including XXX prior its acquisition by Apple in 2014.
- The first patents were filed in XX. A total of XXX applications with broad geographic coverage have been filed (XXX families). XXX have been granted, 3 rejected and XX abandoned. The balance is pending as of Dec. 2017.
- Many patent families have already received large numbers of citations from other applicants.
- All this indicate an overall strong IP position in the field with many seminal patents [1] and possibly significant blocking potential in various of the technology nodes (see next section of the report).
- However, while the portfolio covers a broad scope of technology nodes, patents often focus on the technological ecosystem developed around the company's MEMS transfer technology. The blocking potential might therefore be more limited for transfer technologies that differ enough from that of Apple/Luxvue.

[1]: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX



OCULUS/INFINILED/MLED (US)

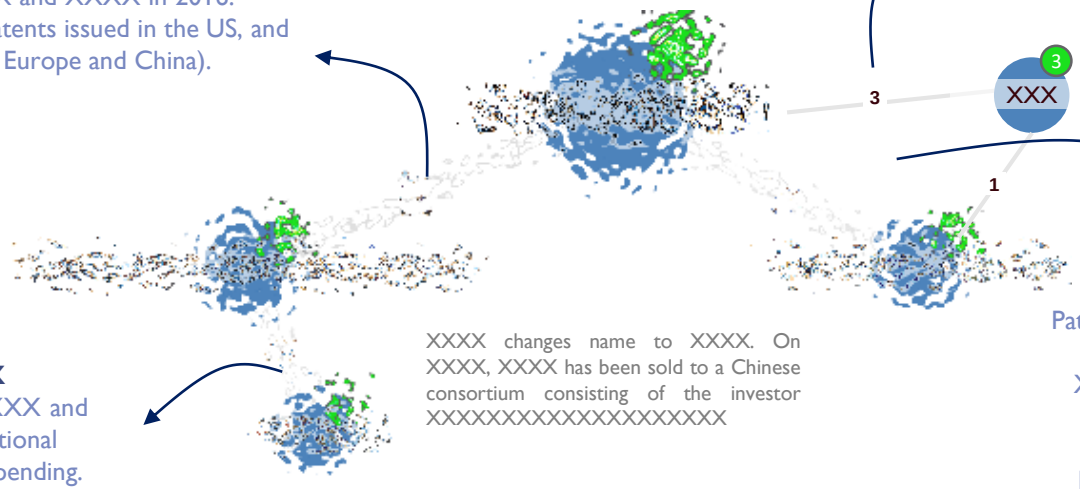


COLLABORATION NETWORK

3 Number of microLED display patent families

2 Number of co-assigned patent families

Co-assigned patents revel mostly collaborations between companies and research organizations. Notable exception include XXXX collaboration with XXXX and XXX with XXXX.



XXXXXXXXXXXXXX
Patents co-filed by XXXX and XXXX in 2016.
XXXXXXXX, XXXXXX (patents issued in the US, and pending applications in Europe and China).

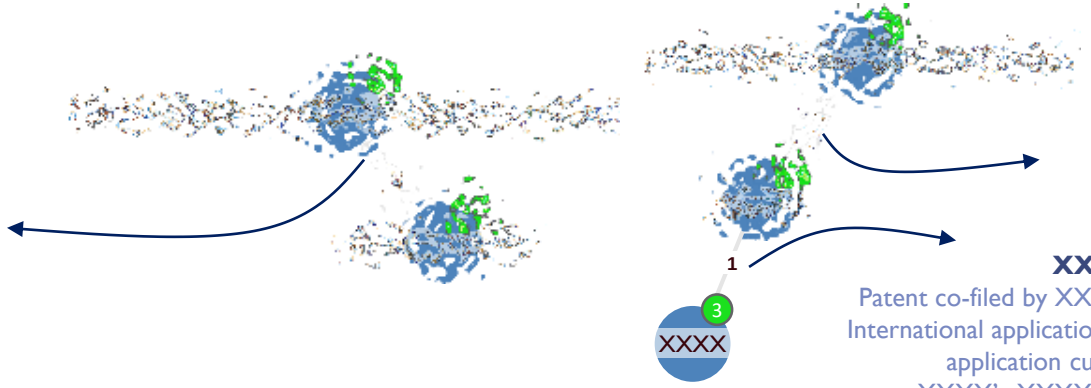
XXXXXXXXXXXXX
XXXXXX (patent granted in USA).
XXXXXXXXXXXXXXX
XXXXXX (patent granted in USA and Korea, and currently pending application in Europe).
Patent rights acquired by XXXX from XXXX in 2017.

XXXXXXXXXXXXXX
Patent co-filed by XXXXXXXXXXXXX and XXXXXXXXXX in 2015. International application XXXXXXXX currently pending.

XXXX changes name to XXXX. On XXXX, XXXX has been sold to a Chinese consortium consisting of the investor XXXXXXXXXXXXXXXXXXXX

XXXXXXXXXX
Patent co-filed by XXXXXXXX and XXX in 2007.
XXXXXX (patents issued in USA, Japan, Taiwan, China, Korea and Malaysia)

Patent rights acquired by XXXXX from XXXXXXXXXX in March 2017.



XXXXXXXX
Patent co-filed by the XXXX and XXXXXXXXX in 2014.
European application XXXXXXX currently pending.

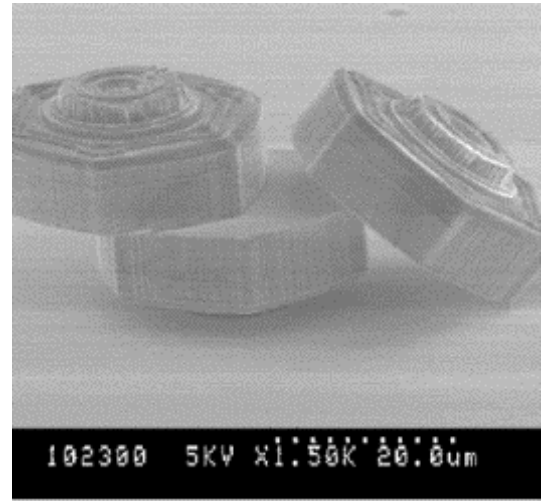
XXXXX
Patent co-filed by XXXX and XXX n 2015.
International application XXXX and European application XXXX currently pending.

XXXXX
Patent co-filed by XXXX and XXXX in 2016.
International application and European XXXXX application currently pending.
XXXX's XXXXX granted in 2017.

FLUIDIC SELF ASSEMBLY

In fluidic assembly, the µLED are dispersed in a liquid binder

- In fluidic self assembly processes, the microLED die are dispersed in a fluid which then flows onto the surface of the substrate where the emitters have to be assembled.
- Self assembly is usually ensured by giving the die specific shapes and etching small cavities (AKA "wells") with matching shapes on the receiving substrate.
  - **XXXX** developed triangular, hexagonal pillar or disk - shaped µLED
  - **XXXX** has various patents with disk shape emitters fitted in a concave shape well.
- Alternatively or in addition, the process can be assisted by electrostatic force or electromagnetic polarization.
- Some companies focus on making the process deterministic enough so that each cavity is filled with the corresponding LED emitter.
- Other companies plan for multiple redundancies with subpixels containing multiple emitters to ensure that a sufficient number of microLED chips will populate the cavity and guaranty that each subpixel can light up.
  - **XXXX** in Korea have proposed various strategies leading to semi-randomly organized LED arrays.



microLED build for geld/fluidic transfer (source: Nth Degree)

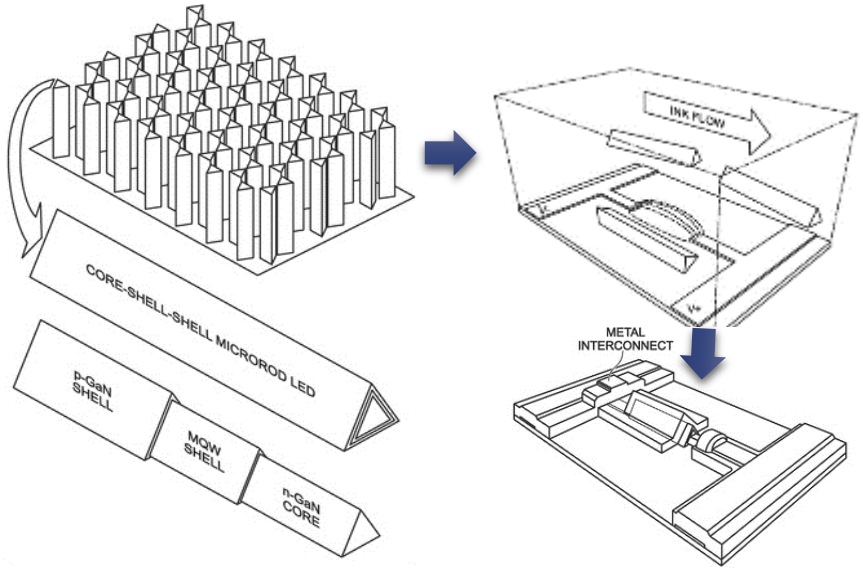
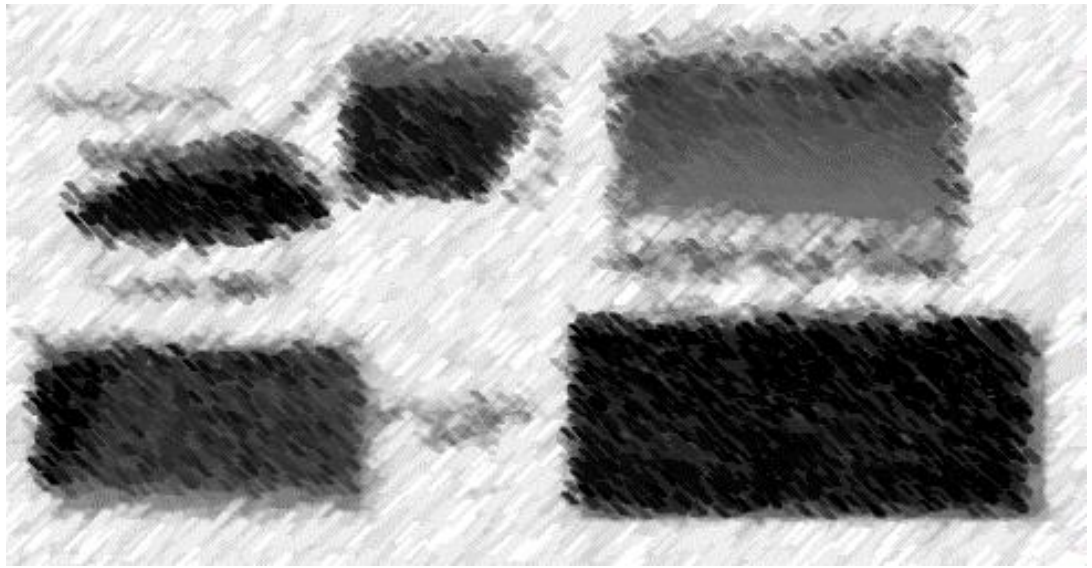


Illustration sharp patent US US9252328

RANKING BY STRENGTH INDEX OF THE PATENT PORTFOLIO

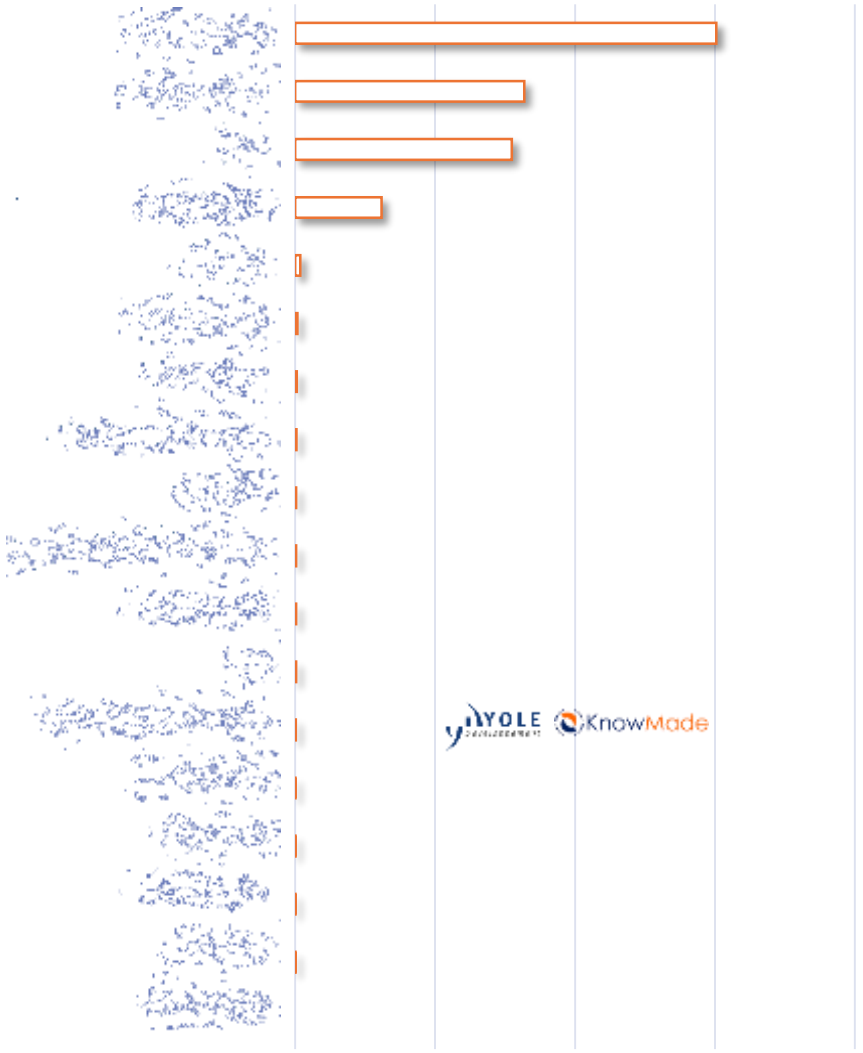
XXXXXXX and XXXXXX together dominate with their XXXXXXXXX transfer technology

- XXX ranks first. The organization holds a small of number of patent families but gets a lot of citations. The funding patent family for their technology represented for example by XXXX filed in 2007 is co-assigned to XXXXX.
- The two organizations together therefore have a strong position in the field and a long history in developing transfer technologies based on XXXXX:



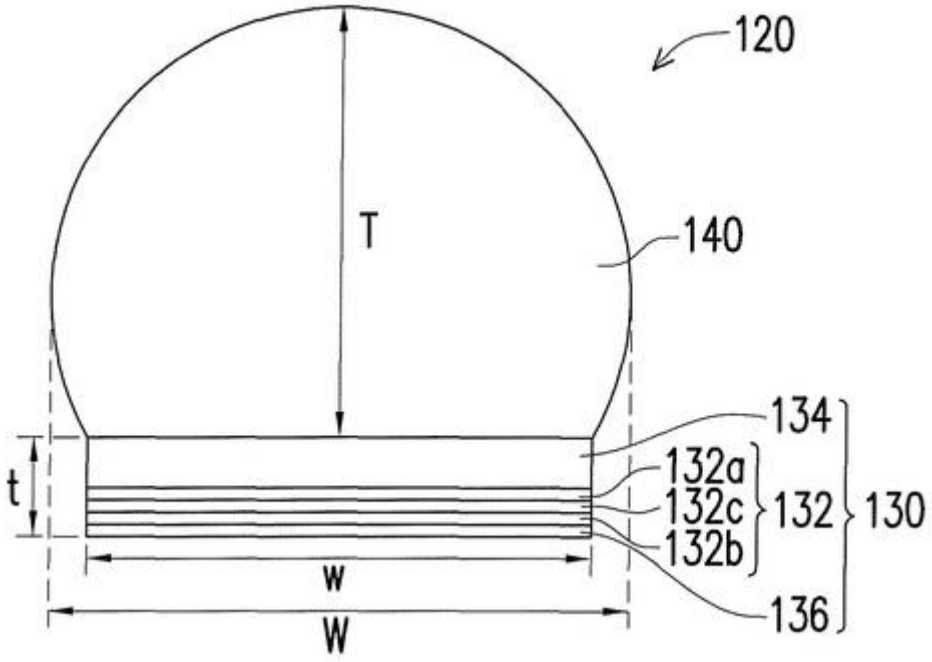
The technology was originally developed at XXXX and relies on XXXXXXXXXXXXXXXXXX.

Strength index of the patent portfolio



ITRI has developed at least 3 different transfer technologies

- Taiwan's ITRI has filed patents describing various transfer processes (e.g.: XXXXXX "----------").
- However, the most original is probably XXXXXXXXXXX ("----------") which describes a self assembly method where microLED with a large spherical electrodes are electrostatically charged by going through a nozzle and find their bonding pads through a combination of electrostatic attraction, gravity and selective masking on the receiving substrate



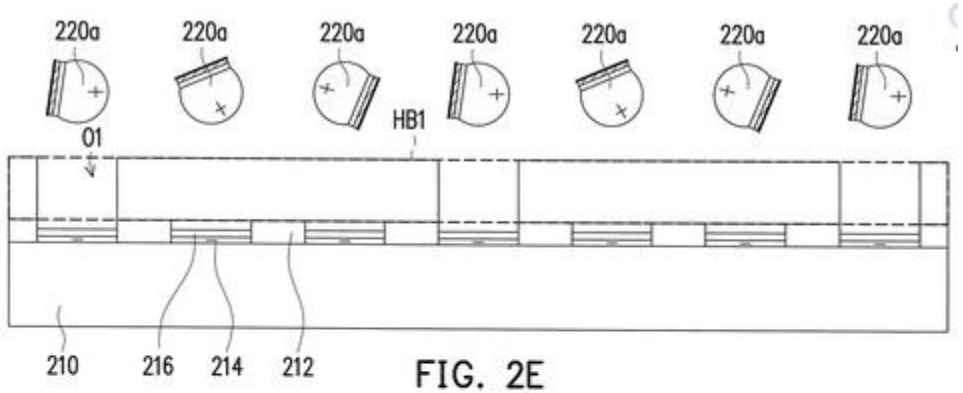


FIG. 2E

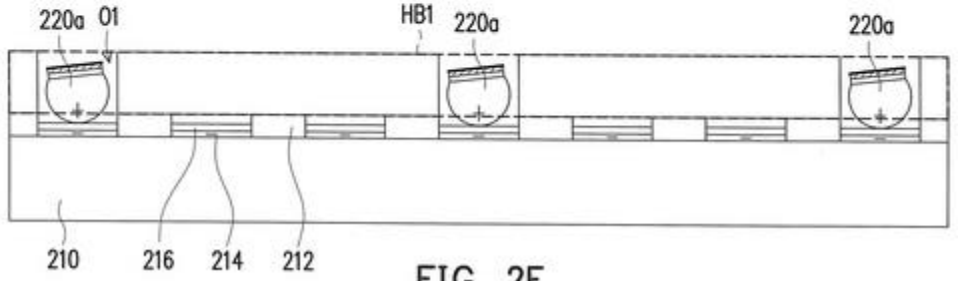


FIG. 2F

X-CELEPRINT (UK)– UNIVERSITY OF ILLINOIS (US) - WO2008143635

Optical systems fabricated by printing-based assembly

Abstract

The present invention provides optical devices and systems fabricated, at least in part, via printing-based assembly and integration of device components Optical systems of the present invention comprise semiconductor elements assembled, organized and/or integrated with other device components via printing techniques that exhibit performance characteristics and functionality comparable to 10 single crystalline semiconductor based devices fabricated using conventional high temperature processing methods Optical systems of the present invention have device geometries and configurations, such as form factors, component densities, and component positions, accessed by printing that provide a range of useful device functionalities.

1st claim:

A method of making a semiconductor-based optical system, said method comprising the steps of:

providing a device substrate having a receiving surface; and

assembling a printable semiconductor element on said receiving surface of said substrate via contact printing; wherein said printable semiconductor element comprises a semiconductor structure having a length selected from the range of

0. 0001 millimeters to 1000 millimeters, a width selected from the range of 0.0001 millimeters to 1000 millimeters and a thickness selected from the range of 0.00001 millimeters to 3 millimeters.

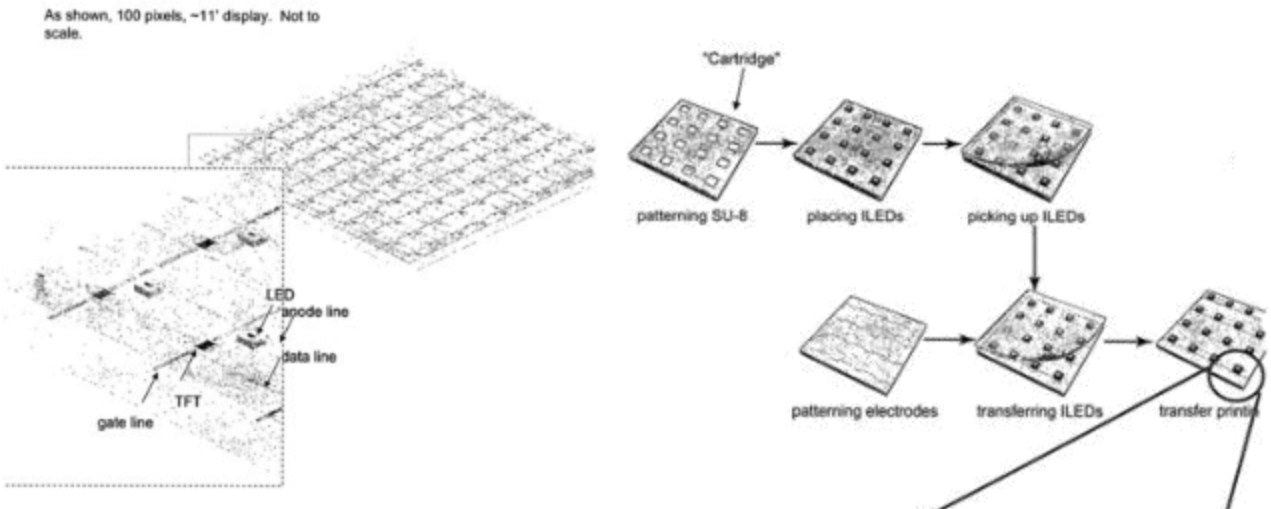


Fig. 4

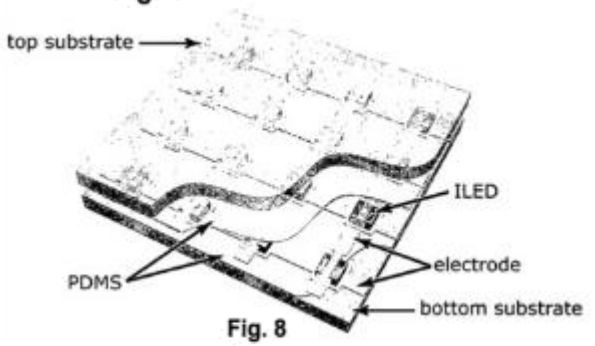


Fig. 8

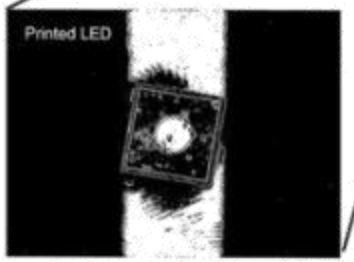


Fig. 11

Description:

The present invention provides a number of classes of optical systems and related methods of making these systems, including systems for light generation and systems for light harvesting, comprising printed inorganic optical and optoelectronic systems with integrated optical components in registry. Light generation systems include printed LED displays, micro LED devices, passive matrix LED displays, active matrix LED displays […] optionally comprising light diffusing optics, light focusing optics and/or light filtering optics. Fig. 4 provides a schematic illustration (not to scale) of a printed active matrix LED display on a glass substrate. The display shown comprises 100 pixels and is an approximately 11 inch display. Thin film transistor (TFT) elements, LED elements, gate lines, anode lines and data lines of the device are indicated in Figure 4.

IP BLOCKING POTENTIAL

XXXXXXXX patents as well as XXXXXXX and XXXXXX's portfolio appear to have the strongest blocking potential.

TRANSFER & INTERCONNECT