



Technology Insight Report

LED Technology In Lighting



Light Emitting Diode or LED Technology in lighting can be traced back to 1927 although it didn't make an entrance into commercial applications till much later. Having taken a back seat for many years largely owing to its high production cost LED lighting is rapidly gaining ground in the lighting space in more recent times. With the increasing demand for greener, more energy efficient products as well as the environmental strain on energy resources in our times is LED technology the answer to the future of our lighting needs? Where is LED technology headed and does it have the research momentum and industrial backing to take on the light bulb which was perhaps the most life-changing invention of our time?

Overview

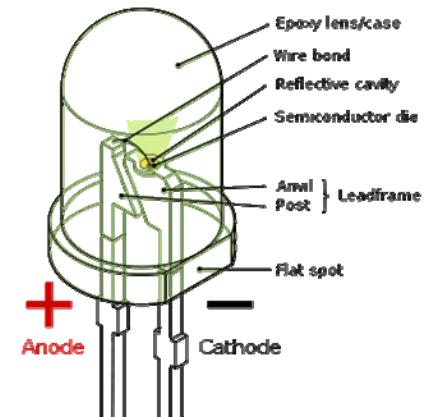
Introduction to Light-Emitting-Diode or LED Technology

A light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices, and are increasingly used for lighting. Introduced as a practical electronic component in 1962, early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet and infrared wavelengths, with very high brightness.

The LED is based on the semiconductor diode. When a diode is forward biased (switched on), electrons are able to recombine with holes within the device, releasing energy in the form of photons. This effect is called electroluminescence and the color of the light (corresponding to the energy of the photon) is determined by the energy gap of the semiconductor. An LED is usually small in area (less than 1 mm²), and integrated optical components are used to shape its radiation pattern and assist in reflection. LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, faster switching, and greater durability and reliability. However, they are relatively expensive and require more precise current and heat management than traditional light sources. Current LED products for general lighting are more expensive to buy than fluorescent lamp sources of comparable output.

They also enjoy use in applications as diverse as replacements for traditional light sources in automotive lighting (particularly indicators) and in traffic signals. Airbus uses LED lighting in their A320 Enhanced since 2007, and Boeing plans its use in the 787. The compact size of LEDs has allowed new text and video displays and sensors to be developed, while their high switching rates are useful in advanced communications technology.

Source: http://en.wikipedia.org/wiki/Light-emitting_diode



Light Emitting Diode

Like a normal diode, the LED consists of a chip of semiconducting material doped with impurities to create a p-n junction. As in other diodes, current flows easily from the p-side, or anode, to the n-side, or cathode, but not in the reverse direction. Charge-carriers—electrons and holes—flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon.

The wavelength of the light emitted, and therefore its color, depends on the band gap energy of the materials forming the p-n junction. In silicon or germanium diodes, the electrons and holes recombine by a non-radiative transition which produces no optical emission, because these are indirect band gap materials. The materials used for the LED have a direct band gap with energies corresponding to near-infrared, visible or near-ultraviolet light.

A Brief History of Light Emitting Diode (LED) Technology

Electroluminescence was discovered in 1907 by the British experimenter H. J. Round of Marconi Labs, using a crystal of silicon carbide and a cat's-whisker detector. Russian Oleg Vladimirovich Losev independently reported on the creation of a LED in 1927. His research was distributed in Russian, German and British scientific journals, but no practical use was made of the discovery for several decades. Rubin Braunstein of the Radio Corporation of America reported on infrared emission from gallium arsenide (GaAs) and other semiconductor alloys in 1955. Braunstein observed infrared emission generated by simple diode structures using gallium antimonide (GaSb), GaAs, indium phosphide (InP), and silicon-germanium (SiGe) alloys at room temperature and at 77 kelvins.

In 1961, experimenters Robert Biard and Gary Pittman working at Texas Instruments found that GaAs emitted infrared radiation when electric current was applied and received the patent for the infrared LED.

The first practical visible-spectrum (red) LED was developed in 1962 by Nick Holonyak Jr., while working at General Electric Company. Holonyak is seen as the "father of the light-emitting diode". M. George Craford, a former graduate student of Holonyak, invented the first yellow LED and improved the brightness of red and red-orange LEDs by a factor of ten in 1972. In 1976, T.P. Pearsall created the first high-brightness, high efficiency LEDs for optical fiber telecommunications by inventing new semiconductor materials specifically adapted to optical fiber transmission wavelengths.

Up to 1968 visible and infrared LEDs were extremely costly, on the order of US \$200 per unit, and so had little practical application. The Monsanto Company was the first organization to mass-produce visible LEDs, using gallium arsenide phosphide in 1968 to produce red LEDs suitable for indicators. Hewlett Packard (HP) introduced LEDs in 1968, initially using GaAsP supplied by Monsanto. The technology proved to have major applications for alphanumeric displays and was integrated into HP's early handheld calculators. In the 1970s commercially successful LED devices at under five cents each were produced by Fairchild Optoelectronics. These devices employed compound semiconductor chips fabricated with the planar process invented by Dr. Jean Hoerni at Fairchild Semiconductor. The combination of planar processing for chip fabrication and innovative packaging techniques enabled the team at Fairchild led by optoelectronics pioneer Thomas Brandt to achieve the necessary cost reductions. These techniques continue to be used by LED producers.

Source: http://en.wikipedia.org/wiki/Light-emitting_diode

Glimpses of LED Technology



Traffic Signals



Airplane Lighting



Car Lighting

LED Lighting Technology – Insights from Patents

Patent data can help uncover the trends, gaps and opportunities that exist around use of LEDs in lighting industry. By observing trends in patent filings by innovators and businesses it's possible to take a closer look into LED lighting and gauge where it's headed. Some of the questions around this technology we are now starting to see more often in our daily lives are:

- How research activity around LED lighting technology evolved since 1920 and which companies spearhead the research?
- Who are the innovators whose filings dominate LED lighting technology?
- Which countries are showing the maximum activity in LED lighting research?
- How does LED lighting compare with other forms viz. Incandescent and Fluorescent lighting?
- How the filings are spread across key LED Lighting products in the market?

To get some answers and a better insight into the IP activity that surrounds it, we carried out a quick analysis using Patent iNSIGHT Pro software.

Search Strategy

The first step is to create and define a patent set that will serve as the basis of our analysis. Using commercial patent database PatBase as our data source we used the following search query to create our patent set:

(LED or "Light emitting diode")

AND

(building or office or house or mall or highway or shop or home or apartment or condo or bungalow or freeway or resort or warehouse or autobahn or factory or industry or plant or mine or multiplex or indoor or auditorium or hall or room or arena or school or college or university or showroom or hotel or campus or street or road)

AND

International classes (F21V or F21S)

After reducing results to one member per family the final set had **6581** records.

Class Descriptions

F21V - MECHANICAL ENGINEERING; LIGHTING; HEATING; WEAPONS; BLASTING >> LIGHTING >> FUNCTIONAL FEATURES OR DETAILS OF LIGHTING DEVICES OR SYSTEMS THEREOF; STRUCTURAL COMBINATIONS OF LIGHTING DEVICES WITH OTHER ARTICLES

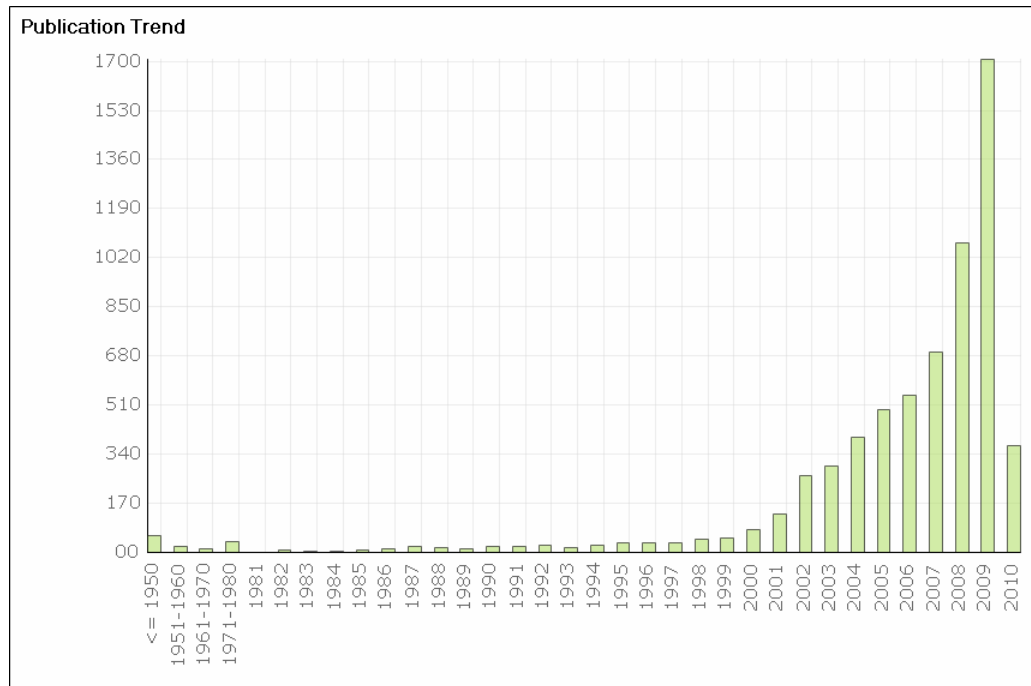
F21S - MECHANICAL ENGINEERING; LIGHTING; HEATING; WEAPONS; BLASTING >> LIGHTING >> NON-PORTABLE LIGHTING DEVICES OR SYSTEMS THEREOF

IP Activity across Last 60 Years

What has been the IP publication trend for LED light technologies from 1950 till present date?

Patents related to LED technology can be traced back to before 1950 and the real surge in the activity around this technology has happened in the last decade.

Patent publication trends are accurate indicators of the emphasis given to a technology during a particular point of time and by laying out the patent activity across a timeline of the last 6 decades, a landscape of how this activity has evolved is created:



How we did it?

Once the patents were populated in Patent iNSIGHT Pro, the publication trend chart was generated on a single click using the dashboard tool.

The same tool also helped generate a tabular report.

To download this tabular report of the IP Activity trend in Microsoft Excel format please click on the link below:



[Download in XLS format](#)

While there were some significant number of patents published from the 50's to the 80's, there seems to be a complete dip in the activity around LED technology for a significant period of time till the last decade where the filings started to climb rapidly. From just 22 filings in 1990, the year 2000 saw the number jump to 80 and shoot up to 1700 in 2009 indicating this technology has gone from 'dormant' to 'very hot' in the very recent years. The first few months of 2010 already show this upward trend and development around LED lighting is only poised to go upward at the same sharp rate it's currently growing at.

LED is clearly getting a lot of attention and investment in current times and comes across as a promising technology in the future of lighting systems.

Key Companies in LED Lighting Technology

Who have been the top assignees or the key players in LED lighting technology?

With the rise in research and development activity around LED related lighting technologies in the last decades, large businesses have established their interest through significant investments. By grouping the patent filings by companies, we can establish who the top assignees or key players in LED lighting are:

ASSIGNEE NAME	TOTAL
KONINKLIJKE PHILIPS ELECTRONICS N V	135
SAMSUNG ELECTRO MECHANICS CO	128
PHILIPS SOLID-STATE LIGHTING SOLUTIONS INC.	80
KOITO MANUFACTURING CO. LTD.	55
FU ZHUN PRECISION INDUSTRY (SHEN ZHEN) CO. LTD.	47
DONGGUAN KINGSUN OPTOELECTRONICS CO	37
TOYODA GOSEI CO. LTD.	36
SONY CORPORATION	34
MATSUSHITA ELECTRIC WORKS LTD	30
SHARP KABUSHIKI KAISHA	28

How we did it?

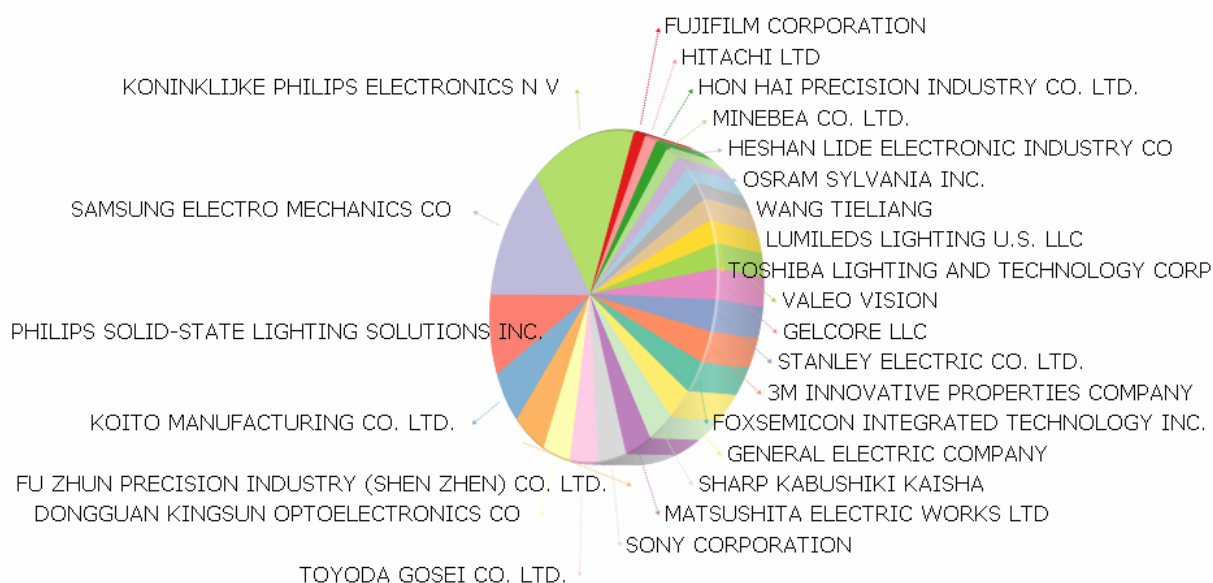
Using the co-occurrence analyzer in Patent iNSIGHT Pro a matrix of top 25 assignees with respect to time was created. A pie chart and a tabular report was then generated from the co-occurrence analyzer

To download the tabular results please click on the link below:

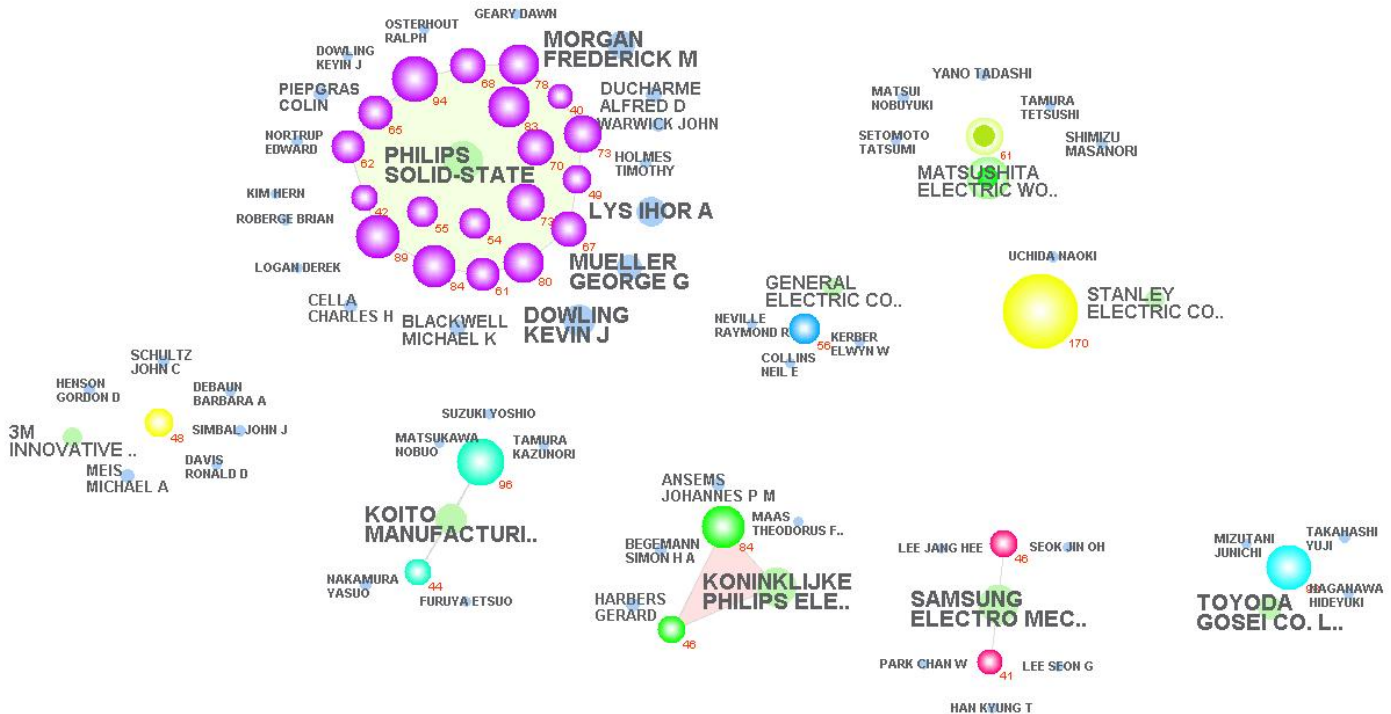


[Download in XLS format](#)

With companies like Phillips, Samsung and Koito leading the table with the most patents a number of the leading companies in the general lighting systems space appear to be pursuing LED technology with enthusiasm as a future technology which has strong potential in commercial markets.



Who are the key inventors who have made significant contributions in LED lighting research?



Records: 30/6581

The most prolific innovations are often the ones that are so significant that future innovators build on these to develop the technology further. Patent citations can reveal who are these inventors and assignees who have made these big contributions to LED:

The VizMap chart shows the top assignees and the inventors behind the most cited patents in the LED lighting sphere.

How we did it?

Using the VizMAP tool, patents with 40 or more forward citations were extracted from the patent set creating a set of frequently cited patents. These were then expanded by assignee and inventor names. The patents displayed are colored by assignee and their significant inventors are shown in **bolder** text.

Geographical Interest in LED

IP filings in LED Lighting are spread across which countries?

Country Code	Total
US	7845
CN	3238
JP	2521
DE	1223
KR	1034
TW	813
GB	809
AU	770
CA	701
AT	291
FR	177
ES	165
IN	150
MX	133
IT	106
BR	101
HK	84
NL	81

How we did it?

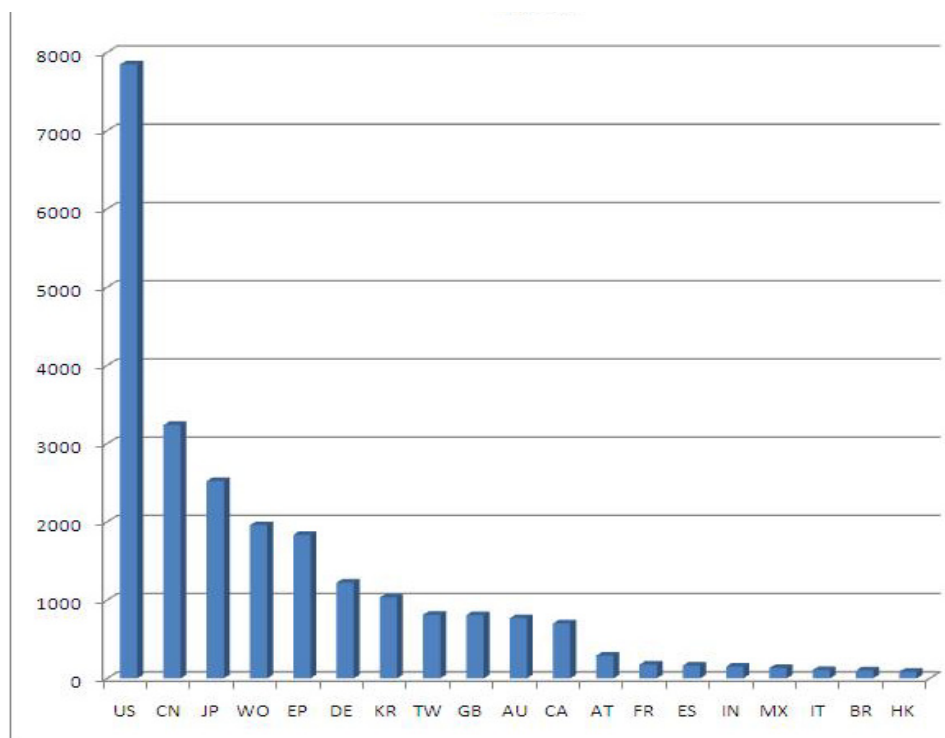
First a coverage analysis of the selected patent portfolio was done. The coverage analysis included all family members of all 6851 patents in our portfolio. The top 40 countries were then selected from this matrix.

For an excel export of the full 40 countries please download from the link below:



[Download in XLS format](#)

The US, China, Japan, Germany and Korea make up the top 5 locations geographically leading the evolution of lighting systems putting most of the industrially developed nations at the spearhead. However, developing countries also feature in the top few indicating that there is healthy interest in pursuing this greener and more energy efficient form of lighting which could have an impact on their energy requirements in future.



Industrial Applications of LED Technology

The classification of patents filed corresponding to LED can reveal significant details on the industrial applications of LED technology. By co-relating the patent families or classification against these patents, the uses and applications of the light emitting diode in various lighting systems is brought out. A look into the uses of LED shows it's found itself into a very extensive list of applications across a number of industry segments. Some of these segments include:

Electric Light Sources
Semiconductor Technology
Audio Electronics
Optics
Medical Devices
Computer Peripheral Equipment
Traffic Control Systems
Scanning Equipment
Computer Data Transfer Devices
Heat Transfer & Control Systems
Kitchen Appliances
Dental Equipment
Automobile Lighting Systems

While LED can be found across several other areas, it's predominantly featured in lighting systems and devices. LED lighting research specialized for use in specific areas can be found in healthcare centers, cinema halls, hotels, aircraft, automobiles, computer peripherals and other such areas. The commercial and industrial applications spread wide and with the growing trend in patent filings around LED, the applications are also likely to widen very quickly in the coming months and years.

For the complete list of top industries where LED technology is being applied please download from the link below



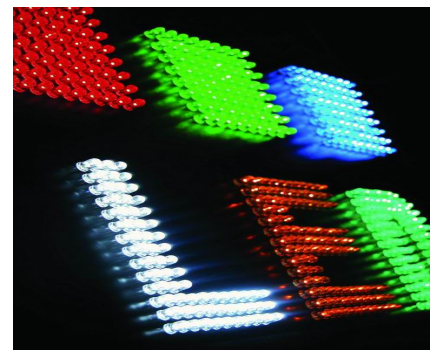
[Download Excel export of Top industries](#)



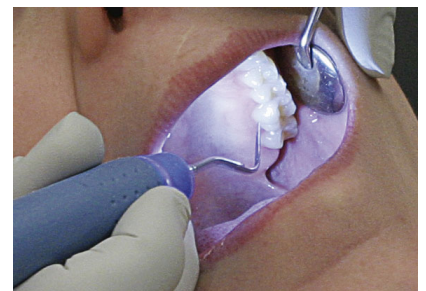
Bridge Illumination



Indoor Lighting Fixtures



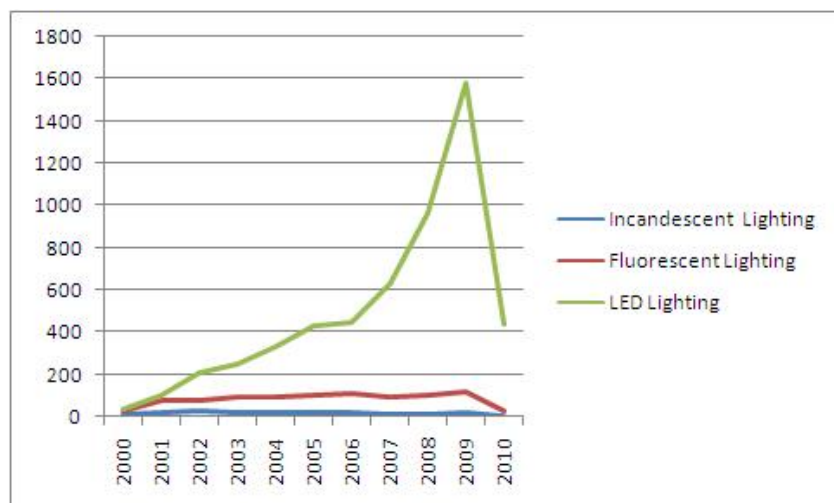
Digital Signage



Dental Equipment

LED Technology in Lighting Research A Comparison

How much of the total research around lighting systems is now LED based? How popular is LED technology among lighting innovators as compared to incandescent and fluorescent lighting research?



How we did it?

To compare the trend for the three lighting technologies, a quick search was done individually for incandescent lighting, fluorescent lighting and LED lighting while restricting the results to patents filed from 2000 to 2010. The results when exported to excel display the last decade with the publication trends for each technology alongside. Using the dashboard within Patent iNSIGHT Pro a trend chart is generated to display the results in a form where they can easily be compared as shown on the left.

By analyzing the patent filing trends over the last decade from (2000 to 2010) it's evident LED technology filings dominate the publication trends by a wide margin with fluorescent technology still seeing some activity and incandescent technologies dwindling far behind. 2009 which is the last complete year for which we have data shows 17 patents for incandescent lighting, 122 for fluorescent lighting and a stunning 1584 patents for LED based lighting.

Publication Years	Incandescent Lighting	Fluorescent Lighting	LED Lighting
2000	8	27	34
2001	16	82	102
2002	26	83	206
2003	18	94	246
2004	16	92	330
2005	18	108	429
2006	17	114	448
2007	11	95	627
2008	14	103	966
2009	17	122	1584
2010	3	27	437

From this publication trend not only are we seeing incandescent lighting towards the end of its innovation life cycle but the rate at which LED technologies are growing is impressive.

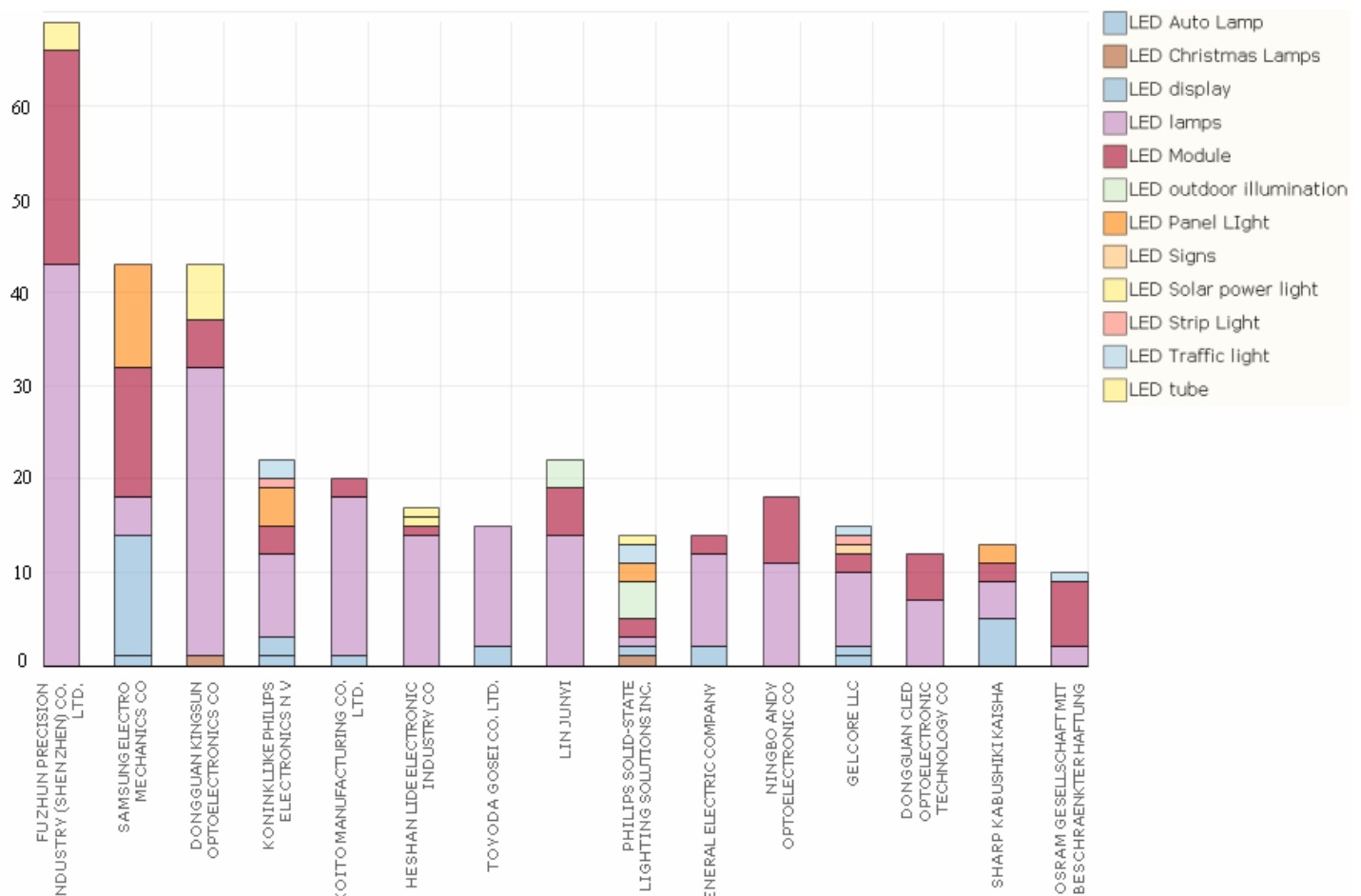
LED Lighting Products across key Companies

What are some of the LED lighting products being researched and who are the key companies for these products?

This chart helps get an insight into some of the LED lighting product categories along with a listing of the top assignees in each category. It highlights the focus areas within lighting being pursued by each company.

How we did it?

To identify some of the product categories and the top assignees within them the Patent iNSIGHT pro clustering engine was used. The results display the selected categories



For example, Samsung, Phillips and Koito all have a patent in the LED Auto Lamps category and are evenly matched there. Fu Zhun Precision dominates in the LED lamps category with the maximum IP records.

This spread of LED products across companies is also better interpreted in a heatmap of products vs. companies. This is shown below.

along with the number of patent filings within each category. For the complete export of products Vs assignees please download from the link below:



[Download in XLS format](#)

LED Products		LED Auto Lamp	LED Christmas Lamps	LED display	LED lamps	LED Module	LED outdoor illumination	LED Panel Light	LED Signs	LED Solar power light	LED Strip Light	LED Traffic light	LED tube
Companies	Total												
Total	274	4	2	26	188	80	7	19	1	1	2	6	11
FU ZHUN PRECISION INDUSTRY (SHEN ZHEN) CO. LTD.	44				43	23							3
SAMSUNG ELECTRO MECHANICS CO	36	1		13	4	14		11					
DONGGUAN KINGSUN OPTOELECTRONIC S CO	31		1		31	5							6
KONINKLIJKE PHILIPS ELECTRONICS N V	21	1		2	9	3		4			1	2	
KOITO MANUFACTURING CO. LTD.	18	1			17	2							
HESHAN LIDE ELECTRONIC INDUSTRY CO	15				14	1				1			1
TOYODA GOSEI CO. LTD.	14			2	13								
LIN JUNYI	14				14	5	3						
PHILIPS SOLID-STATE LIGHTING SOLUTIONS INC.	13		1	1	1	2	4	2				2	1
GENERAL ELECTRIC COMPANY	13			2	10	2							
NINGBO ANDY OPTOELECTRONIC CO	12				11	7							
GELCORE LLC	12	1		1	8	2			1		1	1	
DONGGUAN CLED OPTOELECTRONIC TECHNOLOGY CO	11				7	5							
SHARP KABUSHIKI KAISHA	10			5	4	2		2					
OSRAM GESELLSCHAFT MIT BESCHRAENKTER HAFTUNG	10				2	7						1	

Where Does This Technology Stand in 2010?

LED technology has been around for a long time and ignored perhaps because it was not cost effective enough to produce despite its efficiency and lower energy consumption. However, in the last decade or so IP filings around LED technology for lighting systems has drastically risen with nearly all the top lighting companies showing a keen interest in developing more IP within this space. With research around incandescent lighting and to a lesser extent fluorescent lighting dropped, it appears that LED is quickly becoming very relevant in terms of the future of lighting systems. Patent publication trends show a steady and sharp increase in filings over the recent years and the current year's figures for the first few months look equally promising for this technology.

From what we have seen through the insights revealed by IP activity and patent data, LED technology is going to play an important role in lighting systems across various industries. It may well be what the light bulb was several years ago.

About Patent iNSIGHT Pro

Patent iNSIGHT Pro™ is a comprehensive patent analysis platform that allows you to accelerate your time-to-decision from patent analysis activities. Designed from inputs by experienced patent researchers, Patent iNSIGHT Pro easily blends into your existing Research workflow. Patent iNSIGHT Pro is used by leading legal services, Pharmaceutical & biotech, electronics companies and research organization across US, Europe, South America and India with more than 180 end users. Patent iNSIGHT Pro is developed and marketed by Gridlogics, a research driven IT Company specializing in providing intellectual property analysis and visualization solutions to aid R&D and corporate strategy.

Gridlogics is headquartered in Pune, India and has a sales presence in Delhi, Mumbai and USA.

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Visit us at: www.patentinsightpro.com

Or call us at: 1-408-786-5524

Or mail us at: contact@patentinsightpro.com