Presented at IPC Printed Circuits Expo®
SMEMA Council APEX®
Designers Summit 04

Non-Telecom Optoelectronics

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Abstract

When we think of optoelectronics in the USA, we automatically think of telecom applications. These fueled huge growth at the turn of the millennium, and even after the bubble burst in 2001-2, telecom represented a significant business and the future of telecommunications. Meanwhile, a number of consumer, medical, automotive, and other applications have developed rapidly, ranging from imaging, displays, biological analysis, and video gaming to lighting. Worldwide non-telecom optoelectronics is now more than 50% of the optoelectronics market. Many issues being tackled by organizations, such as NEMI, are relevant to this area where low-cost packaging has critical technical demands. This paper reviews these applications, the packaging and assembly challenges they present, and the standardization opportunities worldwide.

Introduction

The world-wide optical equipment telecom/datacom business is significant, at $8.5bn[9] but there are other significant markets out there – the display market at $50bn[15] as well as lighting and many smaller markets, e.g. digital cameras and scanners (approximately $3bn in the USA alone).

Introduction

The world-wide optical equipment telecom/datacom business is significant, at $8.5bn (Welch 2003) but there are other significant markets out there – the display market at $50bn[15] as well as lighting and many smaller markets, e.g. digital cameras and scanners (approximately $3bn in the USA alone).

We will attempt to categorize and review these businesses in the following way:

- Conversion of light to electricity
- Conversion of electricity to light
- Light for vision
- Light as an energy source
- Light as a source of energy
- Light as a medium to derive information
- Light as a medium to transmit information
- Light as a medium to display information.

Conversion of Light to Electricity

Most commonly this is carried out using a semiconductor material doped to produce P-type and N-type regions. When a photon enters the semiconductor it can promote an electron into the conduction band in the N-type semiconductor and generate an electrical current as the electron moves around the circuit to fill the vacancies in the p-type semiconductor.

Conversion of Electricity to Light

The total lighting market is significantly larger than the optoelectronics market at $25bn[14] (Figure 1).

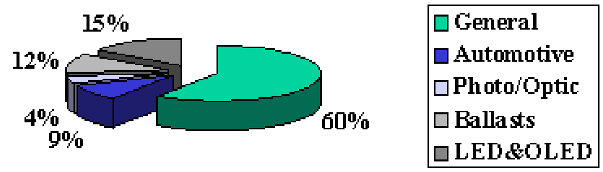

Figure 1 – Total Lighting Market $25bn

There are four main categories of lighting that we will discuss:

1. Incandescent lighting, where a filament is heated to a temperature where light is emitted. Normally the spectral range is wide and the percentage of light emitted in the visible range is low. This is the baseline against which other lighting is judged because it is a mature technology.

2. Fluorescent lights excite a gas with a high voltage and convert the UV portion of light to visible light using phosphors. These are currently the most efficient light sources. In electronics applications the main use is as the illuminating component for backlit flat panel LCD displays which normally have a long thin fluorescent light source which is diffused by lenses and filters behind the screen.
3. Discharge lights (becoming common on automobiles) use a high pressure system which generates light from high pressure Xenon and ionized salts with an efficiency at least three times greater than incandescent bulbs. There is a considerable electronics content in the control systems of these lights and the associated hardware, for example in Europe new regulations dictate load-leveling mechanisms be used to prevent glare to oncoming drivers. (Prismark July 2003)
4. LED lights - an N-type to P-type junction similar to that used in the conversion from light to electricity can also be used as a diode – a one-way valve allowing electrons to flow from N to P but not vice versa. If we force the reverse current by applying voltage, then in some systems electrons will emit visible light as they lose energy from the valence band to the conduction band. The energy (color) of the light can be adjusted by altering the chemical composition of the junction to alter the band gap (see www.howstuffworks.com).

Most lighting systems have been around for a very long time. Even the neon light is over a century old and fluorescent lights date from the 1930's. White LED lighting dates from 1997 and is undergoing rapid development. The market was $2.6bn in 2002 with a growth rate of over 10%.[1] LED lighting technology has improved rapidly (almost following Moore's law in terms of light output and reduced cost) to the stage where it has adequate brightness for many applications and has an efficiency intermediate between incandescent and fluorescent (incandescent 15 Lumens/Watt, fluorescent 75, LED 30 but capable of over 150 in the lab.[9] About 25% of the energy usage in the USA is used for lighting and the most energy-efficient solution is fluorescent light but paradoxically there is environmental pressure to reduce the amount of fluorescent lights because they are a significant user of mercury (about 20mg per bulb) that is not recycled. Discharge lighting is also under scrutiny for mercury use but innovative solutions are being developed[14] LED lighting is a tiny part of the lighting market ($3.8bn for bulbs in the USA alone, according to Freedonia), but all the major lighting companies such as Osram and Philips are extremely active in this area. Automotive lighting is another growth area – about 11% of the market according to Prismark – because of low power consumption, small size and long life.

Light as an Energy Source

Photovoltaic cells – solar cells represent a rapidly growing energy source but only account for a minute proportion of the world's energy generation. They rely on a "free" source of energy (the sun) and have an efficiency of 15%. Given that the sun can apply about a kW per square meter, it is not surprising that solar energy has been strongly promoted. Not all of it can be absorbed by silicon, however as the energy is spread over a wide spectrum and silicon is transparent to some frequencies in the infrared. Efficiency is increased through anti-reflective coatings. The main drawback is the capital cost of generation, about $4 per watt which has limited the size of the current market to about $2bn.[2] This means that the application is limited to remote, luxury or space applications, or applications where the power consumption is very low (e.g. power for emergency phones, outdoor lighting and satellites and hand-held calculators). For a really nice simple summary of solar cell technology consult www.howstuffworks.com.

Light as a Source of Energy

Of the $4.8 billion value of laser sources produced in 2003, 59% were diode lasers and 41% non-diode.[12] By far the largest applications in non-diode lasers were materials processing and medical therapeutics using a wide range of gas and solid-based technologies. The materials processing applications include welding, cutting, via drilling, solder reflow and part marking. Medical applications include ophthalmology and various surgical and cosmetic applications

Light as a Medium to Derive Information (Imaging)

Charge coupled devices, avalanche photodiodes and PIN diodes are used to form images in scanners, cameras and other imaging devices. This is a significant component business and in 2002 was estimated at about 50% of the $4bn components market. Military applications include laser radar ("ladar" and "lidar") that can image through foliage or detect jet engine contrails by aerosol light backscatter.[10]

There is a huge level of activity in the biotechnology world as we set up "lab on a chip" and other diagnostic tools to generate analytical data on pathogens and other materials of interest. In many cases, a phosphorescent reagent can be made to bind to a particular genetic sequence in order to provide a highly selective analytical technique. Detection of low light levels in small samples thus becomes critical especially as applications are ruggedized for real-world security and other applications.

Light as a Medium to Transmit Information (Data Transmission)

We normally think of datacom/telecom infrastructure when we think of data transmission but in fact there are other areas where data transmission is becoming increasingly important and optoelectronics can contribute significantly.

Telematics – information systems management – is driving new local area optical networking concepts like the MOST (Media Oriented Systems Transport consortium) high speed optoelectronics networks already in place in several European vehicles such as the BMW 7 series, Volvo XC 90 and the Citroen C8. When you consider that a typical SUV, minivan or crossover vehicle may need to accommodate radio, CD, DVD, GPS, video, phone and wireless Internet capacity, common protocols and standards and a network that is reliable for the life of the vehicle (over 16 years in the USA) are becoming a necessity.

Light as a Medium to Display Information

As in lighting, there are a number of competing technologies:

1. Cathode-ray tube (CRT)– bulky but relatively inexpensive in moderate sizes and capable of a broad spectrum of colors and intensities. Works by scanning an electron beam across phosphors that emit light.
2. Liquid crystal display (LCD) – flat panel that must be backlit. Traditionally limited in color spectrum and intensity as well as size (each pixel is individually addressed by transparent conductors made of materials such as indium tin oxide) and viewing angle. Relatively slow switching. Inexpensive in small sizes. They work by rotating the plane of polarized light between two polarizing filters.
3. Plasma display – high intensity, broad color spectrum, wide viewing angle best suited to large displays. System loses significant luminance over time and has relatively high power consumption. Phosphors are laid in grooves on a glass or titanium backing and are addressed by orthogonal transparent electrodes on a glass front panel.
4. Light emitting diodes, used mainly in simple displays and signs, represented a significant market of $1.6bn in 2002[1] approximately 50% of the market.
5. Organic LEDs (OLED) – high color and intensity. New technology available in small displays. Potential to use innovative production technologies such as ink jetting. New technologies such as phosphorescent OLEDs are rapidly increasing efficiency[5] and promise cheap, flexible displays.
6. Switched passive arrays generating a flexible paper-like array are another new technology. These flexible displays can be based on a number of LCD technologies, as well as electrical field switched systems using black and white particles embedded into beads.[6] techniques such as vacuum fluorescent displays are used in automotive systems where durability and longevity are critical. (Figure 2)

Figure 2 - Automotive Digital Displays using a Range of Technologies

Color display is measured in terms of the 1953 NTSC triangle which maps out the hues visible to the human eye and those that can be generated by mixing red, yellow and green. Because phosphors are not "pure" colors, the normal CRT or plasma display can cover about 70% of this triangle[11] whereas LCDs traditionally covered a smaller range. The newer LCD's however, have leveled the playing field and are virtually equivalent – even switching times have been improved. Plasma displays also show promise for improvement with "nano-emissive" displays developed by Motorola promising improved performance. In 2003 the TV market is dominated by CRTs with 97% of the market, the rest split between LCD and plasma: but with recent price reductions and the entry of new players such as Gateway and Dell into the market the share of non-CRT displays is expected to double in 2004[4] In general, the LCD panels are dominant below 37" diagonal and plasma displays are dominant above 37" where they also compete with projection TVs. LCD displays have already surpassed CRTs for PC monitors in 2003.

Perhaps the largest display user is the cell phone with over 400 million made per year. Here a mix of monochrome and color technologies using LCD, OLED and low temperature polysilicon is also in flux as competing technologies vie for dominance.

Summary
There are significant opportunities for optoelectronic products outside the conventional telecom/datacom arena. From lighting to automotive data busses to biological analysis, all will require components that must be packaged and interfaced so as to provide low-cost and reliable performance.[7]

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Useful Web Sites

1. www.howstuffworks.com for excellent chapters on photovoltaics, LEDs etc.
2. www.lumileds.com and www.osram-os.com for LED lighting
3. www.mostcooperation.com for automotive optoelectronics
4. www.semi.org for future technology reports on displays
5. www.siemens.com/pof “Pictures of the Future”