

Polymer Light-Emitting Diode

In subject area: [Engineering](#)

Polymer light-emitting diodes (PLED) are devices that convert electric energy into light through the process of electron-hole recombination in photoconductive polymers, offering advantages such as low cost, flexibility, and smooth brightness. They can be constructed from various conjugated polymers and may consist of single or multilayer configurations.

AI generated definition based on: [Natural Fibre Reinforced Vinyl Ester and Vinyl Polymer Composites, 2018](#)

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Chapters and Articles

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Chapter

Electrical-Based Applications of Natural Fiber Vinyl Polymer Composites

[2018, Natural Fibre Reinforced Vinyl Ester and Vinyl Polymer Composites](#)

Faris M. AL-Oqla, ... Osama Fares

18.2.4 Polymer light-emitting diodes

[Photoconductive polymers](#), since they were invented, received high attention especially in the field of converting electric energy



advantages polymers have, i.e., low cost, flexibility to fit any shape, high temperature resistance, PLEDs have smooth brightness, short [response time](#), and a large viewing angle. Fig. 18.5 shows an example of commercially available PLEDs. This makes PLEDs suitable for applications requiring large array of displays (Hameed et al., 2010). Radiation occurs in [PLED](#) due to electron-hole recombination. The cathode injects electrons to the lowest unoccupied molecular orbit (LUMO) of the polymer. Whereas, anode injects holes to the highest occupied molecular orbit (HOMO) of a CP. The materials selected to form the anode, the cathode, and the [emissive layers](#) forming the PLED can affect the reliability and the efficiency of the diode. PLED can be of single layer or multilayer device. One example of PLED is the one constructed from [conjugated polymers](#) including [polyacetylene](#), [polypyrrole](#) (PPy), [polythiophene](#), [polyaniline](#) (PANI), and poly(*para*-phenylene vinylene) (Belgacem and Gandini, 2011). Another example of the active element used in PLED is the poly(*p*-phenylene vinylene) (PPV). Fig. 18.6 below shows an example of multilayer PLED in which glass is used as substrate (Hameed et al., 2010). This substrate is precoated with a [thin film](#) of [indium tin oxide](#) (ITO). Then a [TPD](#) layer of an excess number of holes is placed on the substrate. Another layer of Alq3 is then placed. Alq3 is a highly electroluminescent compound formed of 8-hydroxyquinoline [aluminum](#).

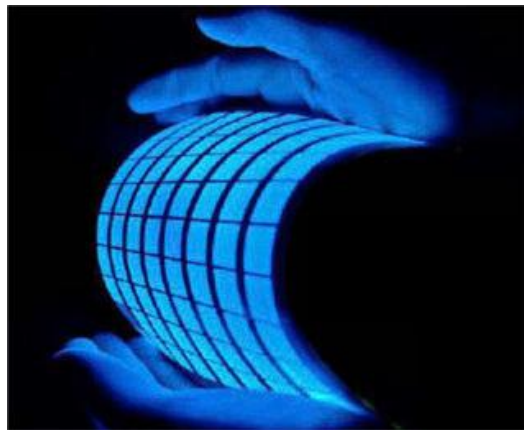


Figure 18.5. Example of commercially available PLED.


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Review article

A review on optoelectronic device applications of 2D transition metal carbides and nitrides

2021, Materials & Design

Xiwei Zhang, ... Lin Ju

3.3 Light emitting diodes

Light emitting diode (LED) is an electronic device that can emit light when an electrical current is passed through it. In the future, new type of [LED](#) which have high efficient with low power consumption, high brightness and solution-processed fabrication will play more and more important roles in flexible and wearable electronics. However, the development of solution-processable transparent electrode with a sufficiently high conductivity has restricted the development of this kind of devices. MXenes are considered to be one of the most promising candidates of novel transparent electrodes because of their high conductivity, optical transparency, and mechanical conformability [38] (Figs. 11 to 12) (Table 3).

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Chapter

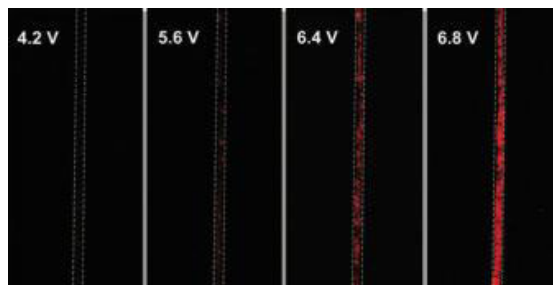
Light emitting textiles for a photodynamic therapy

2016, [Smart Textiles and their Applications](#)

J.-B. Tylcz, ... S. Mordon

4.3 Future of light-emitting fabrics

The last decades were able to witness the advent and democratization of light-emitting devices such as organic light-emitting diodes, polymer light-emitting diodes or polymer light-emitting [electrochemical cells](#) (PLECs) for multiple applications: panel displays, signage, smartphones, televisions and even photodynamic therapy [2]. They have become smaller, more flexible and can even be produced in different shapes and colours. In 2012 a research team from Iowa State University was able to build a one-dimensional electroluminescent device that has a [nanofibre](#) form [16], as illustrated in Fig.4.20. With this solution, [optical fibres](#) will no longer be needed since the electroluminescent nanofibres (called TELF) will [emit light](#) when powered by an electric current. These devices are flexible and can be easily integrated into a [textile substrate](#) to make light-emitting fabrics.

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Chapter

OPTIMIZED POLYMERIC STRUCTURES OF ORGANIC ACTIVE ELECTRONIC COMPONENTS

2020, *Polymers in Organic Electronics*

Sulaiman Khalifeh

6.2.3.5 Organic light-emitting diodes

The organic light-emitting diodes OLEDs (or “polymer light-emitting diodes” PLEDs) are high performance light-emitting diodes of structures formed by organic/polymer semiconductors. The most widely used polymer for such structures is poly(phenylene vinylene) PPV of a bandgap about 2.5 eV with the capability of emitting yellow-green light. Poly(phenylene vinylene) is made up of benzene rings (phenylene units) linked to one another *via* two carbons (each one of them is also bonded to a single hydrogen atom) as illustrated in Figure 6.12.¹⁴⁹ To optimize poly(phenylene vinylene), it has to be modified by attaching alkyl side-chains, such as $(\text{CH}_2)_n\text{CH}_3$ to a phenylene ring. It can be achieved by dissolution in convenient solvent (e.g., xylene) to form uniform thin-films (100 nm thick) on substrates by spin-coating.¹⁴⁹

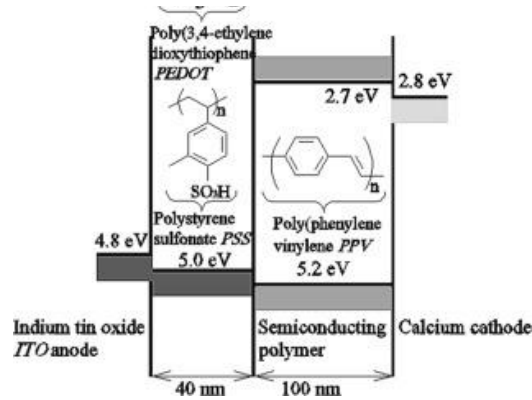


Figure 6.12. Bandgap of organic semiconductors used for structuring organic light-emitting diodes.

[Data from Richard Friend, Jeremy Burroughes and Tatsuya Shimoda,

Polymer diodes, *Cambridge Display Technology* 1999.]Copyright © 1999

According to Figure 6.12,¹⁴⁹ poly(phenylene vinylene) is sandwiched between a calcium cathode and an anode made from a conducting polymer on an [indium](#) tin [oxide](#) ITO layer. Thus, calcium can inject electrons into the associated polymeric film, while the anode injects holes. Both electron and hole capture one another within the poly(phenylene vinylene) layer, thus forming

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Chapter

Carbon Nanotube Fibers for Wearable Devices

2017, *Industrial Applications of Carbon Nanotubes*

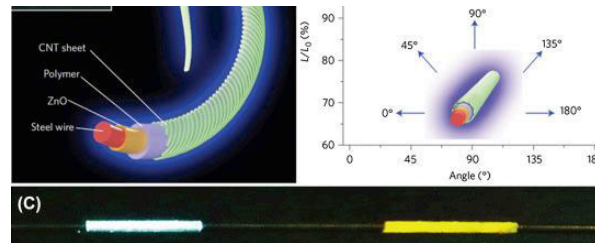
Y. Yao, ... T. Chen

12.3.5 Wearable Fiber-Shaped Polymer Light-Emitting Diode Based on CNTs

Like the fiber-shaped solar cells mentioned earlier, fiber-shaped polymer light-emitting diodes (PLEDs) with a coaxial structure have also been realized by using all-solution-based processes (54,55). In a typical fiber-shaped PLED, a modified steel wire was used as the core cathode, a layer of CNT sheet was used as the



planar PLEDs, the fiber-shaped structure enabled fiber device luminance from all of the outer surface, and the brightness did not depend on the observation angles (Fig. 12.8B). Because of its unique structure and ease of fabrication, it was convenient to integrate a series of devices with different emitting colors into one single-fiber substrate by changing the electroluminescent polymer materials during preparation processes. As a simple model, two PLEDs with blue and yellow luminance were fabricated on one fiber electrode; selected lighting can be easily realized according to different application requirements (Fig. 12.8C–E). The fiber-shaped PLEDs maintained over 90% of their maximum brightness after 100 cycles of bending with a radius of curvature of 6mm, indicating high flexibility. Like other fiber-shaped electronics, the fiber-shaped PLEDs can be easily woven into other textiles (Fig. 12.8F), and PLEDs with different colors can be selectively lit to produce the required configurations (Fig. 12.8G–I).



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Chapter

A new technology platform for fully integrated polymer based micro optical fluidic systems

2006, 4M 2006 - Second International Conference on Multi-Material Micro Manufacture

J. Nestler, ... D. Dresse

2.1 Polymer Light Emitting Diodes and Photodetectors

PLEDs and polymer [photodiodes](#) PPDs are potentially very attractive [light sources](#) and detectors for (disposable) lab-on-chip applications for several reasons. First, organic diodes are very efficient: As light sources their efficiency is comparable to fluorescent lamps ($\sim 100\text{lm/W}$) with our PLEDs emitting a power per unit area of up to 20mW/cm^2 and our photodiodes show an [external quantum efficiency](#) of more than 70 % (see Fig.2). Second, the peak wavelength can be tuned over the visible range by chemical modification of the emitting molecule, and thus can be matched to the specific requirements of the application. Third, these devices are ultra-flat ($< 500\text{nm}$) and compatible with bendable substrates. Last and very importantly, PLEDs and PPDs can be produced by purely additive print processes at room-temperature and can thus be monolithically integrated into almost any system [1].

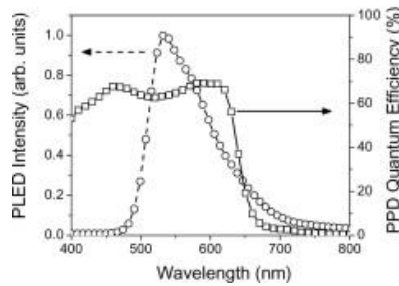


Fig.2. Top: Schematic diagram of light-coupling from PLED into waveguide (WG) and detection by the PPD. Bottom:

Electroluminescence spectrum of a polyfluorene-based PLED (circles) as well as external quantum efficiency of a typical bulk heterojunction C60-polythiophene PPD (squares).

We currently investigate the near-field coupling of PLEDs and PPDs to [waveguides](#). PLEDs have been successfully implemented directly on Ta₂O₅ [planar waveguides](#).

The probably biggest challenge of using PLEDs and PPDs in a lab-on-chip environment is the severe requirements of these devices in terms of encapsulation and protection against oxygen and

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Review article

Shining carbon dots: Synthesis and biomedical and optoelectronic applications

2016, *Nano Today*

Fanglong Yuan, ... Shihe Yang

Light-emitting diodes

Light-emitting diodes (LEDs) have been the subject of intense academic research for years, aiming at their potential applications in liquid-crystal displays and full-color displays and as the next generation of lighting sources in our daily life [200,201]. As a new kind of fluorescent [QDs](#) system, the emerging quantum-sized [CDs](#) appear to be a promising alternative to rare earth-based



cost and [low environmental impact](#). The large [PL](#) bandwidth of CDs make them good candidates for fabricating white LEDs (WLEDs), which have become an important energy-saving technology for the sustainable development of our society due to their projected long working life time, [low power consumption](#), fast [response time](#) and compact size. Therefore, some efforts have been made to realize the great potential applications of CDs in LEDs.

Generally, the applications of CDs in LEDs can be divided into two types based on the excitation mode: One is based on the optical excitation, which results in color-conversion LEDs using CDs as the phosphors component, and the other is through direct electrical excitation, resulting in LEDs based on the [electroluminescence](#) (EL) of CDs.

LEDs based on the PL of CDs

The LEDs based on the PL of CDs usually consist of UV or blue chips and fluorescent CDs. The CDs are used as phosphors and can be excited by the strong UV or blue light from [EL](#) of the chips. One of the problems with the powders of CDs is the very weak fluorescence due to aggregation induced quenching (AIQ) effect, which greatly hampered the development and applications of CDs in LEDs. To avoid the AIQ effect, many groups have demonstrated that CDs embedded in [solid matrices](#) such as [borax](#) (as is illustrated in Fig. 9a) [52], [silicone](#) [202–204], starch [205], [cellulose nanofiber](#) [206], and resin [207–211] can preserve the fluorescence, renewing the promise of CDs in WLEDs. Tang et al. showed [GQDs](#) as an excellent light converter by coating a layer of their GQDs onto a commercially available blue LEDs centered at 410nm for the first time [74]. Upon the coating of the GQDs, the intensity of the blue light weakened and a broad band peaking at about 510nm arose. Concomitantly, the Commission International d'Eclairage (CIE) [chromaticity coordinates](#) of the LEDs shifted from (0.242, 0.156) to (0.282, 0.373), demonstrating the ability of GQDs to convert blue light into white light. The behavior of color conversion was understood as the mixing of the 410nm emission from the blue LEDs and a broad emission at 510nm given by GQDs under the 410nm excitation. Moreover, Chen et al. fabricated WLEDs with UV chips and fluorescent CDs with PL QY up to 47% as phosphors prepared by unzipping [photonic crystals](#), and realized warm white light with color coordinates of (0.45, 0.44) for the first time as shown in Fig. 9b [212]. Before long, they



with CIE coordinates realized at (0.34, 0.35) close to the pure white light emission were fabricated by combining the yellow emitted CDs with blue GaN-based LED chips [213]. Rhee et al. fabricated large-scale (20×20cm) freestanding luminescent films of the CDs based on a poly(methyl methacrylate) matrix, which not only provide mechanical support but also disperse the CDs to prevent solid-state quenching [214]. Finally, they demonstrated WLEDs consisting of the films as color-converting phosphors and InGaN blue LEDs as illuminators, and the WLEDs exhibited no temporal degradation in the emission spectrum under practical operation conditions (Fig. 9c). Although a single phosphor can be easily combined with blue LEDs for WLEDs, the resulting correlated color temperature (CCT) can not be readily varied without compromising the high color rendering index (CRI). Coating UV LEDs with multicolor phosphors can maintain high CRI by changing the ratio of the phosphors. Therefore, in order to enhance the CRI and tune the CCT of WLEDs, Sun et al. fabricated WLEDs which integrated high PL QY blue CDs with yellow and red Cd-free zinc copper [indium sulfide](#) (ZCIS) core/shell QDs, which is shown in Fig. 9d [215]. The as-prepared WLEDs exhibited a very high CRI of 93, exceeding that of the YAG:Ce based commercial WLEDs (CRI<75). Thereafter, Sun et al. further realized WLEDs with high CRI (85–96) and widely variable CCT (2805–7786K) by combining three phosphors based on blue CDs, green and red polymer dots (Fig. 9e). The WLEDs showed excellent color stability against the increasing current because of the similar response of the tricolor phosphors to the UV light variation [216].

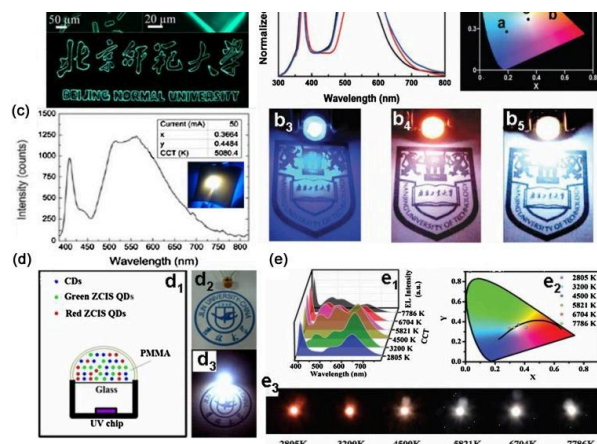


Fig. 9. (a) Fluorescence microscopy images and graphic patterns on a copper piece of B-GQDs crystals obtained by evaporating B-GQDs borax aqueous solution at room temperature. Reprinted with permission from [52]. Copyright 2014 Elsevier. (b) Emission spectra, CIE 1931 chromaticity coordinates and photographs of the corresponding LEDs. Reprinted with permission from [212]. Copyright 2012 Royal Society of Chemistry. (c) Emission spectra, CIE chromaticity coordinate and photograph of the WLEDs. Reprinted with permission from [214]. Copyright 2013 American Chemical Society. (d) Schematic diagram and the photographs of the WLEDs without and with biased current. Reprinted with permission from [215]. Copyright 2014 AIP Publishing. (e) EL spectra, CIE color coordinates and true-color images of various WLEDs. Reprinted with permission from [216]. Copyright 2015 Royal Society of Chemistry.

Though LEDs based on the PL of CDs have been demonstrated by incorporating CDs into solid matrices, the introduction of a thick solid matrix layer will depress the luminescence from chips and also increase the costs. The best way is to achieve high-quality luminescence in the solid state for fluorescent CDs and then directly use these materials as phosphors in LEDs. Li et al. prepared intercrossed carbon [nanorings](#) (CNRs) with very pure hydroxyl [surface states](#) for the first time, which enabled them to overcome the AIQ effect, and to emit yellow-orange luminescence in both colloidal and solid states (Fig. 10a). As a direct benefit of such scarce solid luminescence from [CNRs](#), they were used as low-cost and environment-friendly phosphors on blue chips, and hence WLEDs were achieved with optimized color coordinate of (0.28, 0.27), which is close to pure white light (0.33, 0.33) [25]. Through surface modification of CDs or interparticle spacing control their aggregates, tunable solid-state fluorescence (SSF) of nitrogen-doped CDs (NCDs) has been successfully obtained for the first time. WLEDs was further realized by taking advantage of the



hence reduced the cost compared with existing methods (Fig. 10b) [217]. Except the wide applications of CDs as phosphors for fabrication WLEDs, Rhee et al. fabricated LEDs exploiting CDs surface functionalized with para-substituted anilines as a phosphor, converting UV light to a variety of colors (Fig. 10c) with the aid of their excellent fluorescent QY and long-term stability [218].

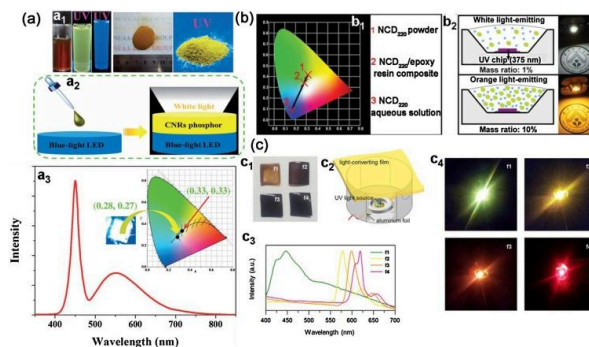


Fig. 10. (a₁) Images of CNRs dispersions and powders under sunlight and UV light, (a₂) Fabrication strategy of WLEDs based on blue LEDs, (a₃) EL spectra of WLEDs. The insets are the digital image of the device and the corresponding CIE chromaticity diagram. Reprinted with permission from [25]. Copyright 2015 John Wiley and Sons. (b₁) CIE coordinates of NCD₂₂₀ powder, composite, and NCD₂₂₀ aqueous solution under UV light, (b₂) Schematic and photographs of the white and orange LEDs. Reprinted with permission from [217]. Copyright 2016 John Wiley and Sons. (c₁) Photographs of light-converting films, (c₂) Construction of LEDs, (c₃) Emission spectra and (c₄) photographs of LEDs. Reprinted with permission from [218]. Copyright 2015 Nature Publishing Group.

However, up to now, the research of the CDs-based LEDs is still at an early stage with relatively low efficiencies compared with well developed QDs-LEDs. [Luminous efficiency](#) and CRI are important parameters to evaluate the quality of WLEDs, and it is still difficult to obtain CDs-based WLEDs with high CRI and high [luminous efficiency](#) due to the low QY of the long wavelength emission from CDs. Therefore, new strategies for large-scale production of CDs with high QY of the long wavelength emission beyond the blue light region need to be developed for the LED application.

LEDs based on the EL of CDs

For applications in EL devices, CDs can also be used as an active emission layer sandwiched in a multilayer device structure. The first electrically driven LEDs based on CDs was reported by Gupta et al. with the fabrication of [organic LEDs](#) (OLEDs) based on GQDs



phenylenevinylene) (MEH-PPV) with different GQDs doping concentrations were employed as the active emission layer and tested in OLEDs under the optimized conditions. As shown in Fig. 11a, the turn-on voltage of the device decreased from about 6V for the pure MEHPPV sample to about 4V for MEH-PPV with 1% MB-GQDs. At a higher concentration of 3% MB-GQDs, [charge trapping](#) as well as a shortening effect occurred, possibly due to agglomeration. The maximum light-emission intensity increased with the addition of MB-GQDs to MEH-PPV, directly reflecting the enhanced [internal quantum efficiency](#). In mechanism, the MB-GQDs dispersed in the MEH-PPV afforded additional electrical transport paths that improved [charge injection](#) and consequently the carrier density, therefore resulting in a lower turn-on voltage. After that, WLEDs based on an [emissive layer](#) of CDs passivated with 1-hexadecylamine which was sandwiched between a poly(ethylenedioxythiophene):polystyrenesulphonate (PEDOT:PSS) hole injection layer and a 1,3,5-tris(*N*-phenylbenzimidazol-2-yl) benzene (TPBI) electron transport layer have been successfully demonstrated for the first time by Wang et al. [219]. A maximum [external quantum efficiency](#) of 0.083% at a current density of 5 mA cm^{-2} with a CRI of 82 and CIE coordinates of (0.40, 0.43) is realized, indicating that CDs have great potential to be an alternative phosphor for fabricating white light EL devices.

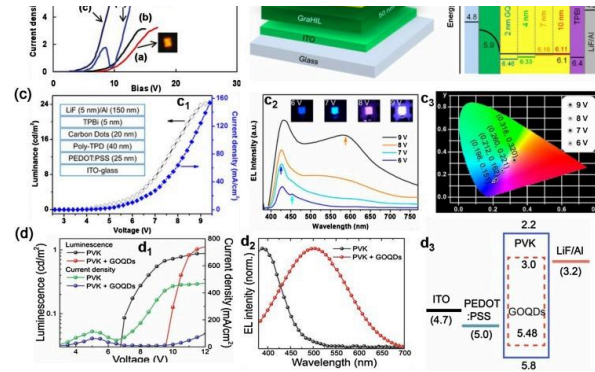


Fig. 11. (a) Current density of MEH-PPV with different concentrations of MB-QDs as a function of the applied voltage. Reprinted with permission from [119]. Copyright 2011 American Chemical Society. (b) Physical and electronic structures of OLEDs employing the QDs. Reprinted with permission from [101]. Copyright 2014 American Chemical Society. (c₁) Current density and brightness of the CDs-LEDs, (c₂) EL spectra and true color photographs of blue, cyan, magenta, and white emissions, (c₃) CIE coordinates of the CDs-LEDs operated under different voltages. Reprinted with permission from [220]. Copyright 2013 American Chemical Society. (d₁) Current density and brightness of PLEDs using pristine PVK and GOQDs blended PVK as emissive layers, (d₂) EL spectra and schematic energy diagram (d₃) of PLEDs.

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Chapter

Developments in digital print technology for smart textiles

2009, [Smart Clothes and Wearable Technology](#)

C. Treadaway

15.4.2 Light-emitting textiles and flexible displays

Textiles in which pattern may comprise moving images and dynamic changing colours may be possible as a result of technological advances in flexible textile displays using polymer light-emitting diodes (PLEDs). This emissive technology consists of a polymer material, printed onto a substrate of glass or plastic,



energy efficient and is currently being developed into ultra-thin displays. This technology can also be used in reverse to create photovoltaic (PV) devices, which convert light into electricity and are used to make [polymer solar cells](#) (Lee, 2005). These will provide bendable, disposable solar power sources for numerous applications and have the potential to power flexible PLED textile displays, capable of displaying pattern and moving video images. Applications requiring dynamic patterns, which may be responsive to light or emotion, will provide new creative challenges to designers in the future. Surface patterns that evolve in real time will bring a new meaning to the concept of 'design collection' and will require agility in creative thinking and ability

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Review article

Broadly tunable metal halide perovskites for solid-state light-emission applications

2017, [Materials Today](#)

Sampson Adjokatse, ... Maria Antonietta Loi

Introduction

Solid-state light-emitting devices such as light-emitting diodes (LEDs) and lasers play important roles in modern day life. They have the potential to address urgent challenges not only relating to general lighting and display applications but also relating to energy saving and greenhouse gas emissions [1]. Through development of materials science, a variety of [light emitting](#) materials have been demonstrated since the first demonstration of visible-spectrum LEDs based on gallium arsenide phosphide (GaAsP) over five decades ago [2]. This has led to the evolution of various [LED](#) technologies: inorganic semiconductor LEDs [2–7], [organic LEDs](#) (OLEDs) [8–11], polymer LEDs (PLEDs) [12,13],



Perovskites are a class of compounds that adopts the ABX_3 three-dimensional (3D) structural framework (see Fig. 1a), where A and B are cations of various valence and [ionic radii](#) and X is an anion. For metal-halide [hybrid perovskites](#), the A component is usually a monovalent organic cation [typically methylammonium ($CH_3NH_3^+ = MA^+$) or formamidinium ($HC(NH_2)_2^+ = FA^+$)], an atomic cation (typically [Cs⁺](#)) or a mixture thereof, the B component is often a divalent metal cation (usually Pb^{2+} , Sn^{2+} or a mixture) and X component is a [halide](#) anion (typically Cl^- , I^- , Br^- or a mixture thereof) [28–36]. The synthesis of this class of materials is usually performed in solution from which bulk, layered or nanostructured perovskites can be obtained. For example, Liu *et al.* [37] and Shi *et al.* [38] have shown that large-sized perovskite single crystals with dimensions exceeding 10mm with high [crystalline quality](#) can be grown. Figure 1b shows a photograph of a representative $MAPbX_3$ (X=Cl, Br, I) perovskite single crystals grown using a solution method [37]. The substitution of the halogen ion transforms the color of the single crystals from colorless (X=Cl) to orange (X=Br) and then to black (X=I). Mohite and colleagues [39] also demonstrated the formation of continuous perovskite [thin films](#) with millimeter-scale crystalline grains that are devoid of pinholes via solution-based hot-casting technique (Fig. 1c). In addition to bulk (single crystals and films) perovskites, [nanostructures](#) (quantum dots, [nanoplatelets](#) and nanowires) (Fig. 1d) of exceptional photophysical properties have also been reported [40–43].

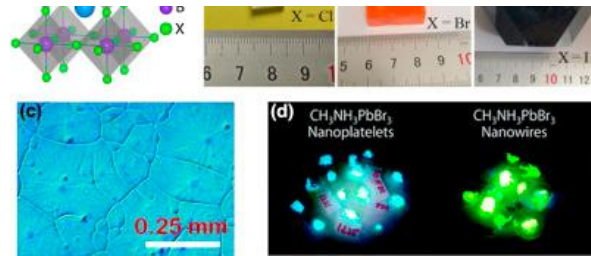


Figure 1. (a) Schematic model of the perovskite crystal structure. 'A' represents the organic or inorganic cation, 'B' represents the metal ion, and 'X' represents the halogen ion; (b) photographs taken from the as-grown $\text{CH}_3\text{NH}_3\text{PbX}_3$ crystals. Reprinted with permission from [37]; (c) optical micrograph showing continuous perovskite thin film with millimeter-scale crystalline grains formed via solution-based hot-casting technique [39]. Reprinted with permission from AAAS; (d) photographs of thin films of blue-emitting nanoplatelets and green-emitting nanorods, taken under UV radiation [141]. Reprinted with permission of The Royal Society of Chemistry.

Hybrid perovskites have demonstrated their superiority in the [photovoltaic](#) field as light absorbers with current certified [power conversion efficiency](#) (PCE) of 22.1% [44]. They have also shown to have characteristics that are ideal for light emission-based and X-ray detection technology [20,23–26,45–47]. In fact, they exhibit tunable color emission and high [quantum efficiency](#), making them suitable for the fabrication of cheap and green electroluminescent devices. Devices such as light-emitting diodes

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Chapter

A new technology platform for fully integrated polymer based micro optical fluidic systems

2006, 4M 2006 - Second International Conference on Multi-Material Micro Manufacture



2 Micro Optical Concepts

2.1 Polymer Light Emitting Diodes and Photodetectors

PLEDs and polymer [photodiodes](#) PPDs are potentially very attractive [light sources](#) and detectors for (disposable) lab-on-chip applications for several reasons. First, organic diodes are very efficient: As light sources their efficiency is comparable to fluorescent lamps ($\sim 100\text{lm/W}$) with our PLEDs emitting a power per unit area of up to 20mW/cm^2 and our photodiodes show an [external quantum efficiency](#) of more than 70 % (see Fig.2). Second, the peak wavelength can be tuned over the visible range by chemical modification of the emitting molecule, and thus can be matched to the specific requirements of the application. Third, these devices are ultra-flat ($< 500\text{nm}$) and compatible with bendable substrates. Last and very importantly, PLEDs and PPDs can be produced by purely additive print processes at room-temperature and can thus be monolithically integrated into almost any system [1].

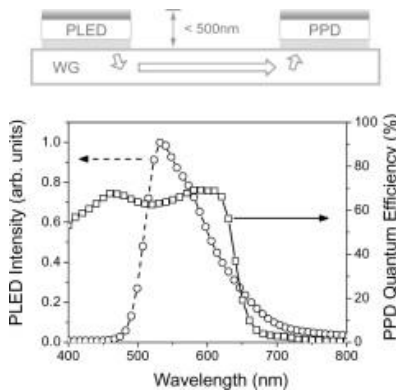


Fig.2. Top: Schematic diagram of light-coupling from PLED into waveguide (WG) and detection by the PPD. Bottom: Electroluminescence spectrum of a polyfluorene-based PLED (circles) as well as external quantum efficiency of a typical bulk heterojunction C60-polythiophene PPD (squares).

We currently investigate the near-field coupling of PLEDs and PPDs to [waveguides](#). PLEDs have been successfully implemented directly on Ta_2O_5 [planar waveguides](#).

The probably biggest challenge of using PLEDs and PPDs in a lab-on-chip environment is the severe requirements of these devices in terms of encapsulation and protection against oxygen and moisture. We are currently addressing this issue by developing



2.2 Waveguides and coupling gratings

[Grating couplers](#) built into waveguides are very effective for coupling light from the [free space](#) to a [waveguide](#) and vice versa. Moreover, they can be used as [refractive index](#) sensor. High index waveguides can be very effective light collectors from sources located in the [evanescent wave](#). They can also be used to perform optical processing inside a waveguide: wavelength filtration like in telecom or for polarisation processing. Amongst the different principles to couple light into and out of a waveguide (direct butt-coupling, prism coupling, grating coupling), the grating coupler is one of the most attractive and effective: it is fully planar and, therefore, compatible with technologies of the microelectronic industry for mass production. Grating couplers are also versatile because their efficiency can be controlled by the grating groove depth and profile shape and they can be adjusted to the free space beam size.

Waveguides with gratings have been used for refractive index sensing, the basic principle is to monitor the [propagation constant](#) of the waveguide mode using the coupling properties of the waveguide grating. The propagation constant of the waveguide mode is affected by the change of refractive index occurring in the medium located in the vicinity of the waveguiding layer (high refractive index layer). The propagation constant can be monitored by the coupling angle [2], the [grating period](#) [3] or the wavelength of the light [4]. This was applied in [biochemical](#) sensing: in this case, the grating waveguide surface is functionalized with a recognition molecule such as an antibody, when molecules (antigens) bind to the functionalized surface, the refractive index and thickness of a thin layer on top of the grating change and modify the propagation constant that can be monitored in real time. The grating of the waveguide can be optimized for the different types of sensing such as thin layer sensing (case of antibody antigen interaction), matrix like sensing (case of a sensitive hydrogel) and particle sensing (case of cell sensing) [5].

When light sources are located in the vicinity of a waveguide mode (the so-called [evanescent](#) wave), the coupling efficiency to the waveguide mode is very high. This was applied for a fluorescent biosensor: the waveguide mode excited the fluorescent molecules and the coupled fluorescent light was analysed as a function of the [analyte concentration](#) [6]. This principle will also be applied in the case of the coupling of the



couple to the evanescent mode of the waveguide.

Waveguide grating have also interesting properties for intra-waveguide optical processing: when guided light is incident at an angle onto the grating there will be only one wavelength under which light will be reflected (the Bragg wavelength). This reflection will also have polarization properties that can be used for polarization [interferometry](#) [7]. If we now consider a grating with a variable periodicity along the [propagation direction](#) - a chirped grating - , the [Bragg wavelength](#) will vary with the position and an integrated spectrometer can be realized this way (see Fig.3).

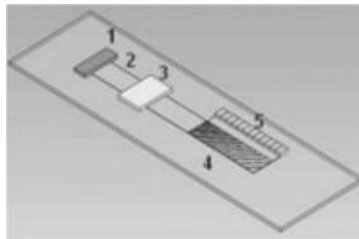


Fig.3. Schematic diagram of a waveguide-plasmon sensor comprised of a PLED (1) coupled to a planar waveguide (2) region, a plasmon resonance section (3) and an integrated spectrometer (4). A slanted and chirped grating redirects the light to the detector line array (5).

A simplified version with less potential for integration is a simple straight grating without constant period. It also has dispersing properties but needs propagation through the free space and needs additional [optics](#) for light collection. It is, however, a good alternative in such cases where the detection part can be realized at an external readout system.

3.3 Replication technology for waveguides and gratings

Disposable sensor concepts also demand for low-cost fabrication technologies related to waveguides and gratings.

A few years ago, a sensor platform based upon an integrated [optical sensor](#) chip was already developed for applications in biochemical and chemical sensing. The fabrication technology involves replication of a [microstructured polymer](#) chip followed by the [vacuum deposition](#) (DC [magnetron](#) sputtering) of a TiO₂ waveguide film [8,9]. The original grating microstructure is fabricated by e-beam writing and, after processing, electroformed to a nickel shim for the replication process which can be hot

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