Available online at www.sciencedirect.com

ScienceDirect

materialstoday: PROCEEDINGS

Materials Today: Proceedings 3 (2016) 733 – 738

12th International Conference on Nanosciences & Nanotechnologies & 8th International Symposium on Flexible Organic Electronics

Inkjet Printed Organic Light-emitting Electrochemical Cells for Disposable Lab-on-chip Applications Manufactured at Ambient Atmosphere*

Z. Shu[a,b]*; O. Pabst[b], E. Beckert[b], R. Eberhardt[b], A. Tünnermann[a,b]

[a]*Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University Jena, Max-Wien-Platz 1, D-07743 Jena*
[b]*Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Department of Precision Engineering, Albert-Einstein-Str. 7, D-07745 Jena*

Abstract

Microfluidic lab-on-a-chip devices can be used for chemical and biological analyses such as DNA tests or environmental monitoring. Such devices integrate most of the basic functionalities needed for the analysis on a microfluidic chip. When using such devices, cost and space intensive lab equipment is thus not necessary. However, in order to make a monolithic and cost-efficient/disposable sensing device, direct integration of excitation light source for fluorescent sensing is often required. Organic light emitting diodes (OLEDs) have the advantages of self-emitting property, high luminous efficiency, full-color capability, wide viewing angle, high contrast, low power consumption, low weight and flexibility. All these capacitate OLEDs to be a suitable optical source for microfluidic devices. However, low work function cathode and/or electron injection layer like Ba, LiF are indispensable for high bright OLEDs, which require vacuum deposition and inert fabrication atmosphere. Hereby we introduce a fully solution processable deviation of OLEDs, organic light-emitting electrochemical cells (OLECs) as a low-cost excitation light source for a microfluidic sensing platform. By mixing metal ions and a solid electrolyte with light-emitting polymers as active materials, an in-situ doping and in-situ PN-junction can be generated within a three layer sandwich device. Because of this doping effect, work function adaption is not necessary and air-stable cathodes like silver can be used. A manufacturing process for fully solution-processed OLECs is presented, which consist of an inkjet-printed silver cathode, spin-coated blue light-emitting polymer plus dopants and an inkjet-printed PEDOT:PSS transparent top anode. Furthermore, by

* Corresponding author. Tel.: +49-3641-807 353; fax: +49-3641-807 604.
E-mail address: zhe.shu@iof.fraunhofer.de

Selection and peer-review under responsibility of the Conference Committee Members of NANOTEXNOLOGY2015 (12th International Conference on Nanosciences & Nanotechnologies & 8th International Symposium on Flexible Organic Electronics)
doi:10.1016/j.matpr.2016.02.004

replacing silver with ITO, a fully transparent blue OLEC is able to emit > 2500 cd/m^2 light under pulsed driving mode, which fulfils requirements for simple fluorescent on-chip sensing applications.

Selection and peer-review under responsibility of the Conference Committee Members of NANOTEXNOLOGY2015
(12th International Conference on Nanosciences & Nanotechnologies & 8th International Symposium on Flexible Organic Electronics)

Keywords: OLED; OLEC;Inkjet printing; Spin-coating; Organic Light-emitting Diodes; Organic Light-emitting Electrochemical Cells; Microfluidic; Ambient Manufactury; Lab on a chip;

1. Introduction

Due to significant demands for low-cost and disposable biological/medical sensing devices, efforts are made to develop microfluidic lab-on-a-chip systems for point of care applications [1]. Microfluidic chips are miniaturized microanalysis labs fabricated on compact chip substrates, in which small fluid volumes can be controlled, mixed, and analysed. In order to realize most of the basic functionalities needed for the analysis on a microfluidic chip without external components, functional units such as valves, pumps, heaters, fluorescent light sources, and detectors are required [2]. Although fluorescent sensing is the most common analytical and diagnostic method in biological and medical applications [3], very few examples of fully integrated compact and low cost fluorescence sensing systems on microfluidic chips can be found. This is mainly due to the reason that widely used sensing units based on LASERs, LEDs, and silicon photodiodes have relatively large dimensions and can only be integrated by external bonding. Organic light emitting diodes (OLEDs) have the advantages of self-emitting property, high luminous efficiency, full-color capability, wide viewing angle, high contrast, low power consumption, low weight and flexibility. All these capacitate OLEDs to be a suitable optical source for microfluidic devices [4]. However, low work function cathode and/or electron injection layer like Ba, LiF are indispensable for high bright OLEDs, which require vacuum deposition and inert fabrication atmosphere [5]. Therefore, a fully solution processable deviation of OLEDs, organic light-emitting electrochemical cells (OLECs) could be a low-cost excitation light source for a microfluidic sensing platform. By mixing metal ions and a solid electrolyte with light-emitting polymers as active materials, an in-situ doping and in-situ PN-junction can be generated within a three layer sandwich device. Because of this doping effect, work function adaption is not necessary and air-stable cathodes like silver can be used [6]. Here, we introduce a manufacture process of OLEC by inkjet printing and spin-coating, which could be a potential low-cost integration method for fluorescent sensing excitation light source for disposable and portable lab-on-a-chip systems. Inkjet printing is a drop-on-demand type digital deposition technique. By directly printing the functional ink onto various substrates like glass and polymeric chips, inkjet printing can integrate various functionalities using only small amounts of material under ambient conditions [7]. As no vacuum conditions and shadow masks are needed, inkjet printing provides a versatile manufacturing approach for low cost and simple microfluidic chips.

2. Experimental

Material: Blue light-emitting polymer was purchase from Merck KGaA (SPB-02T). Solid electrolyte dicyclohexano-18-crown-6 (DCH18C6) and salt Lithium trifluoromethanesulfonate ($LiCF_3SO_3$) were purchased from Adrich-sigma. To prepare the OLEC ink, SPB-02T was first dissolved into cyclopentanone, and followed by DCH18C6 and $LiCF_3SO_3$ to obtain polymer volume concentration 10 mg/mL and 1 : 1 : 0.18 mass ratio of polymer, DCH18C6 and $LiCF_3SO_3$ [8]. The ink was stirring overnight and heated at 50 °C. The ink was filtered through 1 µm pore size PTFE filters before use. Silver nanoparticle dispersion (Cabot CCI-300) was purchased from Cabot Printed Electronic Materials, and the so-called high conductive PEDOT:PSS ink (PEDOT:PSS P Jet HC V2) was purchased from Heraeus. Both silver and PEDOT:PSS inks were filtered through 0.2 µm pore size filters before injection into printer cartridge. The patterned ITO glass substrates and encapsulation epoxy were purchased from Ossila Inc.
Equipment: Unijet Omni-100 inkjet printer (Unijet, South Korea) with DMC printhead with 10 pL nozzles were used for inkjet printing experiments. A Zygo white light interferometer was used to measure the layer thickness and surface profile. A Plasma oven with 2.4 GHz generator with argon and oxygen flow was used for surface activation.