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# Thin-film organic photodiodes for integrated on-chip chemiluminescence detection – application to antioxidant capacity screening

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ABSTRACT

We demonstrate that solution processed thin-film organic photodiodes (OPDs) can be used as compact and sensitive integrated detectors for antioxidant capacity screening. The OPDs were fabricated with blends of regioregular poly(3-hexylthiophene) (P3HT) and (6,6)-phenyl $C_{61}$ butyric-acid methyl-ester (PCBM). The devices had a broadband photoresponse from 350 nm to 650 nm with a peak responsivity of 0.25 A/W at 550 nm and a dark current density of 0.59 μA/cm$^2$ under 10 mV bias for a device area of 1 mm$^2$. The signal rise and fall times of the detectors were 0.51 μs and 0.66 μs, respectively. The detectors were applied to an on-chip peroxyoxalate chemiluminescence (PO-CL) assay for antioxidant capacity determination. Antioxidant standards were injected into a stream of PO-CL reagents, resulting in a CL emission decrease that correlated with the antioxidant capacity. For the encountered CL signals the OPDs provided a comparable response to photomultiplier tubes (PMTs) commonly used in analytical applications. Antioxidant capacity screening results showed excellent consistency between the two detection methods. The compact and portable detection system is suited not only to low-cost in-the-field antioxidant capacity screening, but could have wider applications for chemiluminescence based diagnostic tests at the point-of-care.



## 1. Introduction

A variety of medical, industrial, and analytical applications require the sensitive detection of light originating for example from chemiluminescent (CL) [1], bioluminescent [2] or fluorescent systems [3]. In CL assays, emitted light is usually converted to an electrical signal with either a photomultiplier tube (PMT) [4–11] or an inorganic semiconductor photodiode (ISPD) [12]. The large size and high voltage requirements of PMT detectors severely limit their use in compact portable instruments. While ISPDs are more suitable for portable applications [13], their fabrication is comparatively complex and they are not compatible with direct fabrication on plastic microfluidic substrates as commonly used for low-cost disposable devices [14]. The emergence of organic/polymer electronic devices that can be fabricated at low cost, e.g. by printing onto flexible substrates, offers new prospects in this area [15]. The combination of organic photodiodes (OPDs) with microfluidic chip structures, for instance, provides a promising route towards disposable, compact and portable devices for environmental, bioanalytical and diagnostic applications.

The work reported herein demonstrates that solution processed thin-film OPDs based on 1:1 weight ratio blends of regioregular poly(3-hexylthiophene) (P3HT) and (6,6)-phenyl $C_{61}$ butyric-acid methyl-ester (PCBM) as the photoconducting materials can be used as sensitive integrated detectors for CL-based antioxidant assays. Specifically, we show that integrated microscale CL can be implemented in a low-cost format using poly(dimethylsiloxane) (PDMS) instead of glass [7–9], quartz [4,10] or silicon [5,12] as the substrate material for the microfluidic chip, and organic photodiodes instead of silicon photodiodes or PMTs as on-chip detectors. PDMS has good biocompatibility and optical transparency over the entire visible range, and more importantly allows for rapid prototyping and scalable manufacture at low cost and with high fidelity. At the same time, organic photodiodes may be fabricated at low temperature using simple layer-by-layer deposition procedures that are fully compatible with plastic substrates. The combination of PDMS

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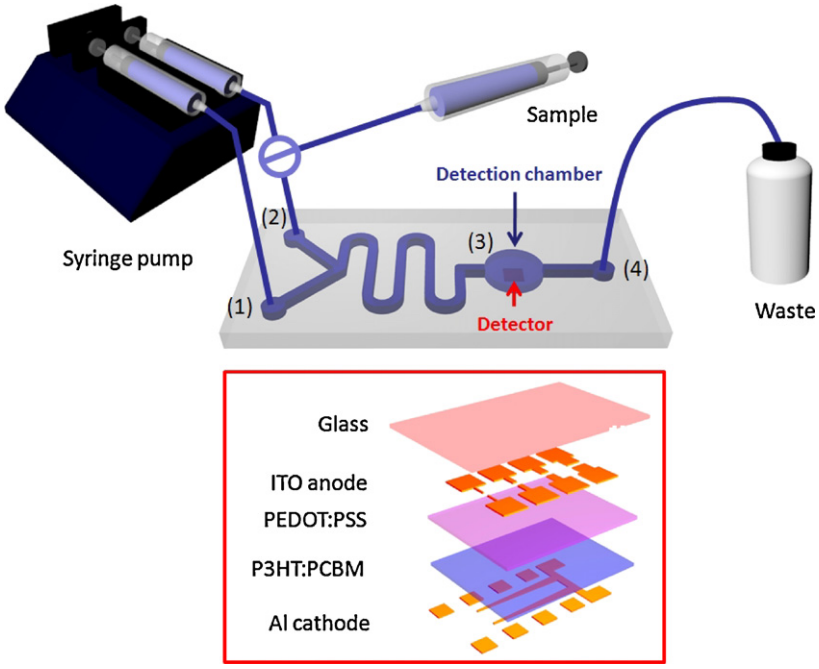


**Fig. 1.** Schematic of the experimental set-up for on-chip antioxidant capacity screening. The PDMS microchip comprised two inlets (1 and 2), a 800 μm-wide, 800 μm-deep and 5 cm-long mixing channel, a 5 mm-diameter circular detection chamber (3), and an outlet (4). Inlets 1 and 2 were connected to syringe pumps loaded with reagent A (PO-CL reagent/dye/catalyst) and reagent B (hydrogen peroxide), respectively. The antioxidants were injected into the hydrogen peroxide stream resulting in a decrease of CL intensity. An organic P3HT:PCBM photodetector was used to detect the CL intensity, as depicted in the bottom inset.

microfluidic devices with organic photodiodes thus offers an attractive route towards fabrication of low-cost portable devices, which integrate microfluidic circuits and detectors into a single monolithic device.

Our detection system was tested by application to an on-chip antioxidant capacity assay. Antioxidants, either as food additives or as pharmaceutical supplements, terminate radical reactions *in vivo*, which can otherwise damage life-essential molecules such as nucleic acids and proteins. Antioxidants include vitamins, such as vitamin C and E, polyphenols and other electron donor molecules [16,17]. Small amounts of reactive oxygen species (ROS), including the hydroxyl radical ($HO^{\bullet}$), superoxide ion ($O^{2-\bullet}$) and hydrogen peroxide ($H_2O_2$), are constantly generated in aerobic organisms in response to both external and internal stimuli [18]. In a healthy person, production of ROS is balanced by the antioxidant defense system. In a situation where a serious imbalance between production of ROS and antioxidant defense occurs, cell injury takes place. This situation is often defined as "oxidative stress" which results in damage to DNA, proteins, lipids and uric acid. Antioxidant intake is considered essential to prevent ROS induced damage in living cells.

In this work, a peroxyoxalate chemiluminescence (PO-CL) assay was employed to determine the antioxidant capacity of various biological extracts. PO-CL is based on hydrogen peroxide induced oxidation of an aryl oxalate ester which results in the formation of an electronically excited intermediate. In the presence of an added fluorophore, energy transfer occurs to the fluorophore which returns to the ground state with concomitant emission of light. PO-CL thus constitutes an indirect CL method with the emission defined by the fluorophore rather than the CL reagent itself. Antioxidants present during the PO-CL reaction scavenge hydrogen peroxide and thus result in a decrease in CL emission. The method used here to determine antioxidant capacity was first proposed by Arnous and co-workers for cuvette-based measurements using standard bench-top instrumentation [19]. Here, we used a microfluidic chip with integrated OPDs and validated our method by comparison against similar measurements using PMT based detection. In previous work, we have reported chemiluminescence detection on a microfluidic chip using vacuum-deposited small molecule detectors [20], and more recently the use of solution-processed organic detectors for the on-chip determination of hydrogen peroxide, yielding sensitivities comparable to silicon photodiodes [21,22]. Here we demonstrate that by localising the detector in the vicinity of the analytical microchannel and by using detectors with maximum responsivity at the CL emission wavelength, we can achieve sensitivities comparable to PMT detection in a compact and low-cost format.

## 2. Experimental

### 2.1. Chemicals

All chemicals were analytical grade and used without further purification. PO-CL reagents were extracted from Omniglow lightsticks (Omniglow Ltd, Salisbury, Wiltshire, UK). The active ingredients were bis(2-carbopentyloxy-3,5,6-trichlorophenyl)oxalate (CCPO), 9,10-bis(phenylethylnyl)-anthracene (green dye), sodium salicylate (catalyst) and hydrogen peroxide (oxidant). Solution A (PO-CL reagent/dye/catalyst) and solution B (hydrogen peroxide) from the lightsticks were employed in all experiments. A mixture of ethyl acetate and acetonitrile in a volume ratio of 3:7 was used as a solvent system for the preparation of antioxidant standards. As typical plant-based antioxidants, α-tocopherol (vitamin E), β-carotene (vitamin A) and quercetin were employed (Sigma–Aldrich, Gillingham, UK).

### 2.2. Microfluidic chip

The schematic layout of the integrated microfluidic device is shown in Fig. 1. The microfluidic PDMS chips were fabricated in-house using standard soft lithography techniques as described previously [23–25]. The PDMS layer was sandwiched between two glass plates with the top plate comprising capillary reservoirs which

were connected to the microchannel ends through drilled access holes. For simplicity the glass plates are not depicted in Fig. 1. Permanent bonding of this hybrid microchip was achieved by exposing the PDMS layer to an oxygen plasma for 30 s prior to microchip assembly (Plasma Prep II, Structure Probe Inc., West Chester, USA). This yielded a robust microchip system which showed no fluid leakage even at high flow rates and after extended use. The two inlets of the microchip were connected to a precision syringe pump (PHD 2000, Harvard Apparatus, Kent, UK) loaded with PO-CL solutions A and B. Injection of the antioxidant plug was achieved via an in-line Rheodyne injection valve (50 μL injection loop) which was connected to the hydrogen peroxide inlet.

### 2.3. Evaluation of hydrogen peroxide scavenging capacity

The employed method was first proposed for the determination of hydrogen peroxide scavenging capacity of natural and polyphenolic antioxidants by Arnous et al. [19] and Mansouri et al. [26]. The method is based on an indirect PO-CL assay with 9,10-diphenylanthracene (DPA) as the fluorescent probe. The peroxyoxalate reacts with hydrogen peroxide in the presence of the DPA fluorophore which produces intense and short-lived blue emission. When an antioxidant is present in the assay, it acts as a scavenger on hydrogen peroxide and thus inhibits light emission. By using a constant amount of peroxyoxalate reagent and hydrogen peroxide, the traces of an antioxidant can thus be quantified from the reduction of the CL intensity. The CL intensity $I$ is related to the antioxidant concentration $C$ by

$$\frac{I_o}{I} = a \times C + b \quad (1)$$

where $I_o$ is the CL intensity in the absence of antioxidant, and $a$ and $b$ represent the gradient and the y-intercept of the graph, respectively. Setting $I_o/I = 2$ in the above equation, the concentration of the antioxidant causing a 50% reduction in CL intensity can be calculated. This concentration is denoted here as $IC_{50}$. The hydrogen peroxide scavenging activity ($SA_{HP}$) in $\mu M^{-1}$ is defined as

$$SA_{HP} = \frac{1}{IC_{50}} \quad (2)$$

### 2.4. Sample preparation for antioxidant capacity screening

Five herbs were selected as samples for the total antioxidant assay: *Alpinia galanga* (Galagal), *Kaempferia galanga* (Krachai), *Cymbopogon citratus* (Lemongrass), *Mentha piperita* (Mint) and *Ocimum spp* (Thai basil). The extraction scheme was adapted from the method reported by Parejo et al. [27]. The plants were dried in an oven at 40 °C overnight to ensure constant weight, followed by powdering in a mill. An amount of 2.5 g of each dried and powdered plant material was then subjected to extraction with 25 mL methanol by stirring for 4 h, followed by maceration for 24 h. After filtration, methanol was evaporated and the extracts were redissolved in 25 mL of water, kept at 4 °C for 12 h, and then filtered again, thus yielding the crude extract (CE1). This extract was then partitioned with hexane (25 mL fractions were repeatedly extracted until discoloration of the organic solvent was observed), thus obtaining both the hexane fraction (H × F) and the clean crude extract (CE2). The CE2 was then continuously partitioned with dichloromethane and ethyl acetate. Finally, the ethyl acetate fraction (EAF) was measured for total antioxidant capacity using the microfluidic method described above with PMT or OPD based detection.

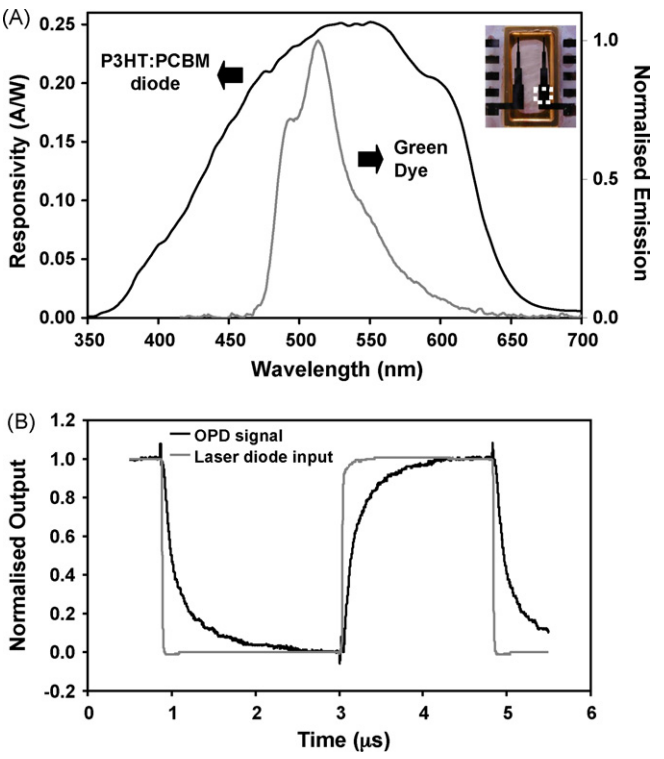


**Fig. 2.** Performance characteristics of employed organic photodetectors. (A) Responsivity of P3HT:PCBM OPD and overlap with CL emission of Cyalume Green. The inset depicts a photodetector device with 8 pixels of varying size with the dotted line denoting the 9 mm² pixel used for the measurements reported here. (B) Typical response curve for a 9 mm² P3HT:PCBM photodetector pixel. The grey line shows the laser diode illumination. The photodetector response indicates a rise time of ~0.51 μs and a fall time of ~0.66 μs.

### 2.5. Responsivity and transient response of P3HT:PCBM organic photodiodes

The responsivity of the solution-processed thin-film P3HT:PCBM organic photodiodes was determined using a 150 W xenon lamp (Bentham Instruments Ltd., Reading, UK), a CM110 monochromator (CVI Technical Optics, Onchan, UK), and a 236 Source-Measure-Unit (SMU) (Keithley, US). The spectrum was corrected for the intensity of incident light using a reference spectrum from a calibrated silicon photodiode (UV-818, Newport, UK). The responsivity of the photodiode and emission spectrum from the CL reaction are shown in Fig. 2A. The transient response of the organic photodiode was measured by illumination with square wave modulated light at 250 kHz from a fast response semiconductor laser diode (647 nm, ~1 mW) and the transient voltage was measured across a 50 Ω terminating resistor with a Tektronix TDS220 digital oscilloscope. As shown in Fig. 2B the observed rise and fall times of the 1 mm² OPDs were 0.51 μs and 0.66 μs, respectively, corresponding to a bandwidth of ~500 kHz.

### 2.6. Chemiluminescence detection

#### 2.6.1. PMT based detection

An inverted fluorescence microscope (MEA153; Seefelder Messtechnik, Germany) equipped with a Hamamatsu R3896 photomultiplier tube [28] served as a reference detection system. Briefly, emission was collected by a microscope objective (10×, 0.42 NA) (Newport, Irvine, CA, USA), passed through a dichroic mirror, a suppression filter and through an adjustable detection window before entering the PMT.

*2.6.2. Integrated on-chip detection with OPDs*

The OPD was placed directly beneath the microfluidic chip with the detector pixel coinciding with the microfluidic detection chamber, located 5 cm downstream of the point-of-confluence between the two inlet streams. The OPD was fabricated using a 1:1 weight ratio blend of poly(3-hexylthiophene) (P3HT) and (6,6)-phenyl $C_{61}$ butyric-acid methyl-ester (PCBM), as described in detail elsewhere [22]. The photocurrent of the OPD was measured with a Keithley 2400 Source Meter.

## 3. Results and discussion

### 3.1. A miniaturised PO-CL assay for TAC evaluation

Following on from our previously reported assay for total antioxidant capacity (TAC) determination [23], we have now successfully implemented integrated thin-film organic photodiodes instead of PMT based detection to yield a highly miniaturised and portable analytical device. The advantages of the microfluidic platform were exploited in a simple 2-inlet microchip with an in-line Rheodyne injection valve (50 μL injection loop) connected to the hydrogen peroxide inlet. An integrated system with an organic photodetector (Fig. 1) was developed and its performance was compared with a conventional PMT based detection system. While α-tocopherol (vitamin E), β-carotene (vitamin A) and quercetin served as model antioxidants for system evaluation, the method was subsequently applied to the TAC determination of herbal extracts.

Representative signal profiles obtained for multiple injections of α-tocopherol antioxidant plugs using PMT and OPD based detection are depicted in Fig. 3A and B, respectively. While current analysis times are of the order of 200 s per antioxidant injection it should be noted that the proof-of-concept experiments reported here were solely chosen to demonstrate the validity, accuracy and reproducibility of this microfluidic method for antioxidant capacity determination. Reductions in microchannel dimensions and injected antioxidant plug volumes in conjunction with parallel operation could afford significantly faster analysis and increased sample throughput.

The shape of the signal profiles obtained with PMT based detection (Fig. 3A) was similar to that obtained with OPD detection (Fig. 3B). The shape of the transient response is relatively complicated. In short, the response to an individual plug of antioxidant can be divided into three parts: (i) an initial spike in the intensity above the background level, followed by (ii) a broad dip beneath the background level; and (iii) a final spike above the background level. The two spikes are counter-intuitive but may be rationalised in terms of a local enhancement in hydrogen peroxide concentration at the front and rear of the injected plug due to stacking effects [29]. In the intermediate region, the signal drops as expected due to the scavenging of hydrogen peroxide by the antioxidant. This is the most obvious point at which to determine the antioxidant capacity but the positive spikes can also be used to for quantitation and in fact provide superior limits of detection compared to measurements at the trough. In this mode of analysis, Eqs. (1) and (2) are again used to determine the capacity with $I_0$ now corresponding to the height of the spike obtained from a solvent plug containing no antioxidant. Here, we monitor on the spike preceding the dip in the signal as denoted by the arrows in Fig. 3A and B.

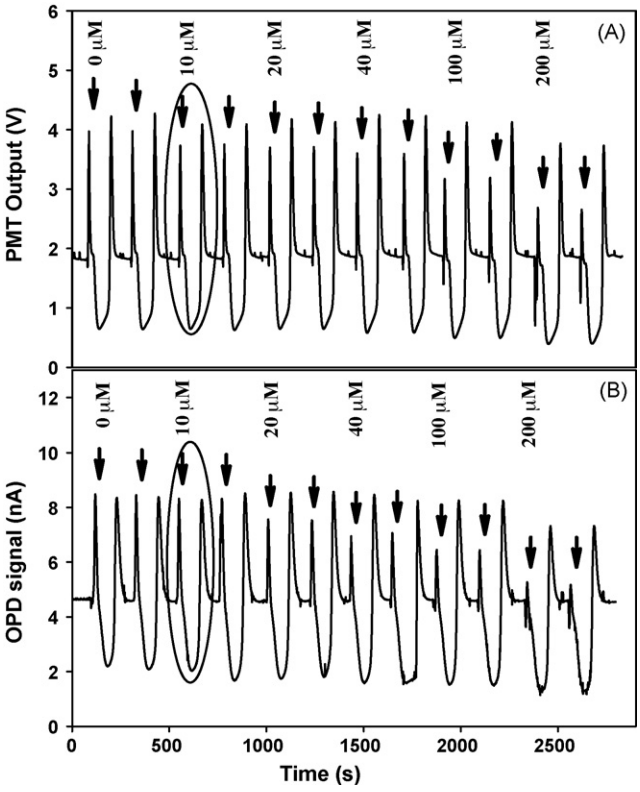


**Fig. 3.** Examples of the transient signal profiles obtained from the 2-inlet microchip for duplicate injections of 0–200 μM α-tocopherol antioxidant plugs (plug volume 50 μL) with (A) PMT detection and (B) OPD detection. The circled area corresponds to the signal set obtained from a single injection while the arrows mark the peak used for quantitation. The calibration curves were calculated using the averages from each concentration and the results are summarised in Table 1.

Excellent linearity was obtained over the entire α-tocopherol concentration range of 10–200 μM. The calibration equations, linear correlation and concentration range obtained from both PMT and OPD based detection of α-tocopherol, β-carotene and quercetin are summarised in Table 1. The dynamic range obtained for all three antioxidants is similar for both detection schemes. The comparative sensitivity of the miniaturised OPD detection system relative to conventional PMT detection was investigated through the measurement of hydrogen peroxide scavenging capacity of the above antioxidant standards. The results are summarised in Table 2. Both detection systems provided excellent consistency (relative standard deviation (RSD) is <2%) for 50 μL injections ($n = 3$) of 10 μM α-tocopherol, 10 μM β-carotene and 50 μM quercetin. Furthermore, micromolar limits of detection (defined here as the concentration of antioxidant required to obtain a reduction in CL signal equal to 3 times the standard deviation of the background level) were obtained for the antioxidants. The antioxidant capacities to quench hydrogen peroxide were calculated from the calibration equation

**Table 1**
Concentration range, calibration equations and linear correlation obtained from the microchip antioxidant assay with PMT and OPD based detection.

| Antioxidant | Working range (μM) | PMT | | OPD | |
|---|---|---|---|---|---|
| | | Linear fit | $r^2$ | Linear fit | $r^2$ |
| β-Carotene | 2–200 | $Y = 0.0031X + 1.0532$ | 0.990 | $Y = 0.0034X + 1.0646$ | 0.990 |
| α-Tocopherol | 10–200 | $Y = 0.0023X + 1.0274$ | 0.997 | $Y = 0.0027X + 1.0725$ | 0.993 |
| Quercetin | 50–1000 | $Y = 0.0003X + 1.0452$ | 0.991 | $Y = 0.0006X + 0.9806$ | 0.992 |

**Table 2**
Summary of the analytical features of the microchip assay for TAC evaluation based on PMT and OPD detection.

| Figure of merit | PMT | | | OPD | | |
|---|---|---|---|---|---|---|
| | β-Carotene | α-Tocopherol | Quercetin | β-Carotene | α-Tocopherol | Quercetin |
| 1. [a]Precision (RSD), $n = 3$ | 0.72 | 0.46 | 1.53 | 0.86 | 0.41 | 1.60 |
| 2. [b]Limit of detection (μM) | 1.92 | 9.92 | 48.08 | 1.87 | 9.40 | 47.60 |
| 3. [c]$SA_{HP}$ ($\times 10^{-3}$ $\mu M^{-1}$) | 3.27 | 2.36 | 0.31 | 3.63 | 2.96 | 0.59 |

[a] Calculated from the signal of 10 μM β-carotene, 10 μM α-tocopherol and 50 μM quercetin.
[b] Calculated from $3\sigma$ ($n = 7$) of the lowest concentration signal of each working range.
[c] Calculated form the calibration equation.

for $SA_{HP}$. For both detection methods β-carotene was found to be the most efficient hydrogen peroxide scavenger followed by α-tocopherol and quercetin, respectively.

### 3.2. Application to TAC determination of herbal extracts

Five herbal extracts were used as real samples to evaluate the integrated microchip based TAC determination method. The ethyl acetate fraction (EAF) of the sample extracts was diluted 10-fold in ethyl acetate prior to injection. Fig. 4 shows the comparison of signal profiles obtained from PMT and OPD detection of triplicate injections of herb samples *Alpinia galanga* (G), *Kaempferia galanga* (KC) and *C. citratus* (LM) into the microfluidic system. The results show excellent consistency between the two detection methods. Fig. 5 shows the antioxidant content values derived from the PMT and OPD based detection. The results indicate that *C. citratus* (LM) has the highest antioxidant content, followed by *Kaempferia galanga* (KC), *Mentha piperita* (M), *Ocimum spp* (TB) and *Alpinia galanga* (G). According to the *t*-test, the antioxidant content values obtained by PMT and OPD based detection are not significantly different at 95% confidence level ($t_{observed} = 1.217$, $t_{critical} = 2.571$). The results thus demonstrate that our OPD based detection method is sufficiently accurate for TAC determination.

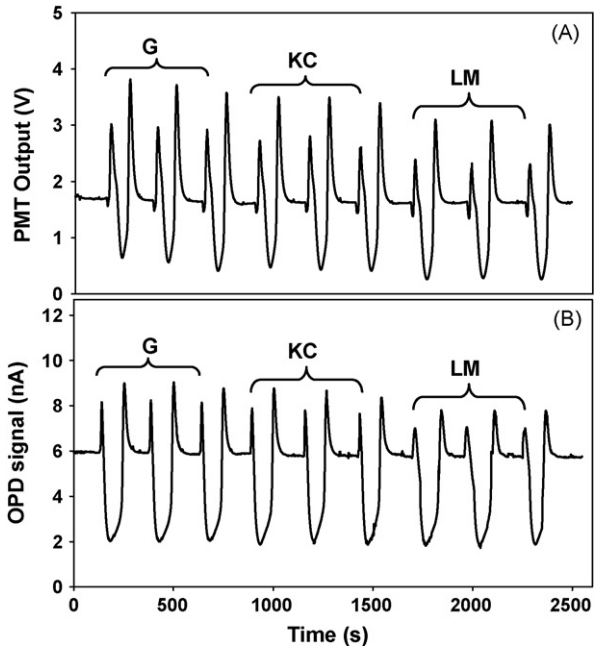


**Fig. 4.** Examples of the signal profiles obtained from the 2-inlet microchip after triplicate injections of herbal extract plugs (plug volume 50 μL) with (A) PMT detection and (B) OPD detection. G: *Alpinia galanga*, KC: *Kaempferia galanga*, LM: *Cymbopogon citratus*.

### 3.3. Comparison of PMT and OPD based detection

The similar detection limits achieved for the two investigated detection methods are somewhat surprising considering that PMT based detection involves signal amplification via a photoelectric cascade and should thus be more sensitive than OPD based detection. In our application, however, the following parameters favour the use of OPDs. Firstly, the planar OPDs are in direct contact with the underside of the microfluidic chip. This minimises the distance between microchannel and detector (typically <1 mm) and results in high efficiency collection of the diverging CL emission. In contrast, microscope optics were required to focus the CL emission onto the PMT. Secondly, the responsivity of the P3HT:PCBM OPD was well matched to the green PO-CL emission (>50% quantum efficiency at 520 nm). In contrast, the employed standard PMT exhibited comparatively poor responsivity in the blue and green wavelength range (~20% quantum efficiency at 520 nm) [28]. While in absolute terms PMTs are more sensitive, the described application serves to highlight the benefits afforded by OPDs in terms of integration and responsivity.

The main factor limiting sensitivity of OPD based detection systems is the dark current which is caused by surface and bulk leakage currents. In general terms, thicker active OPD layers result in lower dark currents but also impact on the response time of the detectors, which increases with layer thickness. Given the flow injection mode of the above experiments, which requires a fast detector response, OPDs with an active P3HT:PCBM layer of 150 nm were employed [22]. The dark current is also affected by the ambient temperature. Experiments were thus carried out in a controlled environment at room temperature. In-the-field employment of devices in extreme temperatures would necessitate basic levels of temperature control, as would the use of silicon photodiodes or PMTs.

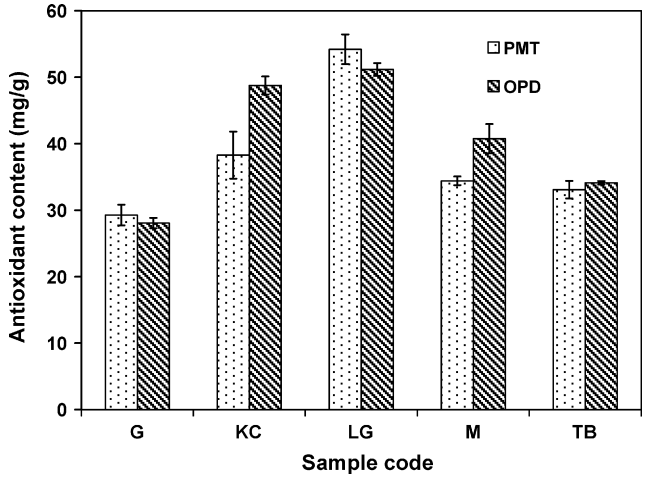


**Fig. 5.** Comparison of the estimated antioxidant content of five herbal extracts measured by integrated OPD and PMT detection. Determination for each sample was carried out in triplicate. G: *Alpinia galanga*, KC: *Kaempferia galanga*, LM: *Cymbopogon citratus*, M: *Mentha piperita*, TB: *Ocimum spp*.

The measurements reported herein were conducted over a time period of a few hours, which is in line with anticipated in-the-field use. During this time no deterioration of the OPD output was observed. The shelf lifetime of encapsulated OPDs can reach more than three years. Encapsulation is required to prevent exposure of the active layer and electrodes to oxygen and moisture [22].

## 4. Conclusions

We have demonstrated that an integrated microscale CL assay can be implemented in a quantitative and low-cost format. Detection is based on a PO-CL reaction using cheap and commercially available reagents. In conjunction with moulded PDMS microfluidic chips and organic photodetectors this offers an attractive route towards the fabrication of portable low-cost quantitative analytical tests, which incorporate the microfluidic circuit and detector in a single monolithic device. Since chemical reactions can proceed quickly in microfluidic environments, the temporal response of OPDs is a crucial parameter to be considered for this application. Our P3HT:PCBM based OPDs with an active layer thickness of 150 nm typically yield rise times of ~0.5 μs and fall times of ~0.7 μs. This is sufficiently fast for the monitoring of PO-CL signals in response to the injection of antioxidant standards. Here we have demonstrated the successful application of our miniaturised detection system to the determination of antioxidant capacity of a variety of herbal extracts. The compact and portable detection system is suited not only to low-cost in-the-field antioxidant capacity screening of plant-sourced food and pharmaceutical supplements but could also be applied to chemiluminescence based diagnostic tests at the point-of-care. To this end we are currently investigating the implementation of passive fluid delivery schemes and low-cost electronics for signal processing.

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## Biographies

**Dr. Xuhua Wang** is a Research Fellow (Senior Researcher) in Physics at Imperial College London. Besides her academic research, she has significant industrial experiences with pioneering companies (Opsys Ltd, Cambridge Display Technology Ltd, Exitech Ltd and Molecular Vision Ltd) as a senior scientist in developing organic light emitting diodes (OLEDs) for displays and organic electronic devices for Lab-on-a-chip application, lasers for micromachining tools. Her expertise covers a wide range of subjects over many years including high power laser systems, laser photonics, carbon-based materials science and their optoelectronic devices including organic LEDs, transistors, solar cells and sensors.

**Dr. Maliwan Amatatongchai** received her PhD from Mahidol University based on method development of macro- and micro- bore flow analysis including microfluidics. Presently, she is a lecturer at the Department of Chemistry, Ubonratchathani University, Thailand. Her current research interest includes method development rapid assay for drug discovery and development of biocathodes for biofuel cell applications.

**Duangjai Nacapricha** is an Assistant Professor of Analytical Chemistry in the Department of Chemistry, Mahidol University, Thailand. Her research is focused on flow-based analysis and innovation. She is the founder of Flow-Innovation Flow Innovation-Research for Science and Technology Laboratories (FIRST Labs.) that has recently launched 'Siam Gasohol Kit' or SG-Kit for rapid analysis of ethanol in gasohol. She is a co-founder of Scinnotech Co., Ltd.

**Oliver Hofmann** received his PhD from Imperial College London studying microfluidic systems for rapid immunoassays. He has more than 13 years experience in the lab-on-a-chip field with significant industry exposure at Ciba-Geigy (now Novartis) and Vysis Inc. (now part of Abbott). Dr. Hofmann is currently Principal Scientist at Molecular Vision Ltd. with responsibility for developing microfluidics based diagnostic devices for the point-of-care.

**Dr. John de Mello** is a Reader in Nanomaterials at the Department of Chemistry, Imperial College London. His research focuses on the study and application of nanoparticles and organic semiconductors, with emphasis on their use in optoelectronic devices and chemical sensors. He is a co-founder of Molecular Vision Ltd. and was a recipient of the Brian Mercer Award for Innovation in Nanotechnology.

**Donal Bradley** FRS is the Lee-Lucas Professor of Experimental Solid State Physics at Imperial College London. Over the past twenty five years he has established a wide-ranging research programme in molecular electronic materials and devices, the results of which have been published in more than 470 papers and numerous patents, including the fundamental patent and first paper on conjugated polymer electroluminescence. The Institute for Scientific Information identifies him as one of the two hundred most cited physicists worldwide and he was a co-recipient of the 2003EU Descartes Prize. He was elected a Fellow of the Royal Society in 2004 and a Fellow of the Institute of Physics in 2005. Professor Bradley is a co-founder of Cambridge Display Technology Ltd and Molecular Vision Ltd.

**Andrew deMello** is Professor of Chemical Nanosciences in the Department of Chemistry at Imperial College London. His research group is engaged in a broad range of activities in the general area of microfluidics and nanoscale science. He was awarded the 2009 Clifford Paterson Medal by The Royal Society and the 2009 Corday Morgan Medal by the Royal Society of Chemistry. He is co-founder of Molecular Vision Ltd.