Hybrid GaN microLED platform for fluorescence sensing

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Abstract - **A hybrid GaN μLED platform developed for wearable illumination is adapted here for fluorescence sensing. Proof-of-principle detection of colloidal quantum dots down to 80 pM using a mobile phone camera is demonstrated.**

Mechanically-flexible and wearable photonics have many applications including for novel forms of displays, illuminating safety clothing, and health technology [1, 2]. In this context, we have been working on a light emitting, mechanically flexible device for area illumination at wavelengths in the UV and visible [3]. Our device consists of an array of μLEDs combined with a polydimethylsiloxane (PDMS) slab waveguide structure (Fig. 1). PDMS is a biocompatible elastomer, often employed in microfluidics, and can be made mechanically flexible. Light from the μLED device is guided within the PDMS by total internal reflection, and by incorporating light diffracting and/or colour converting structures within the platform it is possible to obtain homogenous area illumination at different wavelengths as shown in Figs. 1a and 1b. Herein, we adapt this hybrid μLED device platform and demonstrate its capability for fluorescence sensing.

Fluorescence is a well-established biochemical sensing technique used for diagnostics. It is typically based on biomolecular processes whereby analytes are captured on a surface and coupled to fluorescent tags. The latter are then excited using a laser or LEDs and the resulting fluorescence is measured to assess the presence and amount of analytes. The approach taken here is based on total internal reflection fluorescence (TIRF) [4]. As light from the μLEDs is waveguided in the PDMS, an evanescent wave is formed near the PDMS interface. This evanescent wave probes the region very near (<100nm) the surface of the PDMS guide and therefore triggers fluorescence only if a label is in this region (Fig. 2a). In turn, TIRF sensing mitigates the issue of autofluorescence that can otherwise be a severe source of noise. The main advantage of the GaN microLED TIRF platform reported here compared to other implementation lies in its potential for small form, low-power instrumentation.

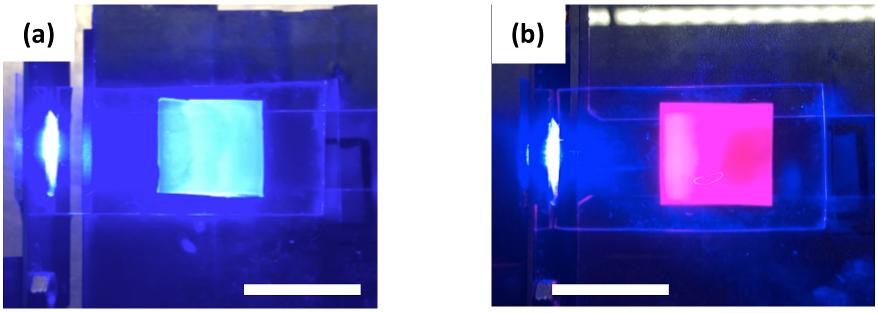

Fig. 1 Photographs of the top of the hybrid microLED/elastomeric platform showing homogeneous (a) blue illumination and (b) red illumination through colour conversion. The scale bars are 1.5 cm.

For the demonstration, the μLED consisted of 10 pixels in parallel, each 100 x 100 μm^2 and separated by 720 μm, as depicted in the inset of Fig. 2b, which otherwise summarizes the device optoelectronic characteristics. The device has a turn-on voltage of 2.6 V. For the fluorescence experiments it is ran at a current of 120 mA producing a total output optical power of 10 mW for a peak wavelength of 445 nm. The PDMS membrane (40 x 20 x 1 mm^3) was edge-coupled to the μLED and the imaging system consisted only of a long-pass filter and a phone camera. For the proof of principle experiment, we have used colloidal quantum dots (CQDs) as fluoresent labels (630nm-emitting CdSSe/ZnS, 6nm mean diameter). Multiple concentrations were obtained by diluting the CQDs in toluene. 2 µL of these different CQD concentrations were drop-coated onto the PDMS waveguide slab. The toluene was then allowed to evaporate in air leaving on the PDMS surface CQD molar concentrations ranging from 770 nM down to picomolar level for reproducibility and limit of detection (LOD) experiments. The same experiments were also conducted with water-soluble CQDs and led to similar results.

Fig. 2c is an image of the PDMS surface with CQD labels taken (at an angle) with the phone camera. The camera settings for measurements were: ISO 800, exposure time 250 ms and 2x zoom. The corresponding pixel noise was 2.1+/-0.8 (relative intensity units). The pixel data from the phone camera was post-processed using Matlab to produce an intensity map (not shown) and a plot of fluoresence intensity versus concentration (Fig 2d). Based on results from the latter and from the noise floor of the system, the LOD of the CQDs is found to be below 80 pM. This is lower than the few nM LOD reported in [5] that used direct CQD excitation, and even lower LOD may be possible.

In summary, we have demonstrated the concept of a fluoresent sensor based on a hybrid µLED/PDMS platform. The detection uses a simple mobile phone (with the addition of a filter). The next steps include bioassay detection but these preliminary results shows the versatility of this GaN µLED platform and its potential for low-cost, low power and small format bio-instrumentation.

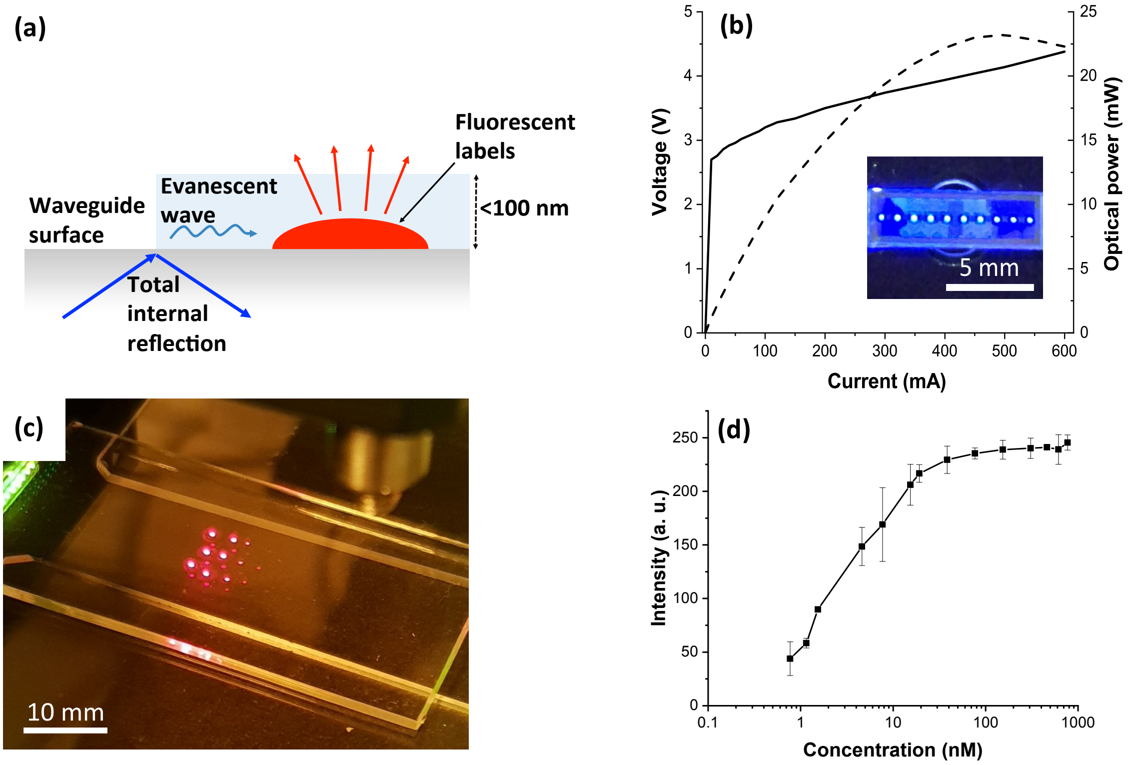

Fig. 2 (a) Schematic of TIRF sensing; (b) electrical and optical characteristics of the LED device, and (inset) photograph of the array; (c) mobile phone picture of the platform showing the red CQD fluorescence; (d) mean pixel intensity versus quantum dot concentration.

This work was partly supported by the EPSRC grant EP/L015595/1 and the MRC Confidence in Concept award (HTAF) MC_PC_17161.

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