3.2: *Invited Paper:* Biopolymers in Light Emitting Devices

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Abstract: *In this paper we describe DNA based fluorescent thin films and light emitting diodes and compare their current performance and future prospects to conventional organic counterparts.*

Keywords: biopolymer, DNA-CTMA, bioLED

The next frontier in organic electronic and photonic devices is the use of biomaterials, either naturally occurring or artificially produced based on biological methods. Biomaterials with unusual properties not easily replicated in conventional organic or inorganic materials can provide another degree of freedom in terms of device design and produce enhancements in device performance. Furthermore, natural biomaterials are a renewable resource and are inherently biodegradable.

We are investigating the use of deoxyribonucleic acid (DNA) as a photonic material and as an integral element of biopolymeric organic light emitting diodes. We have shown [1] that these BioLEDs have significantly higher luminance and luminance efficiency compared to conventional OLEDs. The DNA structure shown schematically in Fig. 1 contains two intertwined helices of phosphate and sugar groups interconnected by a set of hydrogen-bound bases. The diameter of the double helix is ~ 2 nm and the planes of the base pairs are separated by a distance of 3.4 Å.

Recent research suggested DNA is a good candidate in polymer materials for photonics applications [2], [3]. Polymer materials are of great interest for photonic applications due to their low cost and flexibility, but they generally also have higher optical loss than most inorganic semiconductor materials. It is believed that the unique double-helix nanostructure of DNA plays an important role in intercalating dye molecules and in enhanced optical properties.

We have utilized salmon DNA reacted with a surfactant [4] to produce a DNA complex (DNA-CTMA) which is water insoluble but soluble in organic solvents. This enables the formation of DNA films that can be incorporated into multi-layer device structures. DNA-CTMA molecular weight reduction is performed by sonication to aid thin film formation and reduce electrical resistivity [5]. We have used DNA-CTMA with molecular weight of ~ 145 kDa, which is equivalent to 220 base pairs and an average molecular length of 75nm.

Figure 1. DNA double helix.

The optical properties of these DNA films are shown in Fig. 2. The transmission spectrum has a minimum at ~ 260 nm which is due to optical absorption by the DNA bases. From ~ 330 nm through the visible and near IR range the transmission of the DNA is nearly 100%. The refractive index decreases monotonically from 1.535 at 300 nm to 1.48 at 1600 nm.

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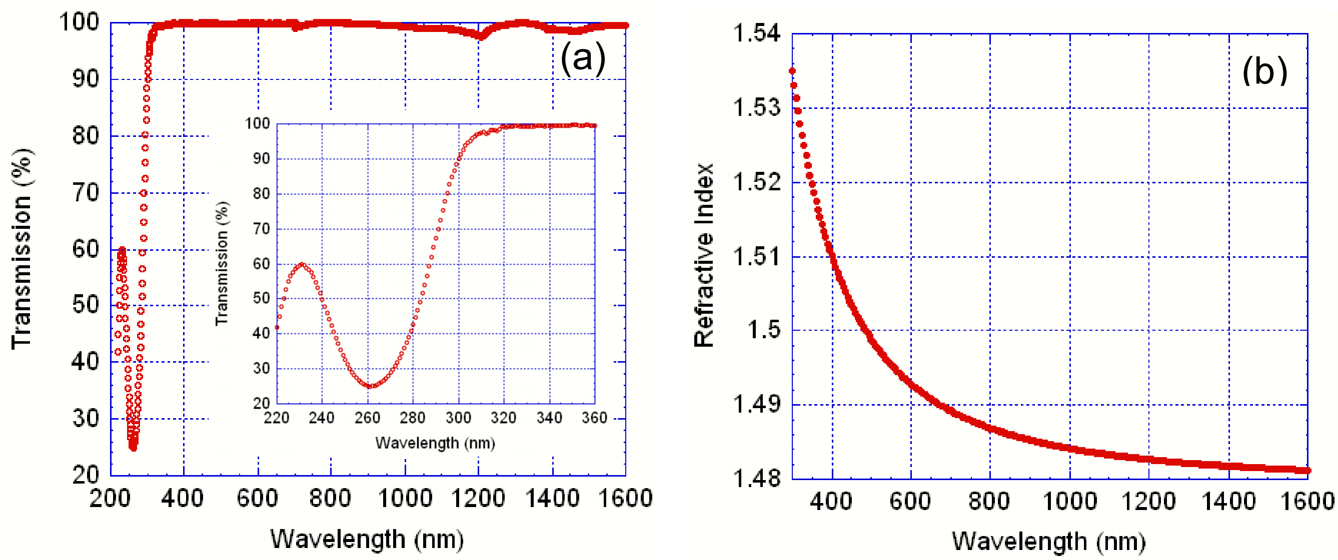

Figure 2. Optical properties of DNA thin films: (a) transmission spectrum; (b) refractive index.

Incorporation of DNA thin films in organic light emitting diodes include light emitting layers or as electron ‘blocking’ layers (EBL). The effect of blocking electron flow is to enhance the probability of radiative electron-hole recombination, leading to increased device luminous efficiency and luminance. The cross-section of a BioLED incorporating a DNA EBL is shown in Fig. 3.

Depending on the details of the structure, one can obtain emission from specific emitter layers. BioLEDs with blue emission from an NPB layer and green emission from an Alq_3 layer are illustrated in Fig. 4. Red emission from the rare earth ion Eu^{3+} doped into the various emitter layers has also been obtained.

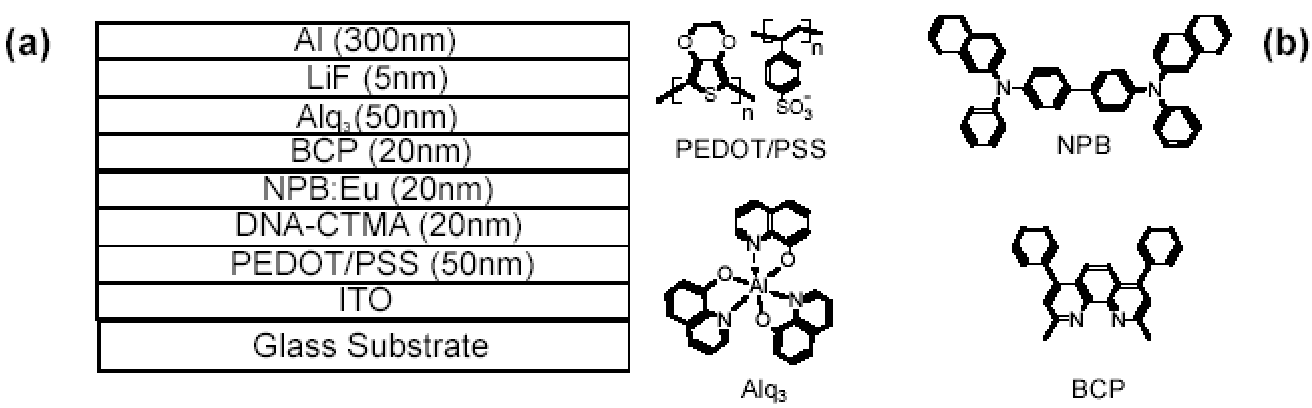

Figure 3. DNA-containing BioLED: (a) cross-section of BioLED structure; (b) chemical structure of the organic components of the BioLED structure.

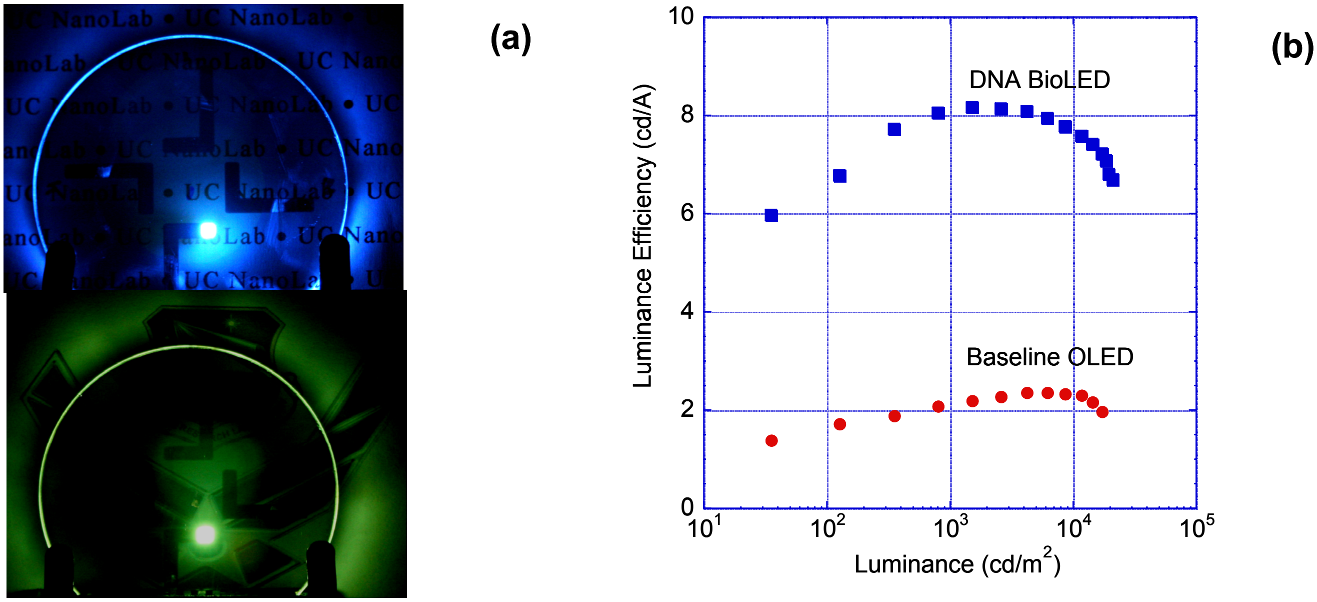

Figure 4. DNA BioLEDs: (a) blue (NPB) and green (Alq_3) emitting devices in operation; (b) luminance efficiency versus luminance for green emitting BioLED and for conventional baseline OLED.

The luminance efficiency from the green emitting DNA BioLED is compared in Fig. 4b to a baseline OLED device as a function of device luminance. The efficiency of the BioLED is clearly superior, reaching as high as 8 cd/A compared to 2 cd/A for the conventional device.

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