Conduction and electroluminescence from organic thin films and nanofibers

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General introduction

Phenylene-based oligomers are of particular interest due to their ability to self-assemble into elongated, crystalline nanostructures – nanofibers. Such nanofibers can emit highly anisotropic, polarized light upon UV light exposure and can function as optical waveguides and random lasers, while chemical functionalization of the molecular building blocks can enable the tailoring of the nanofiber properties for particular applications. The connection of metal electrodes to nanofibers enables the probing of their electrical properties and constitutes a significant step towards the realization of a sub-micron organic LED. In this study, we investigate electrical and light-emission properties of both nanofibers and thin films in a field-effect transistor (FET) configuration.

Research results

Two types of devices have been investigated: FETs based on (I) non-crystalline thin films and (II) crystalline nanofibers. The FET device substrate was made by standard microfabrication techniques. It consists of a highly n-doped silicon substrate, which acts as the FET backgate electrode. The gate oxide is a 200 nm thermally grown silicon dioxide layer, upon which an interdigitated array of gold source and drain electrodes are prepared by photolithography, metal evaporation, and lift-off. The thin film devices were fabricated by vacuum depositing p6P molecules directly onto the device substrates, while the nanofiber devices was prepared by transferring pre-made nanofibers from the growth template mica onto the device substrate. The FET device platform and a diagram of the electrical circuit used when biasing the device with an AC gate voltage for light emission experiments are shown in figure 1.

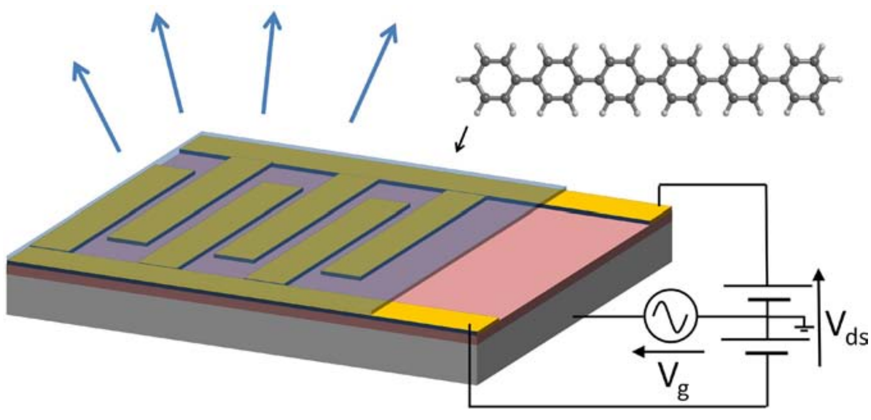

Figure 1: FET device platform consisting of a highly doped silicon substrate acting as the backgate. On top of a silicon dioxide film, gold source and drain electrodes function as bottom contacts to the organic material, p6P (shown in the upper right corner).

Figure 2a shows an optical microscope image of a p6P thin film sample biased with Vd = -Vs = 30 V and a AC gate voltage with an amplitude of 75 V and a frequency of 200 kHz. Clear blue light is emitted from the edges of the source and drain electrodes. The electroluminescence spectrum in figure 2b is recorded to confirm that the blue light is from the p6P material. This EL together with a reference photoluminescence spectrum is normalized to enable a direct comparison of peak positions. When biased in a DC configuration, the p6P thin film showed nice p-type behaviour with a hole mobility around 1×10 cm^2/Vs and an onset voltage of -30 V. The nanofibers also exhbited p-type characteristics, but the output curves suffered high noise, from which the mobility was hard to determine.

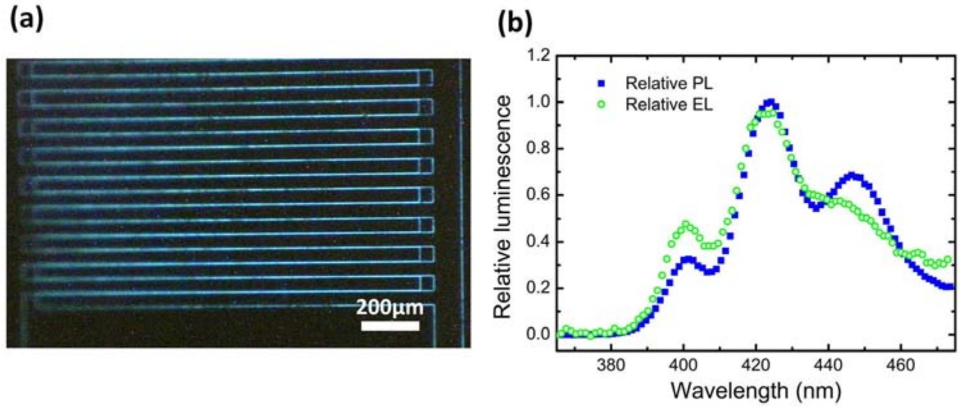

Figure 2: (a) Optical microscope image of the EL output of a 60 nm p6P thin film biased with Vds = 60 V and a sinusoidal gate voltage with an amplitude of 75 V and a frequency of 200 kHz. (b) Normalized PL and EL spectra from a p6P thin film.

Upcoming research 2010

Other organic semiconductors could be investigated based on the bottom contact structure, as well as alternating configurations, such as top-contacts and top gate structure. A self-assembled monolayer (SAM) could be used to modify the metal electrode to improve charge carrier injection hereby leading to more intense electroluminescence. The transferring method of p6P nanofibers should be improved, which can maintain excellent properties of nanofibers after transferring.

Papers

[1] Kjelstrup-Hansen, Norton, da Silva Filho, Brédas, and Rubahn, *Charge transport in oligo phenylene and phenylene–thiophene nanofibers*, Organic Electronics,Vol. 10, p. 1228 (2009).

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[3] Liu, Wallmann, Boudinov, Kjelstrup-Hansen, Schiek, Lützen, and Rubahn, *Electroluminescence of Naphthyl End-Capped Oligothiophenes by Alternating-Current Voltage in an Organic Light-emitting Field-Effect Transistor Con figuration*, submitted to Organic Electronics.